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Transportable gas cylinders - Fully wrapped composite cylinders

Bouteilles à gaz transportables - Bouteilles entièrement
bobinées en matériaux composites

Ortsbewegliche Gasflaschen - Vollumwickelte Flaschen
aus Verbundwerkstoffen

This European Standard was approved by CEN on 9 November 2001.

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Foreword

This document EN 12245:2002 has been prepared by Technical Committee CEN/TC 23 "Transportable gas cylinders", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2002, and conflicting national standards shall be withdrawn at the latest by August 2002.

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports the objectives of the framework Directives on Transport of Dangerous Goods.

This European Standard has been submitted for reference into the RID and/or the technical annexes of the ADR. Therefore in this context the standards listed in the normative references and covering basic requirements of the RID/ADR not addressed within the present standard are normative only when the standards themselves are referred to in the RID and/or the technical annexes of the ADR.

Annex A is normative, annex B is informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

The purpose of this standard is to provide a specification for the design, manufacture, inspection and testing of refillable, transportable fully wrapped composite cylinders.

The specifications given are based on knowledge of, and experience with, materials, design requirements, manufacturing processes and control during manufacture of cylinders in common use in the countries of the CEN members.

1 Scope

This European Standard specifies minimum requirements for the materials, design, construction, prototype testing and routine manufacturing inspections of composite gas cylinders with a water capacity up to and including 450 l for compressed, liquefied and dissolved gases.

NOTE For the purposes of this standard, the word "cylinder" includes tubes up to 450 l water capacity

This standard is applicable to cylinders that comprise a liner of metallic material (welded or seamless) or non-metallic material (or a mixture thereof), reinforced by a wound composite consisting of fibres of glass, carbon or aramid (or a mixture thereof) embedded in a matrix.

This standard is also applicable to composite cylinders without liners.

This standard is not applicable to gas cylinders which are partially covered with fibres and commonly called "hoop wrapped" cylinders. For hoop wrapped composite cylinders see EN 12257.

NOTE The specification does not address the design, fitting and performance of removable protective sleeves. Where these are fitted they should be considered separately.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate place in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 720-2, *Transportable gas cylinders — Gases and gas mixtures — Part 2: Determination of flammability and oxidising potential of gases and gas mixtures.*

EN 1089-1, *Transportable gas cylinders — Gas cylinder identification (excluding LPG) — Part 1: Stampmarking.*

EN 1964-1, *Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless steel gas cylinders of water capacities from 0,5 litres up to and including 150 litres — Part 1: Cylinders made of seamless steel with an R_m value of less than 1100 MPa.*

prEN 1964-2, *Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless steel gas cylinders from 0,5 litres up to and including 150 litres — Part 2: Tensile strength (R_m max) \geq 1100 MPa.*

EN 1964-3, *Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless steel gas cylinders of water capacities from 0,5 litres up to and including 150 litres — Part 3: Stainless steel cylinders.*

EN 1975, *Transportable gas cylinders — Specification for the design and construction of refillable transportable seamless aluminium and aluminium alloy gas cylinders of capacity from 0,5 l up to 150 l.*

EN 12862, *Transportable gas cylinders — Refillable transportable welded aluminium alloy gas cylinders.*

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prEN 13322-1, *Transportable gas cylinders — Refillable transportable welded steel gas cylinders — Part 1: Welded steel.*

prEN 13322-2, *Transportable gas cylinders — Refillable transportable welded stainless steel gas cylinders — Part 2: Welded stainless steel.*

EN ISO 11114-1, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic Materials (ISO 11114-1:1997).*

EN ISO 11114-2, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 2: Non-metallic Materials (ISO 11114-2:2000).*

EN ISO 11114-3, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 3: Autogenous ignition test in oxygen atmosphere (ISO 11114-3:1997).*

EN ISO 11120, *Gas cylinders — Refillable seamless steel tubes for compressed gas transport, of water capacity between 150 l and 3000 l — Design, construction and testing (ISO 11120:1999).*

EN ISO 13341, *Fitting of valves to gas cylinders (ISO 13341:1997).*

ISO 75-1, *Plastics — Determination of temperature of deflection under load — Part 1: General test method.*

ISO 75-3, *Plastics — Determination of temperature of deflection under load — Part 3: High-strength thermosetting laminates and long-fibre-reinforced plastics.*

ISO 175, *Plastics — Determination of the effects of liquid chemicals, including water.*

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles.*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics.*

ISO 1133, *Plastics — Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics.*

ISO 1183, *Plastics — Methods of determining the density and relative density of non-cellular plastics.*

ISO 1628-3, *Plastics — Determination of viscosity number and limiting viscosity number — Part 3: Polyethylenes and polypropylenes.*

ISO 2884-1, *Paints and varnishes — Determination of viscosity using rotary viscometers — Part 1: Cone-and-plate viscometer operated at a high rate of shear.*

ISO 3146, *Plastics — Determination of melting behaviour (melting temperature or melting range) of semi-crystalline polymers.*

ISO 10156, *Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets.*

ISO 15512, *Plastics - Determination of water content.*

ASTM D 2196-86, *Test methods for rheological properties of non-newtonian materials by rotational (Brookfield) viscometer.*

ASTM D 2290-92, *Test method for apparent tensile strength of ring or tubular plastics and reinforced plastics by split disk method.*

ASTM D 2291-83, *Fabrication of ring test specimens for glass-resin composites.*

ASTM D 2343-95, *Test method for tensile properties of glass fibre strands, yarns and rovings used in reinforced plastics.*

ASTM D 2344-84, *Test method for apparent interlaminar shear strength of parallel fiber composites by short beam method.*

ASTM D 4018-93, *Test methods for tensile properties of continuous filament carbon and graphite fibre tows.*

3 Terms, definitions and symbols

For the purposes of this European standard, the following terms, definitions and symbols apply.

3.1 Terms and definitions

3.1.1

ambient temperature

temperature of surroundings varying between 10 °C and 35 °C (for test purposes only)

3.1.2

autofrettage

pressure application procedure which strains the metal liner past its yield point sufficiently to cause permanent plastic deformation, and results in the liner having compressive stresses and the fibres having tensile stresses when at zero internal gauge pressure

3.1.3

batch, (of fibres or components of the resin system)

homogeneous quantity of material, identified and certified as such by the supplier

3.1.4

batch, (of metallic liners)

quantity of liners of the same nominal diameter, thickness, length and design, made successively from the same material cast and subjected to the same heat treatment for the same length of time

3.1.5

batch, (of non-metallic liners)

quantity of liners of the same nominal diameter, thickness, length and design, made successively from the same batch of materials and subjected to the same manufacturing process

3.1.6

batch, (of finished cylinders with liners)

quantity of up to 200 finished cylinders, plus cylinders for destructive testing, of the same nominal diameter, thickness, length and design. The batch may contain different batches of liners (providing the batches are nominally the same and have had the same treatments), fibres and matrix materials

3.1.7

batch, (of finished cylinders with no liners)

production quantity of up to 200 finished cylinders, plus cylinders for destructive testing, of the same nominal diameter, thickness, length and design

3.1.8

burst pressure

highest pressure reached in a cylinder or liner during the relevant burst test

3.1.9

composite overwrap

fibres and matrix taken together as a combined unit

3.1.10

elastomer

material which at ambient temperature can be stretched repeatedly to at least twice its original length and will return with force to approximately its original length immediately upon release of the stress

3.1.11

exterior coating

layer of clear or pigmented material applied to the cylinder as protection or for cosmetic purposes

3.1.12

fibre or strand

load-carrying part of the composite overwrap e.g. glass, aramid or carbon

3.1.13

fully wrapped cylinder

cylinder reinforced by wrapping to take both circumferential and longitudinal stress

3.1.14

liner

metallic or non-metallic vessel that contains the gas but may also contribute to the mechanical behaviour of the cylinder

3.1.15

non-load sharing liner

liner that contributes less than 5 % of the load bearing of the overall cylinder design at test pressure, and is intended only to prevent diffusion of the contained gas

3.1.16

non-metallic liner

liner made from thermoplastic, thermosetting, or elastomer material

3.1.17

cylinder without liner

cylinder having no liner and consisting wholly of the composite winding

3.1.18

matrix

material which is used to bind and hold the fibres in place

3.1.19

rejected cylinder

cylinder which in its present condition has not passed the test requirements

3.1.20

thermoplastic

plastics capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature

3.1.21

thermoset

plastics which when cured by the application of heat or chemical means change into a substantially infusible and insoluble product

3.2 Symbols

p_b	actual burst pressure of composite cylinder, in bar ¹⁾ above atmospheric pressure
p_{bL}	burst pressure of liner, in bar ¹⁾ above atmospheric pressure
p_{bmin}	minimum burst pressure of composite cylinder obtained during design variant approval testing, in bar ¹⁾ above atmospheric pressure
p_h	hydraulic test pressure of composite cylinder, in bar ¹⁾ above atmospheric pressure

4 Design and manufacture

4.1 General

4.1.1 A fully wrapped composite gas cylinder may be manufactured with a metallic or non-metallic liner or without a liner. Cylinders without a liner may be manufactured from two parts joined together with adhesive. An optional exterior coating may be used to provide external protection and when this is an integral part of the design shall be permanent.

