INTERNATIONAL STANDARD

ISO 11119-3

Second edition
2013-04-15

Gas cylinders — Refillable composite gas cylinders and tubes

Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450L with non-load-sharing metallic or non-metallic liners

Bouteilles à gaz — Bouteilles à gaz rechargeables en matériau composite et tubes

Partie 3: Bouteilles à gaz composites entièrement bobinées renforcées par des fibres et tubes d'une contenance allant jusqu'à 450 l avec liners métalliques ou non métalliques ne transmettant pas la charge

Reference number
ISO 11119-3:2013(E)

COPYRIGHT PROTECTED DOCUMENT

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11119-3 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

This second edition cancels and replaces the first edition (ISO 11119-3:2002), which has been technically revised.

ISO 11119 consists of the following parts, under the general title *Gas cylinders — Refillable composite gas cylinders and tubes — Design, construction and testing*:

— *Part 1: Hoop wrapped fibre reinforced composite gas cylinders and tubes up to 450 l*

— *Part 2: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with load-sharing metal liners*

— *Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450L with non-load-sharing metallic or non-metallic liners*

The following part is under preparation:

— *Part 4: Fully wrapped fibre reinforced composite gas cylinders with load-sharing welded metal liners*

Introduction

The purpose of ISO 11119 is to provide a specification for the design, manufacture, inspection and testing of cylinders for world-wide usage. The objective is to balance design and economic efficiency against international acceptance and universal utility.

ISO 11119 aims to eliminate the concern about climate, duplicate inspection and restrictions currently existing because of lack of definitive International Standards and is not to be construed as reflecting on the suitability of the practice of any nation or region.

This part of ISO 11119 addresses the general requirements on design, construction and initial inspection and testing of pressure receptacles of the United Nations "*Recommendations on the Transport of Dangerous Goods Model Regulations*."

Gas cylinders — Refillable composite gas cylinders and tubes —

Part 3:
Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450L with non-load-sharing metallic or non-metallic liners

1 Scope

This part of ISO 11119 specifies requirements for composite gas cylinders up to 150 l water capacity and composite tubes above 150 l water capacity and up to 450 l water capacity, for the storage and conveyance of compressed or liquefied gases.

The cylinders and tubes in this part of ISO 11119 are

a) Type 4 Fully Wrapped Cylinders or Tubes with a non-load sharing liner and composite reinforcement on both the cylindrical portion and the dome ends, and

b) Type 5 Fully Wrapped Cylinders or Tubes without liners (including cylinders without liners manufactured from two parts joined together) and with a test pressure of less than 60 bar.

   The cylinders are constructed:

   1) in the form of a disposable mandrel overwrapped with carbon fibre or aramid fibre or glass fibre (or a mixture thereof) in a resin matrix to provide longitudinal and circumferential reinforcement;

   2) in the form of two filament wound shells joined together.

Cylinders and tubes manufactured and tested to this part of ISO 11119 are not intended to contain toxic, oxidizing or corrosive gases.

This part of ISO 11119 is limited to cylinders and tubes with composite reinforcement of carbon fibre or aramid fibre or glass fibre (or a mixture thereof) in a matrix.

Cylinders and tubes manufactured and tested to this part of ISO 11119 have a minimum design life of 15 years.

This part of ISO 11119 does not address the design, fitting and performance of removable protective sleeves.

NOTE 1 References to cylinders in this International Standard include composite tubes if appropriate.

NOTE 2 ISO 11439 applies to cylinders intended for use as fuel containers on natural gas vehicles and ISO 11623 covers periodic inspection and re-testing of composite cylinders.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 3341, *Textile glass — Yarns — Determination of breaking force and breaking elongation*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 7225, *Gas cylinders — Precautionary labels*

ISO 10618, *Carbon fibre — Determination of tensile properties of resin-impregnated yarn*

ISO 14130, *Fibre-reinforced plastic composites — Determination of apparent interlaminar shear strength by short-beam method*

ISO 11114-1, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials*

ISO 11114-2, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 2: Non-metallic materials*

ISO 13769, *Gas cylinders — Stamp marking*

ASTM D7269, *Standard Test Methods for Tensile Testing of Aramid Yarns*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE References to cylinders include composite tubes if appropriate.