The cylinder may also include additional parts such as rings, bases, etc.

4.1.2 Cylinders shall be designed with one or two openings along the central axis only.

4.2 Liner

4.2.1 Metallic liners

Metallic liners shall be manufactured in accordance with the relevant sections of the following European Standards:

- | | |
|-------------------------------------|---|
| a) seamless steel liners: | EN 1964-1 or prEN 1964-2, as appropriate; |
| b) seamless stainless steel liners: | EN 1964-3; |
| c) seamless aluminium alloy liners: | EN 1975; |
| d) welded steel liners: | prEN 13322-1; |
| e) welded stainless steel liners: | prEN 13322-2; |
| f) welded aluminium liners: | EN 12862; |
| g) steel tubes (i.e. >150 l): | EN ISO 11120. |

The relevant sections are those covering: materials, thermal treatments, neck design, construction and workmanship, mechanical tests.

NOTE This excludes the design requirements, since these are specified by the manufacturer for the design of the composite cylinder. For liners with water capacity above 150 l manufactured of stainless steel, aluminium or welded steel the relevant sections of the appropriate standard also apply.

1) 1 bar = 10⁵ Pa = 0,1 MPa.

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The liner material shall be compatible with the gases intended to be used as determined by EN ISO 11114-1.

4.2.2 Non-metallic liners

4.2.2.1 A cylinder with a non-metallic liner shall be designed as if the liner will be non-load sharing. The liner material shall be compatible with the gases intended to be used as determined by EN ISO 11114-2.

4.2.2.2 Where a metal end boss is used in a non-metallic liner, it shall be considered part of the liner material and shall fulfil the material requirements specified in the relevant standard, as listed in 4.2.1.

The drawing of the liner shall include the specification of the material and material properties of the boss. The following material properties important for design shall be specified in the design as follows:

- minimum yield stress;
- minimum tensile strength;
- minimum elongation of the boss material;
- compatibility with the contained gas as determined by EN ISO 11114-1.

The metal end boss bearing the cylinder thread shall be designed to withstand the torque applied in fitting the valve to the cylinder and the tests specified in Test No 16 (see 5.2.16) and Test No 17 (see 5.2.17).

4.2.3 Design drawing

A fully dimensioned drawing of the liner shall be supplied which includes the specification of the material and material properties. The following material properties shall be specified:

a) for metallic liners:

- minimum yield stress;
- minimum tensile strength;
- minimum elongation;
- minimum burst pressure;
- compatibility with the contained gas as determined by EN ISO 11114-1.

b) for non-metallic liners:

- density;
- melting point, as determined by:
 - ISO 3146 for thermoplastics; or
 - ISO 75-1 and ISO 75-3 for thermoset materials;
- auto-ignition temperature in oxygen as determined by EN ISO 11114-3 (for cylinders for oxidising gases only);

- glass transition temperature as determined by differential scanning calorimetry;
- composition;
- compatibility with the contained gas as determined by EN ISO 11114-2;
- end boss design in accordance with 4.2.2.2.

4.2.4 Design of ends

The external diameter and thickness of the formed neck end of the liner shall be designed to withstand the torque applied in fitting the valve to the cylinder and the tests specified in Test No 16 (see 5.2.16) and Test No 17 (see 5.2.17).

4.2.5 Neck ring

When a neck ring is provided, it shall be of a material compatible with that of the cylinder, and shall be securely attached by a method appropriate to the liner (or cylinder for linerless cylinders) or boss material.

4.3 Composite overwrap

4.3.1 Materials

Material requirements for the fibre and the matrix shall be as specified by the manufacturer.

4.3.2 Winding

Appropriate procedures shall be defined for the winding and curing process to ensure good repeatability and traceability.

The following parameters shall be defined and monitored:

- percentages of the components of the matrix system and their batch numbers;
- the batch numbers of the fibres used;
- the number of strands used;
- the winding tension per strand, (if applicable);
- the winding speed(s);
- the winding angle and/or pitch for each layer;
- resin bath temperature range, (if applicable);
- the number and order of layers;
- the procedure used to obtain correct impregnation (e.g. wet winding or pre-impregnation);
- the polymerisation cycle;
- the polymerisation process (e.g. thermal cycling, ultrasonic, ultraviolet, or radiation).

For thermal polymerisation, the temperature and the length of the polymerisation cycle of the resin system shall be such that they do not adversely affect the mechanical characteristics of the liner. In addition, tolerances for holding time and temperature at each stage shall be defined.

4.3.3 Cylinders without liners comprising two or more parts

For cylinders without liners which comprise two parts joined with adhesive, additional procedures and parameters shall be defined, monitored and recorded as follows:

- percentages of the components of the adhesive system and their batch numbers;
- polymerisation cycle;
- polymerisation process (e.g. thermal cycling, ultrasonic, ultraviolet, or radiation).

4.4 Finished cylinder

4.4.1 Design drawings

A fully dimensioned drawing of all parts that constitute the finished cylinder shall be supplied. The design drawing shall also include tolerances on all dimensions, including out-of-roundness and straightness.

The drawing shall include the specification of the material(s), the material properties and the reinforcement pattern. The specifications and the reinforcement patterns may be given in a technical specification enclosed with the drawing.

The details of an exterior coating, if it is an integral part of the design, shall be defined.

The test pressure, autofrettage pressure (if applicable) and minimum burst pressure for the design shall be specified. The minimum burst pressure shall be at least $2 \times$ test pressure (p_T).

Any special characteristics or special limitations (e.g. design life, underwater suitability, vacuum suitability and/or maximum fitting torque restrictions) shall also be stated.

4.4.2 Cylinders without liner

The composition of the composite materials and also their properties shall be specified, as follows:

- tensile strength;
- tensile modulus;
- elongation;
- heat distortion temperature;
- viscosity.

The composite materials shall be compatible with the contained gas as determined by EN ISO 11114-2. The auto-ignition temperature in oxygen gas shall be determined in accordance with EN ISO 11114-3.

Where a metal end boss is used in a cylinder without liner the drawing of the cylinder shall include the specification of the material and material properties of the boss in accordance with 4.2.2.2.

4.4.3 Autofrettage

Internal pressurisation to autofrettage pressure of cylinders with metallic liners can be part of the manufacturing process; if so this operation shall be executed after polymerisation of the composite for thermosetting resins.

During the autofrettage operation, the following parameters shall be recorded:

- autofrettage pressure;
- length of application of this pressure;
- expansion at autofrettage pressure;
- permanent expansion after autofrettage.

If autofrettage is performed, a check shall be made that the procedure has been effectively performed on all cylinders.

4.4.4 Manufacturing requirements for the finished cylinder

The internal and external surfaces of the finished cylinder shall be free of defects which can adversely affect the safe working of the cylinder. In addition there shall be no visible foreign matter present inside the cylinder (e.g. resin, swarf or other debris).

4.5 Liquefied gases

Cylinders intended to contain non-toxic, non-flammable liquefied gases shall be fitted with a bursting disc designed to operate below $1,15 p_h$.

5 Cylinder and material tests

5.1 General

This clause describes tests to be conducted on fully wrapped composite cylinders, cylinder liners and the materials used in manufacture of cylinders for prototype testing of new cylinder designs, design variant testing and production testing. The tests listed can be required or optional, as identified in the schedule of testing and inspections in annex A.

No tests shall be performed with a removable protective sleeve fitted to the cylinder.

5.2 Test procedures and test requirements

5.2.1 Test No 1 - Composite material tests, including adhesives (where applicable)

Tests shall be carried out on composite materials as follows:

- a) On all cylinders:

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Procedure:

Tests on the composite materials to establish their mechanical properties shall be carried out in accordance with the following procedures:

- i) Tensile properties of fibres:
 - For glass, aramid: - ASTM D 2290-92 & ASTM D 2291-83;
- ASTM D 2343-95;
 - For carbon: - ASTM D 4018-93.

- ii) Shear properties: - ASTM D 2344-84.

Equivalent tests in accordance with alternative standards or test specifications acceptable to the inspection body may be applied.

Criteria:

The mechanical properties shall meet the minimum requirements for the design as specified by the manufacturer.

b) Additional tests on cylinders without liners:

Procedure:

Additional tests on the composite materials and adhesives (if applicable) to establish their other physical properties shall be carried out in accordance with the following procedures:

Tensile strength	- ISO 527-1 and ISO 527-2
Tensile modulus	- ISO 527-1 and ISO 527-2
Elongation	- ISO 527-1 and ISO 527-2
Heat distortion temperature	- ISO 3146 for thermoplastics and ISO 75-1 and ISO 75-3 for thermoset materials;
Auto-ignition temperature in oxygen	- prEN ISO 11114-3 (for oxidising gases only)
Viscosity	- ISO 1628-3 for thermoplastics and ISO 2884-1 or ASTM D 2196-86 for thermosets
Composition	- Test specification acceptable to the inspection body

Equivalent tests in accordance with alternative standards or test specifications acceptable to the inspection body may be applied.

Criteria:

The mechanical properties shall meet the minimum requirements for the design as specified by the manufacturer.