3.1
aramid fibre
continuous filaments of aramid laid up in tow form

3.2
batch
set of homogeneous items or material

NOTE The number of items in a batch can vary according to the context in which the term is used.

3.3
batch of metallic liners
quantity of liners of the same nominal diameter, length, thickness and design, made successively from the same batch of materials, subjected to the same manufacturing process and heat treated to the same conditions of temperature and time

3.4
batch of non-metallic liners
quantity of liners of the same nominal diameter, length, thickness and design, made successively from the same batch of materials and subjected to the same manufacturing process

3.5
batch of finished cylinders
production quantity of up to 200 finished cylinders successively produced by the same manufacturing process, plus finished cylinders required for destructive testing, of the same nominal diameter, length, thickness and design

3.6
burst pressure
highest pressure reached in a liner or cylinder during a burst test

3.7
carbon fibre
continuous filaments of carbon laid up in tow form

3.8
composite overwrap
combination of fibres and matrix

3.9
dedicated gas service
service in which a cylinder is to be used only with a specified gas or gases

3.10
equivalent fibre
fibre manufactured from the same nominal raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties, and where the average tensile strength and modulus is within $\pm$ 5 % of the fibre properties in an approved cylinder design

3.11
equivalent liner
liner that are manufactured from the same nominal raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties as in an approved cylinder design

3.12
exterior coating
layers of material applied to the cylinder as protection or for cosmetic purposes

NOTE The coating can be clear or pigmented.

3.13
glass fibre
continuous filaments of glass laid up in tow form

3.14
liner
inner portion of the composite cylinder, comprising a metallic or non-metallic vessel, whose purpose is both to contain the gas and transmit the gas pressure to the fibres

3.15
matrix
material that is used to bind and hold the fibres in place

3.16
non-load-sharing liner
liner that has a burst pressure less than 5 % of the nominal burst pressure of the finished composite cylinder

3.17
thermoplastic material
plastics capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature

3.18
thermosetting material
plastics that, when cured by the application of heat or chemical means, harden permanently into a substantially infusible and insoluble product

3.19
nominal outside diameter
diameter of the cylinder specified by the manufacturer for the type approval including tolerances (e.g. +/- 1 %)

3.20
Type 4 cylinder
fully wrapped cylinder with a non-load sharing liner and composite reinforcement on both the cylindrical portion and the dome ends

3.21
Type 5 cylinder
fully wrapped cylinder without a liner and with composite reinforcement on both the cylindrical portion and dome ends

3.22
working pressure
settled pressure of a compressed gas at a reference temperature of 15 °C in a full gas cylinder

4 Symbols and units

Symbols and their designations

Symbol	Designation	Unit
p_{bl}	Burst pressure of liner	bar
p_b	Burst pressure of finished cylinder	bar
p_h	Test pressure	bar
p_{max}	Maximum developed pressure at 65 °C	bar
p_w	Working pressure	bar

5 Inspection and testing

ISO 11119-3 is intended to be used under a variety of national regulatory regimes but has been written so that it is suitable for use with the conformity assessment system of the UN Model Regulations for the Transportation of Dangerous Goods. Attention is drawn to requirements in specified relevant national regulations of the country (countries) where the cylinders are intended to be used that might override the requirements given in this International Standard.

To ensure that the cylinders conform to this part of ISO 11119, they shall be subject to inspection and testing in accordance with Clauses 6, 7, 8 and 9 by an inspection body, hereafter referred to as “the inspector”, authorized to do so. Example forms of certificates that can be used are shown in Annexes A and B.

Equipment used for measurement, testing and examination during production shall be maintained and calibrated within a documented quality management system.

6 Materials

6.1 Liner materials

6.1.1 The liner (including metal boss) shall be manufactured from a material suitable for the gas to be contained, as specified in ISO 11114-1 and ISO 11114-2. Metal bosses attached to a non-metallic liner shall fulfil the performance requirements of this document.