5.2.2 Test No 2 - Liner material tests

Procedure:

Tests on the liner material shall be carried out, following the test procedures of the appropriate standards as follows:

- a) Seamless steel - as described in EN 1964-1, prEN 1964-2 or EN ISO 11120, as appropriate;

- b) Seamless stainless steel - as described in EN 1964-3;
- c) Welded steel - as described in prEN 13322-1;
- d) Seamless aluminium - as described in EN 1975;
- e) Welded stainless steel - as described in prEN 13322-2;
- f) Welded aluminium - as described in EN 12862;
- g) Non-metallic - as follows:

1) Thermoplastic materials:

Viscosity	- ISO 1628-3
Melting point	- ISO 3146
Water content	- ISO 15512
Density	- ISO 1183
Melting flow index	- ISO 1133
Chemical resistance	- ISO 175

2) Thermoset and elastomeric materials:

Viscosity	- ISO 2884-1 or ASTM D 2196-86
Elongation at break	- ISO 527-1 and ISO 527-2
Tensile strength	- ISO 527-1 and ISO 527-2
Density	- ISO 1183
Chemical resistance	- ISO 175

Equivalent tests in accordance with alternative standards or test specifications acceptable to the inspection body may be applied.

Criteria:

The mechanical properties shall meet the minimum requirements for the design as specified by the manufacturer.

5.2.3 Test No 3 - Liner burst test at ambient temperature.

Procedure:

The hydraulic burst test shall be carried out using a test rig, which allows pressure to be increased at a controlled rate.

The test shall be carried out in ambient conditions and the temperature on the external surface of the liner shall be maintained at less than 50 °C. The rate of pressurisation shall not exceed 10 bar/s and the duration of the test shall be at least 40 s.

The cylinder shall be pressurised at a controlled rate until failure. The pressure against time curve or pressure against volume curve shall be plotted.

The maximum pressure achieved during the test shall be recorded as the burst pressure.

Criteria:

- burst pressure of the liner (p_{bl}) shall be equal to or greater than the minimum design burst pressure, as specified in 4.2.3;
- burst initiation shall be in the cylindrical part and the liner shall remain in one piece.

Parameters to monitor and record:

- burst pressure;
- the number of pieces;
- description of failure;
- pressure/time curve or pressure/volume curve.

5.2.4 Test No 4 - Hydraulic (proof) test of finished cylinders at ambient temperature

Procedure:

Where cylinders are subjected to autofrettage the hydraulic proof pressure test may immediately follow or be part of the autofrettage operation.

The water pressure in the cylinder shall be increased at a controlled rate until the test pressure (p_h) is reached. The cylinder shall remain at the test pressure (p_h) for at least 30 s.

The limit deviation on attaining test pressure shall be test pressure $^{+3\%}_0$ (p_h).

Criteria:

- pressure shall remain steady;
- there shall be no leaks;
- after the test the cylinder shall show no visible permanent deformation.

Parameters to monitor during the test:

- pressure.

5.2.5 Test No 5 - Cylinder burst test

Procedure:

The hydraulic pressure burst test shall be carried out using a test rig, which allows pressure to be increased at a controlled rate.

The test shall be carried out in ambient conditions and the temperature on the external surface of the cylinder shall be maintained at less than 50 °C. The rate of pressurisation shall not exceed 10 bar/s and the duration of the test shall be at least 40 s.

122 ° F

The cylinder shall be pressurised at a controlled rate until failure. The pressure against time curve or pressure against volume curve shall be plotted.

The maximum pressure achieved during the test shall be recorded as the burst pressure.

Criteria:

- burst pressure shall be greater than or equal to the manufacturer's minimum specified design burst pressure and $2 \times$ test pressure ($p_b \geq 2,0 p_n$);
- burst initiation shall be in the cylindrical part, and the liner (if any) shall fail into not more than three pieces. Damage through impact during the burst test which results in additional fragments shall be disregarded. Only pieces of the liner expelled from the body of the cylinder during the test are to be counted;
- for cylinders without liners manufactured from two parts joined together, the burst shall not result in separation at the joint.

Parameters to monitor and record:

- burst pressure;
- number of pieces;
- description of failure;
- ★ — pressure/time curve or pressure/volume curve. ★

5.2.6 Test No 6 - Resistance to pressure cycles at test pressure (p_n) and ambient temperature.

a) For non-limited life:

Procedure:

The cycle test shall be carried out using a test rig, which allows pressure to be increased and decreased at a controlled rate and automatically suspends the test when the cylinder has failed, either by leakage or rupture.

The test shall be carried out with a non-corrosive liquid subjecting the cylinder to successive reversals at an upper cyclic pressure equal to the hydraulic test pressure (p_n). The value of the lower cyclic pressure shall not exceed 10 % of the upper cyclic pressure and shall have an absolute maximum of 30 bar. :

The cylinder shall actually experience the maximum and minimum cyclic pressures during this test.

The cycle tests shall be carried out in ambient conditions and the temperature on the outside surface of the cylinder shall not exceed 50 °C during the test. The frequency of reversals of pressure shall not exceed 0,25 Hz (15 cycles per minute).

The temperature of the external surface of the cylinder shall be monitored at least twice a day.

The number of cycles achieved during the test shall be recorded.

After completion of this test the cylinder shall then be destroyed (e.g. by bursting), or made incapable of holding pressure.

50°C = 122.0 F

Criteria:

- the cylinder shall withstand 12 000 cycles up to test pressure (p_h) without failure by burst or leakage.

Parameters to monitor and record:

- the temperature of the cylinder;
- number of cycles achieving upper cyclic pressure;
- minimum and maximum cyclic pressures;
- cycle frequency;
- test medium used;
- mode of failure, if appropriate.

UNLIMITED
LIFE

b) For limited life:

Procedure:

This test shall be conducted in accordance with the procedure as described in a) above and consists of two parts run sequentially and continuously. Different criteria apply to the two parts as shown in Figure 1.

After completion of this test the cylinder shall then be destroyed (e.g. by bursting), or made incapable of holding pressure.

Criteria:

- the cylinder shall first withstand N cycles up to test pressure p_h without failure by burst or leakage, where

20 yr = 5000
45 yr = 11250

$N = y \cdot 250$ cycles;

where

LIMITED
LIFE

y is the number of years of design service life and shall be a whole number greater than 10;

- the test shall continue for a further N cycles, or until failure by leakage whichever is the sooner. In either case the cylinder shall be deemed to have passed the test. However should failure during this second half of the test be by burst, then the cylinder shall have failed Test No 6.

	1 st part	2 nd part
Number of cycles	$0 < \dots > N$	$N < \dots > 2N$
Criteria	No leakage/burst = Pass	
	No leakage or burst Pass 1 st part	Leakage = Pass Burst = Fail

Figure 1 — Criteria for Test No 6

Parameters to monitor and record:

- the temperature of the cylinder;
- number of cycles, achieving upper cyclic pressure;
- minimum and maximum cyclic pressures;
- cycle frequency;
- test medium used;
- mode of failure, if appropriate.

5.2.7 Test No 7 - Immersion in salt water

This test is required for all cylinder designs intended for underwater applications and is optional for other applications.

Procedure:

The cylinder shall be finished as for the intended application and without external coating unless this is an integral part of the design.

Two closed cylinders shall be immersed in an aqueous solution containing 35 g/l of sodium chloride at (20 ± 5) °C for 90 days continuously.

The cylinders shall be immersed:

- for 45 days at not less than $2/3 \times$ test pressure (p_h);
- for 45 days without pressure.

The pressure shall be recorded at least at the beginning of the test and after 45 days, prior to de-pressurisation.

Then, following the 90 day immersion:

- one of the two cylinders shall be subjected to Test No 5 (see 5.2.5);
- the other cylinder shall be subjected to Test No 6 (see 5.2.6);

After completion of Test No 6 the cylinder shall then be destroyed (e.g. by bursting), or made incapable of holding pressure.

Criteria:

- for the first cylinder:
- burst pressure shall be greater than or equal to the manufacturer's minimum specified design burst pressure and $2 \times$ test pressure ($p_b \geq 2,0 p_h$);
- for cylinders without liners manufactured from two parts joined together, the burst shall not result in separation at the joint.

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- for the second cylinder, criteria shall be as Test No 6 (see 5.2.6), as appropriate for the design life.

Parameters to monitor and record:

- the temperature of the solution, at least twice a day;
- filling pressure;
- duration of immersion;
- burst pressure;
- description of failure;
- parameters specified in Test No 6 (see 5.2.6).

5.2.8 Test No 8 - Exposure to elevated temperature at test pressure

Procedure:

For a design service life of up to 20 years, two cylinders shall be hydraulically pressurised to test pressure (p_h), and shall be maintained at this pressure for 1 000 h.

For a design service life greater than 20 years, including non-limited life, the test shall run for 2 000 h.

$$158^{\circ}\text{F} \pm 41^{\circ}\text{F}$$

The test shall be conducted at (70 ± 5) °C and a relative humidity of less than 50 %. After this test, the cylinders shall be subjected to Test No 5 (see 5.2.5);

Criteria:

- burst pressure shall be greater than or equal to $2 \times$ test pressure ($p_b \geq 2,0 p_h$).

Parameters to monitor and record:

- measurement of the water capacity before and after test;
- temperature and relative humidity at least twice a day;
- cylinder pressure at least twice a day;
- burst pressure.

5.2.9 Test No 9 - Drop test

Procedure:

Two cylinders, each filled with water to 50 % capacity shall be fitted with a plug, flush with the end of the cylinder. Each cylinder shall then be dropped twice in each of the five positions shown in Figure 2, from a height of 1,2 m on to a steel plate. The protective plate shall be 10 mm thick and sufficiently flat so that the difference in level between any two points on the surface is no more than 2 mm. It shall be replaced regularly and in any event if damaged. The plate shall rest on flat smooth concrete, composed of cement, sand and gravel, and which is at least 100 mm thick. The steel plate shall be in full contact with the concrete so that the plate is fully supported by the concrete.

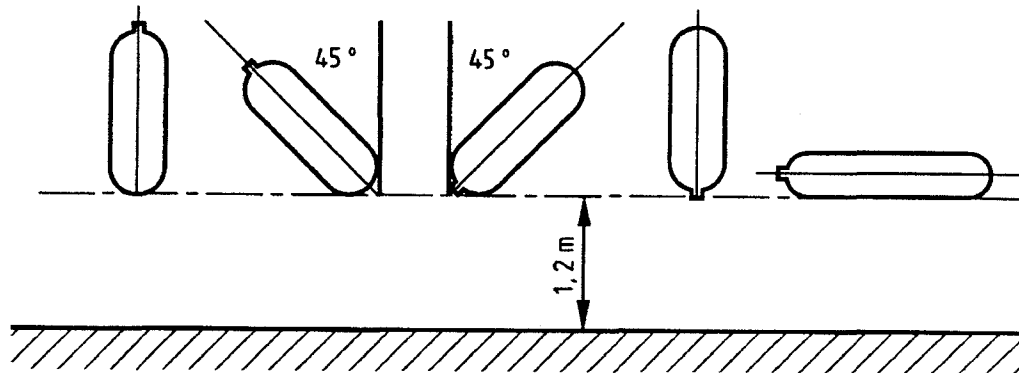


Figure 2 — Positions for the impact test

After the full sequence of drops:

- one of the two cylinders shall be subjected to Test No 5 (see 5.2.5); *BURST*
- the other cylinder shall be subjected to Test No 6 (see 5.2.6). *CYCLE*

After completion of Test No 6 the cylinder shall then be destroyed (e.g. by bursting), or made incapable of holding pressure.

Criteria:

- for the first cylinder:
- burst pressure shall be greater than or equal to the manufacturer's minimum specified design burst pressure and $2 \times$ test pressure ($p_b \geq 2,0 p_h$);
- for cylinders without liners manufactured from two parts joined together, the burst shall not result in separation at the joint;
- for the second cylinder, criteria shall be as Test No 6 (see 5.2.6).

Parameters to monitor and record:

- visual appearance after each drop - position and dimensions of impact damage;
- burst pressure;
- description of failure;
- parameters specified in Test No 6 (see 5.2.6).

5.2.10 Test No 10 - Flawed cylinder test

Procedure:

Two flaws, one longitudinal and the other transverse, shall be made on each of two cylinders in the central part along two planes forming an angle of approximately 120°. The flaws shall satisfy one of the following conditions, as appropriate:

- a) For cylinders with metallic liners the two flaws shall be made with a 1 mm thick cutter to a depth equal to at least 50 % of the wound composite thickness and to a length in the bottom of the flaw equal to five times the composite thickness.
- b) For cylinders with non-load sharing liners or without liners the two flaws shall be made with a 1 mm thick cutter to a depth equal to at least 40 % of the wound composite thickness and to a length in the bottom of the flaw equal to five times the composite thickness.

After introducing the flaws one of the two cylinders shall be subjected to Test No. 5 (see 5.2.5). The other cylinder shall be subjected to Test No 6 (see 5.2.6) except that the upper cyclic pressure shall be $\frac{2}{3} \times p_h$ and the number of cycles shall be a maximum of 5 000.

After completion of Test No 6, the cylinder shall then be destroyed (e.g. by bursting), or made incapable of holding pressure.

Criteria:

- for the first cylinder, burst pressure shall be greater than or equal to $\frac{4}{3} \times$ test pressure ($p_b \geq \frac{4}{3} p_h$);
- for the second cylinder, it shall withstand at least 1 000 pressure cycles to $\frac{2}{3} \times p_h$ without leakage. If the cylinder fails by leakage after 1 000 cycles it shall be deemed to have passed the test. However should failure occur during this second part of the test by burst, then the cylinder shall have failed Test No 10.

Parameters to monitor and record:

- burst pressure;
- number of cycles;
- flaw size;
- description of failure;
- parameters as specified in Test No 6.

5.2.11 Test No 11 - Extreme temperature cycle test

a) Vacuum cycling conditioning

For cylinders with non-load sharing liners (metallic or non-metallic) only, the cylinder shall either be subjected to a vacuum conditioning prior to the extreme temperature cycle test or it shall be clearly marked in accordance with the requirements of clause 7.

Procedure:

The cylinder shall be subjected to a series of cycles from atmospheric pressure to a vacuum.

The cylinder contents shall be evacuated to reduce the pressure to a pressure of 0,2 bar absolute at ambient temperature. The vacuum shall be maintained at this level for at least 1 min.

The pressure in the cylinder shall then be returned to atmospheric pressure.

The above procedure shall be repeated for 50 cycles.

After cycling, the interior of the liner shall be inspected for damage. Any evidence of disbonding, folding or other damage shall be noted and examined again after the extreme temperature cycle test.

NOTE If any observed defects do not cause the cylinder to fail the extreme temperature cycle test, they should nevertheless be subjected to further investigation and/or additional testing.

Parameters to monitor and record during the procedure:

- pressures;
- number of cycles;
- results of visual inspection.

b) Pressure cycling stages**Procedure:**

The cylinder and the contained pressurising medium shall be conditioned for 48 h at atmospheric pressure, at between 60 °C and 70 °C and at a relative humidity greater than or equal to 95 %.

140 °F 158 °F

The hydraulic pressurising medium, located in the circuit external to the cylinder under test, shall commence the cycle testing at ambient temperature. 5 000 cycles shall be applied from a pressure approximately equal to atmospheric pressure to two-thirds of the test pressure (p_h). The cycle testing procedure shall be in accordance with Test No 6 (see 5.2.6) but with the exception that the extreme temperature cycle test has temperature and humidity conditions as specified in this clause. The rate of pressure cycles for this test shall not exceed 0,08 Hz (5 cycles per minute) to enable the temperature conditions to be maintained.

On completion of these cycles the pressure shall be released and the cylinder stabilised at ambient conditions.

The temperature shall then be reduced and the cylinder and the contained pressurising medium stabilised at a temperature between - 50 °C and - 60 °C. The environmental chamber shall be maintained at the specified conditions by regulating the temperature. The cylinder skin temperature shall be measured and recorded.

-58° -76° F

The hydraulic pressurising medium, located in the circuit external to the cylinder under test, shall commence the second stage of cycle testing at ambient temperature. 5 000 cycles shall be applied from a pressure approximately equal to atmospheric pressure to two-thirds of the test pressure (p_h).

On completion of these cycles the pressure shall be released and the cylinder stabilised at ambient conditions. 30 cycles shall be applied from a pressure approximately equal to atmospheric pressure to test pressure (p_t).

Parameters to monitor and record:

- temperatures during each part;
- humidity during 1st part of test;
- test medium used;
- number of cycles, achieving upper cyclic pressure, at each stage;
- minimum and maximum cyclic pressures;
- cycle frequency;
- result of visual inspection.

c) Concluding burst test

The cylinder shall be subjected to Test No 5 (see 5.2.5).

Criteria:

- burst pressure shall be greater than or equal to $1,67 \times$ test pressure ($p_b \geq 1,67 p_t$).

Parameters to monitor and record:

- burst pressure;
- description of failure.

5.2.12 Test No 12 - Fire resistance test

Procedure:

Two cylinders shall undergo this test;

- one in a horizontal position;
- one in a vertical position.

The cylinders shall be fitted either:

- a) with a valve with the type of pressure relief device intended for service (e.g. fusible or burst disc);
or
- b) with a valve fitted with bursting disc set to operate at between test pressure (p_t) and $1,15 p_t$

If the valve in a) is fitted with a fusible plug this shall operate at a minimum temperature of 100 °C.

The cylinders shall be pressurized with either air or nitrogen to $2/3 \times$ test pressure (p_t).

A suitable fire shall be created with either wood or kerosene. Examples of standards that contain directions to produce a suitable fire test are prEN ISO 11439, CGA C14 1992 and EN 3-1.

One cylinder shall be placed in the horizontal position with the lowest part of the cylinder approx. 0,1 m from the top of the firewood or 0,1 m from the surface of the liquid. The fire shall be capable of enveloping the entire length of the cylinder and valve, but in no case shall the flames be allowed to impinge directly on to the pressure relief device.

One cylinder shall be placed in an upright position (valve uppermost), with the lowest part of the cylinder approximately 0,1 m from the top of the firewood or at the surface of the liquid. The cylinder shall be exposed to total fire engulfment, but in no case shall the flames be allowed to impinge directly on to the pressure relief device.