6.1.2 The materials used shall be of uniform and consistent quality. The composite cylinder manufacturer shall verify that each new batch of materials has the correct properties and is of satisfactory quality, and maintain records from which the batch of materials used for the manufacture of each cylinder can be identified.

6.2 Composite materials

6.2.1 The overwrap materials shall be carbon fibre or aramid fibre or glass fibre, or any mixture thereof.

6.2.2 The matrix and, for cylinders manufactured from two halves, the adhesive, shall be a polymer suited to the application, environment and intended life of the product.

6.2.3 The suppliers of the filament material, the matrix component materials and, if applicable, the adhesive component material shall provide sufficient documentation for the composite cylinder manufacturer to be able to identify fully the batch of materials used in the manufacture of each cylinder.

6.2.4 The materials used shall be of uniform and consistent quality. The composite cylinder manufacturer shall verify that each new batch of materials has the correct properties and is of satisfactory quality, and maintain records from which the batch of materials used for the manufacture of each cylinder can be identified. A certificate of conformance from the material manufacturer is considered acceptable for the purposes of verification.

6.2.5 Batches of materials shall be identified and documented to the satisfaction of the inspector.

7 Design and manufacture

7.1 General

7.1.1 A Type 4 fully-wrapped composite gas cylinder with non-load-sharing metallic or non-metallic liner shall comprise of:

a) an internal metal or non-metallic liner which carries no significant load;

b) metallic boss(es) for thread connections, where these are part of the design;

c) a composite overwrap formed by layers of continuous fibres in a matrix and

d) an optional external protection system.

Where necessary, care shall be taken to ensure that there is no adverse reaction between the liner and the reinforcing fibre by the application of a suitable protective coating to the liner prior to the wrapping process.

7.1.2 A Type 5 fully-wrapped cylinder with a test pressure of less than 60 bar can be manufactured either:

a) in the form of a disposable mandrel overwrapped with carbon fibre or aramid fibre or glass fibre (or a mixture thereof) in a matrix to provide longitudinal and circumferential reinforcement or;

b) in the form of two filament wound shells overwrapped with carbon fibre or aramid fibre or glass fibre (or a mixture thereof) in a matrix to provide longitudinal and circumferential reinforcement joined together.

7.1.3 Cylinders shall be designed with one or two openings along the central axis only. Threads shall extend completely through the neck or have sufficient threads to allow full engagement of the valve.

7.1.4 Examples of certificates are shown in Annexes A and B.

7.2 Design submission

7.2.1 The design submission for each new design of cylinder shall include a detailed drawing, along with documentation of the design including manufacturing and inspection particulars as detailed in 7.2.2, 7.2.3 and 7.2.4.

7.2.2 Documentation for the liner and metal boss(es) shall include (but not be limited to):

a) material(s), including limits of chemical analysis;

b) dimensions, minimum thickness, straightness and out-of-roundness with tolerances;

c) process and specification of manufacture;

d) heat-treatment, temperatures, duration and tolerances;

e) inspection procedures (minimum requirements);

f) material properties;

g) dimensional details of valve threads and any other permanent features;

h) method of sealing boss to liner for bonded bosses.

7.2.3 Documentation for composite overwrap shall include (but not be limited to):

a) fibre material, specification and mechanical properties requirements;

b) minimum composite thickness;

c) thermosetting matrix – specifications (including resin, curing agent and accelerator), and resin bath temperature where applicable;

d) thermoplastic matrix system – main component materials, specifications and process temperatures;

e) overwrap construction including the number of strands used, number of layers and layer orientation and tensioning of the fibre at wrapping (where applicable);

f) curing process, temperatures, duration and tolerances;

g) adhesive system, main components and specifications where applicable;

h) adhesive system, curing agent, materials and specifications where applicable;

i) adhesive system, accelerator, materials and specifications where applicable;

j) for cylinders without liners where comprised of two wound shells, dimensions of adhesive bond (length, angle of bond, thickness of adhesive).