If the cylinder is too long to enable the fire to envelop the entire length of the cylinder when in the vertical position, and the cylinder does not have pressure relief devices at both ends, the vertical bonfire test may be replaced by a second test in the horizontal position.

After completion of this test the cylinders shall then be destroyed (e.g. by bursting) or made incapable of holding pressure.

Criteria:

The cylinders shall not burst during a period of 2 min from the start of the fire test. They may vent through the pressure relief device or leak through the cylinder wall or other surfaces.

Parameters to monitor and record during the test:

- type and characteristics of pressure relief device;
- initial pressure;
- time;
- mode of pressure release, if appropriate.

5.2.13 Test No 13 - High velocity impact (bullet) test

Procedure

For cylinders with diameter above 120 mm a cylinder pressurized with air or nitrogen to $\frac{2}{3} \times$ test pressure (p_h) shall be impacted by a 7,62 mm (0,3 calibre) armour-piercing projectile (of nominal length 51 mm) and having a velocity of approximately 850 m/s. The cylinder shall be positioned in such a way that the point of impact of the projectile shall be in the bottom (the area with no circumferential winding) and shot at an angle of approximately 45° to the centre line of the cylinder, so that it will exit through the cylinder wall. Distance from firing location to test cylinder shall not exceed 45 m.

For cylinders with a diameter of 120 mm and below a 5,6 mm (0,22 calibre) projectile of 13,6 mm nominal length may be used.

Criteria:

- the tested cylinder shall reveal no evidence of a fragmentation failure, whether or not the bullet penetrates the cylinder.

Parameters to monitor and record:

- type of projectile;
- initial pressure;
- description of failure;
- approximate size and location of the entrance and exit openings.

5.2.14 Test No 14 - Permeability test of cylinders with non-metallic or without liners

Procedure:

One cylinder shall be pressurised with test gas (see under 'criteria' below) to $2/3 \times$ test pressure (p_h) and the valve and the junctions of the thermoplastic liner or composite with the metallic bosses or rings shall be visually checked for leaks e.g. with soapy water (bubble test). Any leaks shall be eliminated before proceeding with the test. The test cylinder shall be weighed empty, before the test.

The cylinder shall then be hydraulically cycled 1 000 times from zero to $2/3 \times$ test pressure (p_h) before being weighed while empty, and the weight recorded. The cylinder shall then be filled to $2/3 \times$ test pressure (p_h) with test gas (see criteria) at a temperature of 15 °C.

The cylinder shall be weighed and the weight of the gas stored determined and recorded. The cylinder shall then be re-weighed after 1 day, 7 days, 14 days, 21 days and 28 days. For the duration of the test the cylinder shall be stored in an environment with stable temperature and humidity. The graph of weight change against number of days shall be determined.

After the test the cylinder shall be re-weighed empty. Any difference in weight between this measurement and the initial measurement shall be used to determine the effect due to moisture absorption and the weights obtained during the test shall be modified accordingly.

Criteria:

- The maximum rate of weight loss shall be less than X ml/h/l water capacity, where X is as follows:
 - a) for general applications where the rate of permeation of the gas is more than that of air, the test gas shall be the gas for which the cylinder is designed, or alternatively one with a higher permeability rate, and $X = 0,25$;
 - b) for general applications where the rate of permeation of the gas is less than that of air or nitrogen, the test gas shall be either the intended gas, air or nitrogen and $X = 0,25$;
 - c) for specialised applications, the test gas and the value of X shall be agreed between the interested parties according to the application.

Parameters to monitor and record:

- test gas used;
- cycle test medium;
- number of cycles, achieving upper cyclic pressure;
- cycle frequency;

- ambient temperatures and humidity at least twice a day;
- cylinder weights.

Alternative procedures may be used, which may be demonstrated to achieve the same accuracy of results.

5.2.15 Test No 15 - Test of compatibility of thermoplastic liners with oxidising gases

This test shall be carried out for cylinders intended to contain gases which are more oxidising than air (as defined in EN 720-2 or ISO 10156).

Procedure:

The autogenous ignition temperature of the liner material shall be determined in accordance with EN ISO 11114-3.

Criteria:

- the ignition temperature shall be greater than 400 °C.

5.2.16 Test No 16 - Torque test

Procedure:

The cylinder threads shall show no permanent expansion or deformation when mated with a corresponding valve or plug and tightened to 110 % of the maximum torque specified and to the procedure specified in EN ISO 13341, or as recommended in the manufacturer's specification where this standard does not apply. The internal neck thread shall be checked using gauges corresponding to the agreed neck thread to ensure that it is within tolerance.

NOTE For example, where the neck thread is specified to be in accordance with EN 629-1, the corresponding gauges are specified in EN 629-2.

Criteria:

- the threads shall remain within gauge tolerance.

Parameters to monitor and record

- type of valve/plug material;
- valving procedure;
- applied torque.

Where the torque recommended by the manufacturer differs from that specified in EN ISO 13341, this shall be recorded on the label (see clause 7).

5.2.17 Test No 17 - Neck strength

Procedure:

The neck of the cylinder shall show no significant deformation and shall remain within the drawing tolerance when mated with a corresponding valve or plug and tightened to 150 % of the torque specified and to the procedure specified in EN ISO 13341 or as recommended in the manufacturer's specification, where this standard does not apply. If the neck contains a

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threaded insert a permeability test in accordance with Test No 14 (see 5.2.14) shall be carried out after this test.

Criteria:

- the neck shall show no significant deformation.

Parameters to monitor and record:

- type of valve/plug material;
- valving procedure;
- applied torque;
- parameters required in Test No 14 (see 5.2.14), where applicable.

Where the torque recommended by the manufacturer differs from that specified in EN ISO 13341, this shall be recorded on the label (see clause 7).

5.2.18 Test No. 18 - Cylinder stability

For a cylinder designed to stand on its base, the variation from vertical shall be less than 1 % of its height, and the outer diameter of the surface in contact with the ground shall be greater than 75 % of the nominal outside diameter.

5.2.19 Test No. 19 - Neck ring

When a neck ring is fitted, the manufacturer shall ensure that the axial load required to remove the neck ring is greater than 10 × the weight of the empty cylinder and not less than 1 000 N. The minimum torque to turn the neck ring shall be greater than 100 N.m.

5.3 Failure to meet test requirements

5.3.1 Metallic liners

Where the mechanical properties of the liner have not met the requirements of the specification, they may be treated in accordance with the appropriate clauses of the relevant standard, as listed in 4.2.1.

5.3.2 Complete cylinder

For complete cylinders the following procedure may be used for prototype testing, design variant testing and production testing.

In the event of failure to meet test requirements, re-testing shall be carried out, as follows:

- if there is evidence of a fault in carrying out a test, or an error of measurement a second test shall be performed on the same cylinder if possible. If the results of this test are satisfactory, the first test shall be ignored;
- if the test has been carried out in a satisfactory manner, the cause of test failure shall be identified or the batch(es) shall be rendered unserviceable for the intended purpose. If the cause of failure is identified the defective cylinders may be reclaimed by an approved method or shall be rendered unserviceable for the intended purpose. If reclaimed, these acceptable cylinders along with the original satisfactory cylinders shall be considered a new batch and the prototype testing and/or batch test shall be performed again. If any test or part of a test is unsatisfactory, all the

cylinders of the batch or batches covered by the test shall be rendered unserviceable for the intended application.

6 Conformity evaluation

Prototype testing, design variant testing and production testing shall be carried out in accordance with annex A.

7 Marking

The permanent markings, including the stamping (if any), shall be in accordance with EN 1089-1.

Specific additional information shall be included on the label as follows:

- where a cylinder with non-load sharing liner has not completed the vacuum conditioning of the extreme temperature cycle test (Test No 11, see 5.2.11) the following words shall be marked clearly, legibly and indelibly:

"WARNING - THIS CYLINDER MUST NOT BE SUBJECTED TO A VACUUM"

- where a cylinder is approved with a specific pressure relief device intended to prevent failure in the case of fire (Test No 12, see 5.2.12), this requirement shall be stated and the type of device shall be identified on the label;
- where the fitting torque for the valve does not correspond to the values given in EN ISO 13341, the manufacturer's recommendation shall be shown on the label.
- where the cylinder has been approved for special applications this shall be shown on the label e.g. underwater.

Annex A (normative)

Prototype testing, design variant testing and production testing

A.1 General

This annex describes the schedules of tests to be carried out on fully wrapped composite cylinders, as required to verify new cylinder designs (prototype testing), to extend prototype testing to permitted variants (design variant testing) and also to ensure compliance of a production batch of cylinders with the design specification of the prototype cylinder design (production tests).

Testing shall be carried out for each new design or design variant of cylinder (see A.2. and A.3.).

A.2 Prototype testing

A.2.1 General

Prototype testing shall be carried out on each new design of cylinder.

Prototype testing shall be carried out on cylinders of identical design (i.e. materials, liner, manufacturing process) from the same factory, equipment and the same sub-contractor, if applicable. The tests shall be performed on cylinders having the same nominal dimensions (i.e. same diameter, length, liner wall thickness and composite thickness).

The prototype testing is valid for cylinders having the same diameter but whose length may vary from twice the diameter of the prototype tested cylinder to 1,5 times the length of the prototype tested cylinder.

Shorter cylinders i.e. those cylinders whose length is less than twice the diameter of the nominated prototype tested cylinder shall not be considered part of the family and shall be tested individually as a design variant (see A.3).

A.2.2 Definition of new design

A cylinder shall be considered to be of a new design, compared with a previously prototype tested cylinder, when any of the following conditions apply:

- a) it is manufactured in a different factory. However, where a factory moves to a different location with the same equipment, a reduced testing programme may be agreed with the inspection body;
- b) it is manufactured by a significantly different process. A significant change is regarded as a change that would have a measurable change in the performance of the liner and/or finished cylinder. The inspection body shall determine when a change in process or design or manufacture is significantly different from the original prototype tested design;

- c) the liner is manufactured from a material of different composition or outside the composition limits of the material used in the original prototype tested design and/or detailed in the relevant standard listed in 4.2.1;
- d) it is manufactured with a new fibre type.

A fibre shall be considered to be of a new fibre type when any of the following conditions apply:

- 1) the fibre is of a different classification, e.g. glass, aramid, carbon;
 - 2) the fibre is produced from a different precursor (starting material), e.g. polyacrylonitrile (PAN), pitch for carbon;
 - 3) the nominal fibre modulus, specified by the fibre manufacturer, differs by more than $\pm 5\%$ from that defined in the prototype tested design;
 - 4) the nominal fibre strength, specified by the fibre manufacturer, differs by more than $\pm 5\%$ from that defined in the prototype tested design.
- e) it is manufactured using different matrix materials e.g. resin, curing agent, accelerator (see Note 1);
 - f) the hydraulic test pressure has been increased by more than 60 % (see Note 2);
 - g) the cylinder diameter has changed by more than 50 %;
 - h) the autofrettage pressure has changed by more than 5 %.

NOTE 1 Where a new matrix material has been prototype tested for an existing design, then all the manufacturer's existing prototype tested designs are regarded as prototype tested with the new matrix system without the need for any additional prototype testing.

NOTE 2 A cylinder can be used and marked for a lower test pressure than stated in the original prototype testing without additional testing.

A.2.3 Prototype testing requirements

The applicant for prototype testing shall, for each new design of cylinder, submit the documentation necessary for the checks specified below. The applicant shall make available to the inspection body a batch of at least 50 cylinders, and (where appropriate) liners, from which the number of cylinders required for the tests referred to below will be taken. For cylinders with liners the applicant shall also submit a suitable number of liners for testing taken at random from the same batch prior to winding.

However, if the total production is less than 50 cylinders, enough cylinders shall be made to complete the prototype testing in addition to the production quantity, but in this case the prototype testing validity is limited to this particular production batch.

In the course of the prototype testing process, the inspection body shall:

- a) select the necessary cylinders for testing in accordance with the Tables A.1, A.2, A.3 and A.4, as applicable;
- b) verify that:
 - 1) the design conforms to the requirements of clause 4;

- 2) the liners are in accordance with the relevant liner design standard and in compliance with the manufacturing drawing;
 - 3) the internal and external surfaces of the cylinders are free of any defect which may make them unsafe to use;
- c) witness or carry out the tests as stipulated in Tables A.1, A.2, A.3 and A.4, as applicable.

A.2.4 Prototype testing certificate

If the results of the prototype testing are satisfactory, the inspection body shall issue a prototype testing certificate to the manufacturer. This prototype testing certificate may take the form of a type approval certificate, a typical example of which is given in annex B.

If the results are not satisfactory proceed as described in 5.3.

Table A.1 — Composite materials

Test	Prototype testing and design variant testing	Production testing
Test No 1a - All cylinders		
i)- Tensile properties of fibres	2 tests	1 test per batch of fibres
ii) - Shear properties	2 tests	1 test per batch of fibres
Test No 1b - cylinders without liners		
Tensile Strength	1	1
Tensile modulus	1	1
Elongation	1	1
Viscosity	1	-
Heat distortion temperature	1	-
Auto-ignition temperature(oxidising gases only)	1	-
Composition	1	-

Table A.2 — Metallic liners

Test	Prototype testing and design variant testing ^b	Production testing ^b
Test No 2 - Liner material tests to the appropriate standard ^a	Quantity prescribed by appropriate standard	-
Test No 2 - Liner material tests to the appropriate standard ^a mechanical properties only	-	1 per liner batch
Test No 3 - Liner burst test	1	-
Homogeneity (e.g. hardness, electrical conductivity)	100 %	100 %
Visual inspection	100 %	10 %
Dimensional check	100 %	10 %
^a For list of appropriate standards see 5.2.2.		
^b The numbers in the table represent the number of liners or cylinders that shall be subjected to the relevant test.		

Table A.3 — Non-metallic liners and cylinders without liners

Test	Prototype testing and design variant ^d	Production testing ^d
Test No 2 - Materials tests ^a	2	1 ^b
Tests of material homogeneity	100 %	100 % ^c
Visual inspection	100 %	10 %
Dimensional check	100 %	10 %
^a For list of appropriate standards see 5.2.2. ^b Only melting flow index (all), viscosity (all), melting point (thermoplastic) and glass transition temperature (thermoset) tests shall be carried out on each batch of material. ^c A non-destructive test specified by the manufacturer, to demonstrate that no error has been made in the processing of the material shall be carried out. ^d The numbers in the table represent the number of liners that shall be subjected to the relevant test.		

Table A.4 — Tests on finished cylinders

Test	Prototype testing and design variant testing ^g	Production testing ^g
Visual inspection	100 %	10 % ^e
Dimensional check	100 %	10 % ^e
Weight check	100 %	10 % ^e
Water capacity	100 %	10 % ^e
Marking compliance	100 %	100 %
Test No 4 Hydraulic (or proof) test	100 %	100 %
Test No 5 Hydraulic pressure burst test	3	1 per batch ^f
Test No 6 Pressure cycling test	2	Minimum of 1 per 5 batches ^f
Test No 7 Salt-water immersion test ^a	2	-
Test No 8 Exposure to elevated temperature at test pressure	2	-
Test No 9 Drop test	2	-
Test No 10 Flaw test	2	-
Test No 11 Extreme temperature cycle test ^b	1	-
Test No 12 Fire resistance tests	2	-
Test No 13 High velocity impact (bullet) test	1	-
Test No 14 Permeability test ^c	2	-
Test No 15 Compatibility test ^d	1	-
Test No 16 Torque test	1	-
Test No 17 Neck strength test	1	-
Test No 18 Stability test (if applicable)	1	-
Test No 19 Neck ring (if applicable)	1	-
<p>^a Test No 7 is optional except for diving applications where it is required.</p> <p>^b For Test No 11 the vacuum conditioning is optional for cylinders with non-metallic liners and cylinders without liners.</p> <p>^c The permeability test is required for cylinders with non-metallic liners and cylinders without liners.</p> <p>^d The compatibility test is required, either for cylinders with non-metallic liners or cylinders without liners, for service with oxidising gases.</p> <p>^e If one unacceptable defect is found, 100 % of the cylinders in the batch shall be inspected.</p> <p>^f For cylinders greater than 150 l water capacity, a smaller cylinder with the same diameter, thicknesses and wrap pattern may be used for production testing. The comparability of burst and cycle performance shall first be demonstrated before the smaller capacity cylinder may be used.</p> <p>^g The numbers in the table represent the number of cylinders that shall be subjected to the relevant test.</p>		

A.3 Design variant testing

A.3.1 General

For cylinders within the definition of a design variant when compared with a prototype tested design, a reduced testing programme may be carried out. Design variant testing shall be conducted for each design variant of cylinder.

A.3.2 Definition of a design variant

A.3.2.1 Conditions to be satisfied

A cylinder shall be considered to be a design variant compared with a previously prototype tested cylinder when any of the following conditions apply:

- a) the fibres in the design are equivalent to the fibres in a previously prototype tested cylinder (see A.3.2.2.);
- b) the liner in the design is equivalent to the liner in a previously prototype tested cylinder (see A.3.2.3);
- c) the cylinder conforms to the conditions in A.3.2.4.

A.3.2.2 Equivalent fibre

For a fibre having similar nominal mechanical and physical characteristics to the prototype tested fibre, its equivalency shall be verified as follows before it can be considered as an equivalent fibre.

The new fibre with the existing prototype tested resin system shall be subjected to the strand and interlaminar shear tests detailed in Test No 1 (see 5.2.1).

The mechanical properties shall be within $\pm 5\%$ of the nominal properties of the prototype tested fibre.

NOTE Where a new equivalent fibre has been prototype tested for an existing design, then all the manufacturer's existing prototype tested designs are regarded as prototype tested with the new fibre without the need for any additional prototype testing.

A.3.2.3 Equivalent liner

A liner is equivalent to a liner in a previously prototype tested cylinder when any of the following apply:

- a) the liner is of the prototype tested design except that it is manufactured in a different factory;
- b) the liner is of the prototype tested design except that it is manufactured using a significantly different process from that used to produce the prototype tested design;
- c) the liner is of the prototype tested design except that it is given a heat treatment outside the limits specified in the prototype tested design.

The new liner shall be subjected to the material tests specified in the relevant standards, as listed in 5.2.2, and to the liner burst test, in accordance with Test No 3 (see 5.2.3), and shall meet the minimum requirements of the prototype tested design.

NOTE Where a new equivalent liner has been prototype tested for an existing design, then all the manufacturer's existing prototype tested designs are regarded as prototype tested with the new liner without the need for any additional prototype testing.

A.3.2.4 Cylinder variant

A cylinder shall be considered to be a design variant compared with a previously prototype tested cylinder when if any of the following conditions apply:

- a) the nominal length of the cylinder has changed to below $2 \times$ diameter or has increased by more than 50 % of the prototype tested design length;
- b) the nominal outside diameter has changed by more than 2 % and less than or equal to 50 % (see Note);
- c) the hydraulic test pressure has changed by less than or equal to 60 %;
- d) there have been changes to the composite thickness or wrap pattern;
- e) there have been changes to the thickness of the liner, i.e. wall or base thickness has changed;
- f) the liner has material properties outside the prototype tested design limits;
- g) the liner is equivalent to an existing prototype tested design, as specified in A.3.2.3;
- h) the new fibre is equivalent to the fibre in the prototype tested design as specified in A.3.2.2;
- i) the neck thread size has changed;
- j) the nominal autofrettage pressure has changed by 5 % or less, of the prototype tested design autofrettage pressure.

NOTE Where the change in nominal diameter is between 2 % and 20 %, a different test regime is applicable compared to that for changes between 20 % and 50 % (see Table A.5)

The inspection body shall determine the level of testing required and may request other tests than those specified to carry out design variant testing, where it is considered necessary or for special applications.

A.3.3 Design variant test requirements

For each design of cylinder variant the applicant for design variant testing shall submit the documentation necessary for the checks specified below. The applicant shall also make available to the inspection body a batch of cylinders equal to twice the quantity of cylinders required for design variant testing together with any additional information required. In addition the prototype testing certificate of the original design shall be presented.

For cylinders with metallic liners the applicant shall also submit one or more liners taken at random from the same batch just prior to winding.

In the course of the design variant testing process, the inspection body shall:

- a) consider the changes of the design variant against the previously prototype tested cylinder and determine the required level of testing;
- b) select the necessary cylinders for testing in accordance with Table A.5;

- c) verify that:
- the design conforms to the requirements of clause 4;
 - the design is in accordance with the manufacturing drawing;
 - the internal and external surfaces of the cylinders are free of any defect which may make them unsafe to use;
- d) witness or carry out the tests as specified in Table A.5.

A.3.4 Design variant testing certificate

If the results of the design variant testing are satisfactory, the inspection body shall issue a design variant testing certificate to the manufacturer. This design variant testing certificate may take the form of a design variant approval certificate, a typical example of which is given in annex B.

If the results are not satisfactory proceed as described in 5.3.

Table A.5 — Design variant test requirements

Test No	Test	New design	Design Variant Changes						Liner design or thickness	Composite thickness or wrap pattern	Fibre	Neck thread change	Auto-fretage pressure
			Design test pressure	Nominal length - L	Nominal Diameter - D	Design test pressure	Nominal length - L	Nominal Diameter - D					
1	Composite material tests	✓											
2	Liner material test	✓							✓ ^{h)}				
3	Liner burst ^{a)}	✓	changed by ≤ 60 %	new length < 2D	new length > 1,5L	changed by > 2 % and ≤ 20 %	changed by > 20 % and < 50 %			✓ ⁱ⁾			
4	Pressure test	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
5	Burst	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
6	Ambient cycle	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
7	Salt water immersion ^{b)}	✓								✓ ^{h)}			
8	Max. Temperature	✓	✓ ^{h)}							✓ ^{h)}			
9	Drop test	✓	✓						✓	✓			
10	Flaw test	✓							✓	✓			
11	Extreme temperature cycle	✓								✓			
12	Fire resistance	✓					✓ ^{g)}						
13	High velocity impact	✓											
14	Permeability ^{e)}	✓							✓				
15	Compatibility ^{e)}	✓											
16	Torque test	✓											
17	Neck strength	✓							✓				
18	Stability ^{e)}	✓											
19	Neck ring ^{e)}	✓											

^{a)} Cylinders with load bearing liners only.
^{b)} Cylinders for underwater applications only.
^{c)} Cylinders with non-metallic or no liners only.
^{d)} Free standing cylinders only.
^{e)} Cylinders with neck rings fitted only.
^{f)} Where p_{min}/p_n ratio for design variant is less than manufacturer's specified p_b/p_n ratio for prototype design, then Test No. 8 shall be carried out
^{g)} For cylinders leaking in the type approval bonfire test at a pressure > test pressure it is not necessary for this test to be carried out.
^{h)} For equivalent liner testing
ⁱ⁾ For equivalent fibre testing

A.4 Production testing

A.4.1 General

These tests are a series of tests that shall be carried out on either the whole or part of the production batch, as identified in A.4.2, A.4.3, A.4.4 and A.4.5, to ensure the compliance of the batch with the design specification.

A.4.2 Production test requirements

A.4.2.1 For the purpose of production testing, the cylinder manufacturer shall provide the relevant inspection body with:

- a) the prototype testing certificate or the design variant testing certificate;
- b) the material certificates stating the analyses of the liner material and composite materials;
- c) the certificates of compliance stating that the composite overwrap materials meet the supply specifications drawn up jointly by the manufacturer and supplier, and report of material testing in accordance with Table A.1;
- d) heat treatment documentation, as appropriate;
- e) certificates covering any non destructive testing of the liner if applicable;
- f) the serial numbers of the cylinders;
- g) a statement of the thread checking method used and results thereof.

A.4.2.2 During production testing, the inspection body shall:

- a) ascertain that the prototype testing certificate or design variant testing certificate has been obtained and that the cylinders conform to it;
- b) check whether the information supplied by the manufacturer referred to in A.4.2.1 is correct;
- c) select the necessary liners for testing in accordance with A.4.3.1 or A.4.3.2, as appropriate;
- d) verify that composite materials meet the test requirements, specified in A 4.4;
- e) check whether the requirements set out in clause 4 have been met and carry out or witness the inspections in accordance with A.4.5.2;
- f) select the necessary cylinders for testing in accordance with A.4.5.1;

A.4.3 Liner batch tests and inspections

A.4.3.1 Metallic liner

The inspections and tests shall be carried out on a batch of metallic liners as specified in Table A.2.

The liner shall conform to the design drawing of the prototype and the supply specifications drawn up jointly by the manufacturer and his supplier. The inspections shall include both non-destructive tests, i.e. visual, dimensions, etc., and destructive tests i.e. tensile tests.

A.4.3.2 Non-metallic liner

The inspections and tests shall be carried out on a batch of non-metallic liners as specified in Table A.3.

The liner shall conform to the design drawing and the supply specifications drawn up jointly by the cylinder manufacturer and liner supplier. The inspections shall include at least the non-destructive inspections - visual, dimensional, weight, etc., and any appropriate destructive tests.

The measured parameters shall not be less than the minimum design requirement.

One liner from every batch shall be tested to verify that the mechanical properties meet the minimum design requirements. On every test liner there shall be carried out two tensile tests. The tensile strength and the elongation at break shall be tested in accordance with ISO 527-1 and ISO 527-2 (Test No 2, see 5.2.2).

Acceptance of non-metallic liners shall also depend on satisfying the following requirements:

- the properties of the material (raw material as granulate etc.) shall be within the tolerances set by the material manufacturer;
- the process parameters during liner manufacturing shall be within the tolerances agreed during prototype testing of the process;
- the material properties of the liner shall be within the tolerances required by the design requirements. This shall be verified by testing the material from a liner.

A.4.4 Composite materials batch tests and inspections

The tests and inspections shall be carried out on a batch of composite material, fibre, matrix, resin, and adhesive, if applicable, as specified in Table A.1.

The materials shall conform to the design drawing of the prototype and the supply specifications drawn up jointly by the manufacturer and the material supplier.

A.4.5 Tests and inspections of the finished cylinder

A.4.5.1 Tests

For cylinders with non-load sharing liners (non-metallic or welded metallic) or without liners, the manufacturer shall apply tests appropriate to the manufacturing process to demonstrate that the cylinder does not leak.

The tests shall be carried out on a batch of finished cylinders with liners or batch of finished cylinders with no liners as specified in Table A.4, as follows:

- a) the hydraulic proof test (Test No 4, see 5.2.4) on all cylinders;
- b) a hydraulic burst test (Test No 5, see 5.2.5) on one cylinder per batch;

NOTE It can be instructive to compare the results of the hydraulic burst test (Test No 5, see 5.2.5) on the prototype test cylinders, the design variant test cylinders and production test cylinders.

If the results of the hydraulic burst test (Test No 5, see 5.2.5) from the design variant testing and production testing are consistently less than 85 % of the minimum of the burst tests obtained during prototype testing the inspection body may wish to determine the cause of the variation.

Similarly, the maximum burst pressure should not be more than 120 % of the minimum burst pressure specified by the manufacturer.

- c) a pressure cycling test (Test No 6, see 5.2.6) on not less than one cylinder per five batches (i.e. a maximum of 1 000 cylinders produced sequentially).

A.4.5.2 Inspections

The inspections shall be carried out on a batch of finished cylinders with liners or batch of finished cylinders with no liners as specified in Table A.4, as follows:

- a) visual inspection, in accordance with 4.4.4 - 10 % minimum
- b) dimensional check - 10 % minimum
- c) weight check - 10 % minimum
- d) water capacity check - 10 % minimum
- e) compliance of marking - 100 %.

For a), b), c) and d), if one unacceptable cylinder is found then 100 % of the cylinders in the batch shall be inspected.

A.4.6 Batch acceptance certificate

If the results of the checks and tests are satisfactory, the inspection body shall issue a production testing certificate, a typical example of which is given in annex B.

If the results are not satisfactory proceed as described in 5.3.

Annex B
(informative)

Examples of type approval and production testing certificates

B.1 Type approval certificate - composite cylinders with metallic liners

Issued by (Relevant authority) on the basis of applying
EN 12245 - Transportable gas cylinders - Fully wrapped composite cylinders

Approval N° Date

Cylinder Description (Family of cylinders which has received type approval)

Manufacturer's Drawing No:

Design Life Underwater Special Torque Pressure Relief Device

Liner Heat Treatment Details

Finished Cylinder		Liner		Composite Material	
Capacity	l	Material		Fibre(s)	
Test Pressure	bar	Min. thickness	mm	Fibre(s) Tensile Strength	MPa
Diameter	mm	Min. yield stress	MPa	Fibre(s) Modulus	GPa
Length	mm	Min. tensile strength	MPa	Matrix components	
Thread		Elongation	%	Shear Strength	MPa
Autofrettage Pressure	bar	Min. burst pressure	bar	Thickness	mm

Compatible gases:

Manufacturer or agent (Name and address of manufacturer or its agent)

Type approval mark

Details of the results of the examination of the design for type approval are detailed in Qualification Test Report

All information may be obtained from (Name and address of the approving body)

Date Place

Signature

B.2 Type approval certificate - composite cylinders with non-metallic liners

Issued by (Relevant authority) on the basis of applying EN 12245 - Transportable gas cylinders - Fully wrapped composite cylinders

Approval No Date

Cylinder Description (Family of cylinders which has received type approval)
 Manufacturer's Drawing No:
 Design Life Underwater Special Torque Pressure Relief Device

Finished Cylinder		Liner		Composite Material	
Capacity	l	Material		Fibre(s)	
Test Pressure	bar	Density		Fibre(s) Tensile Strength	MPa
Diameter	mm	Melting Point	°C	Fibre(s) Modulus	GPa
Length	mm	Glass Transition Temperature	°C	Matrix components	
Thread		Auto-ignition temperature	°C	Shear Strength	MPa
		Min. thickness	mm	Thickness	mm

Metal End Boss			
Material	Min. Yield Stress	Min. Tensile Strength	Elongation
	MPa	MPa	%

Compatible gases:

Manufacturer or agent (Name and address of manufacturer or its agent)

Type approval mark

Details of the results of the examination of the design for type approval are detailed in Qualification Test Report

All information may be obtained from (Name and address of the approving body)

Date Place

Signature

B.3 Type approval certificate - composite cylinders without liners

Issued by (Relevant authority)..... on the basis of applying EN 12245 - Transportable gas cylinders - Fully wrapped composite cylinders

Approval N° Date

Cylinder Description (Family of cylinders which has received type approval).....
 Manufacturer's Drawing No:
 Design Life Underwater Special Torque Pressure Relief Device.....

Finished Cylinder		Adhesive		Composite Materials	
Capacity	l	Material Components		Fibre(s)	
Test Pressure	bar	Viscosity		Fibre(s) Tensile Strength	MPa
Diameter	mm	Shear Strength	MPa	Fibre(s) Modulus	GPa
Length	mm	Glass Transition Temperature	°C	Matrix components	
Thread		Auto-ignition temperature	°C	Shear Strength	MPa
				Tensile Strength	MPa
				Tensile Modulus	MPa
				Elongation	%
				Min. Thickness	mm

Metal End Boss			
Material	Min. Yield Stress	Min.Tensile Strength	Elongation
	MPa	MPa	%

Compatible gases

Manufacturer or agent..... (Name and address of manufacturer or its agent)

Type approval mark

Details of the results of the examination of the design for type approval are detailed in Qualification Test Report

All information may be obtained from..... (Name and address of the approving body)

Date Place

Signature

B.4 Design variant approval certificate - composite cylinders with metallic liners

Issued by (Relevant authority) on the basis of applying EN 12245 - Transportable gas cylinders - Fully wrapped composite cylinders

Approval N° Date

Cylinder Description (Cylinder which has received design variant approval)
 Manufacturer's Drawing No:

Original Type Approval N° Date

Cylinder Description (Cylinder which had received design approval)
 Design Life Underwater Special Torque Pressure Relief Device
 Liner Heat Treatment Details

Finished Cylinder		Liner		Composite Material	
Capacity	l	Material		Fibre(s)	
Test Pressure	bar	Min. thickness	mm	Fibre(s) Tensile Strength	MPa
Diameter	mm	Min. yield stress	MPa	Fibre(s) Modulus	GPa
Length	mm	Min. tensile strength	MPa	Matrix components	
Thread		Elongation	%	Shear Strength	MPa
Autofrettage Pressure	bar	Min. burst pressure	bar	Thickness	mm

Compatible gases:

Manufacturer or agent..... (Name and address of manufacturer or its agent)

.....

Design variant approval mark

Details of the results of the examination of the design for design variant approval are detailed in Qualification Test Report

All information may be obtained from.....(Name and address of the approving body)

.....

DatePlace

Signature

B.5 Production test certificate

Inspection body

Inspection body's mark

Certificate No. Cylinders manufactured by Date

Country..... Mark

Specification: EN 12245 Type approval or Design Variant No

Description of cylinders

Water capacity Test Pressure..... Design Life

Additional design requirements

Quantity Manufacturer's part no. Serial numbers to

Date of hydraulic pressure test

Customer Name & address

Manufacturing batch no.

Each cylinder was manufactured in accordance with the requirements of EN 12245 and the design defined in type approval or design variant approval.....

All the materials used in the manufacture of the cylinders were identified by individual batch numbers and their properties were verified that they complied with the specification and approved design requirements.

The following materials were used in the manufacture of these cylinders:

Liner - Material designation					
Supplier	Batch No:	Cylinder serial numbers	Yield Stress MPa	Tensile Strength MPa	Elongation %

Fibres				
Supplier	Fibre Type	Batch No:	Tensile Strength MPa	Shear Strength MPa

Resin System Components					
Resin & Designation		Curing Agent & Designation		Accelerator & Designation	
Supplier	Batch No:	Supplier	Batch No:	Supplier	Batch No:

Finished Cylinder			Batch No:
Serial No:	Test Pressure	No: of cycles	Cycle Frequency
Serial No:	Min.Burst pressure	Actual Burst Pressure	Mode of failure

Pressure Test Results		
Manufacturer's part no:	Design Test Pressure	Autofrettage Pressure

Batch No:	Serial No:	Weight kg			Autofrettage Expansions cm ³			Pressure Test Expansions				
		Liner	Comp	Total	Volume I	Total	Perm	Total - T	Perm - P	Elastic	P/T %	

I, the undersigned hereby declare that I have checked that the requirements of Table A.1, Table A.2, Table A.3 and Table A.4 of EN 12245:2001 have been carried out satisfactorily.

Special remarks

.....

General remarks

.....

Certified on (date) Place.....

Signature of the inspector

On behalf of (Inspection body)

Bibliography

EN 3-1:1996, *Portable fire extinguishers — Part 1: Description, duration of operation, class A and B fire test.*

EN 144-1, *Respiratory protective devices — Gas cylinder valves — Thread connection for insert connector.*

EN 629-1, *Transportable gas cylinders — 25E taper thread for connection of valves to gas cylinders — Part 1: Specification.*

EN 629-2, *Transportable gas cylinders — 25E taper thread for connection of valve to gas cylinders — Part 2: Gauge inspection.*

EN 962, *Transportable gas cylinders — Valve protection caps and valve guards for industrial and medical gas cylinders — Design, construction and tests.*

EN 1089-2, *Transportable gas cylinders — Gas cylinder identification (excluding LPG) — Part 2: Precautionary labels.*

EN 1089-3, *Transportable gas cylinders — Cylinder identification (excluding LPG) — Part 3: Colour coding.*

EN 1800, *Transportable gas cylinders — Acetylene cylinders — Basic requirements and definitions.*

EN 12257, *Transportable gas cylinders — Seamless, hoop wrapped composite cylinders.*

EN ISO 11439, *High pressure cylinders for the on-board storage of natural gas as a fuel for automotive cylinders (ISO/DIS 11439:1997).*

prEN ISO 11623, *Transportable gas cylinders — Periodic inspection and testing of composite cylinders (ISO/FDIS 11623:2000).*

CGA C14:1992, *Procedures for testing of DOT cylinder pressure relief device systems*

Council Directive 1999/36/EC of 29 April 1999 on transportable pressure equipment (TPED)

ADR European agreement on the International Carriage of Dangerous Goods by Road

RID Regulations concerning the International Carriage of Dangerous Goods by Rail