7.2.4 Documentation for the composite cylinder shall include (but not be limited to):

a) nominal water capacity in litres at ambient conditions;

b) list of intended contents if intended for dedicated gas service;

c) working pressure, p_w (if applicable) that shall not exceed 2/3 times test pressure;

d) test pressure, p_h;

e) maximum developed pressure at 65 °C for specific dedicated gas(es), p_{max};

f) minimum design burst pressure;

g) design life in years; cylinders with a test pressure of less than 60 bar shall have a non-limited design life;

h) nominal weight of the finished composite cylinder, including tolerances;

i) for cylinders without liners, the method of sealing the boss to cylinder (if applicable);

j) details of components which are permanently attached and form part of the qualified design (e.g. neck rings, protective boots etc).

7.3 Manufacturing

7.3.1 The liner and metal bosses, where incorporated, shall be manufactured in accordance with the manufacturer's design (see 7.2.2).

7.3.2 The composite cylinder shall be fabricated from a non-load-sharing liner, or fabricated on a disposable mandrel, fully over-wrapped with layers of continuous fibres in a matrix applied under controlled tension to develop the design composite thickness as specified in 7.2.3.

Liners can be stripped and re-wound provided that the overwrap has not been cured. The liner shall not be over-wrapped if it has been damaged or scored by the stripping process.

For cylinders without liners, manufactured from two parts joined together, the individual parts shall be wound to develop the required composite thickness before being joined with appropriate adhesive.

7.3.3 After wrapping is completed the composite shall be cured (if appropriate) using a controlled temperature profile as specified in the documentation in 7.2.3. The maximum temperature shall be such that the mechanical properties of the liner material, if fitted, and composite overwrap are not adversely affected.

NOTE If cylinders are subjected to fibre tensioning during wrapping, the tensioning shall be recorded or monitored.

8 Type approval procedure

8.1 General requirements

Each new cylinder design shall be submitted by the manufacturer to the inspector. The type approval tests detailed in 8.2 shall be performed, under the supervision of the inspector, on each new cylinder design or design variant.

8.2 Prototype tests

8.2.1 A minimum of 30 cylinders that are representative of the new design shall be made available for prototype testing. Upon successful completion of all prototype tests, the remaining untested cylinders from the prototype qualification batch can be used for service.

8.2.2 If, for special applications, the total number of cylinders required is less than 30, enough cylinders shall be made to complete the prototype tests required, in addition to the production quantity. Then the approval validity shall be limited to this batch only.

For a limited design change (design variant), in accordance with Table 1, a reduced number of cylinders shall be selected by the inspector.

8.2.3 The batch of liners, prior to being wrapped, shall conform to the design requirements and shall be inspected and tested in accordance with 9.1.

8.2.4 The composite material(s), prior to the cylinders being wrapped, shall conform to the design requirements and shall be tested in accordance with 9.3.

8.2.5 Tests for a new cylinder design shall be supervised by an inspector and shall consist of:

a) hydraulic proof pressure test, in accordance with 8.5.1, or hydraulic volumetric expansion test, in accordance with 8.5.2;

b) cylinder burst test in accordance with 8.5.3;

c) ambient temperature cycle test, in accordance with 8.5.4;

d) environmental cycle test, in accordance with 8.5.6;

e) flaw test, in accordance with 8.5.8;

f) drop test, in accordance with 8.5.9;

g) high velocity impact (gunfire) test, in accordance with 8.5.10;

h) fire resistance test in accordance with 8.5.11;

i) torque test on cylinder neck boss in accordance with 8.5.13;

j) leak test in accordance with 8.5.15;

k) pneumatic cycle test in accordance with 8.5.16;

l) liner burst test in accordance with 8.5.18.

8.2.6 Tests that are optional depending upon the design and intended use of the cylinder are:

a) vacuum test in accordance with 8.5.5;

b) environmentally assisted stress rupture test in accordance with 8.5.7;

c) permeability test in accordance with 8.5.12 if cylinders are manufactured with non-metallic liners or without liners;

d) salt water immersion test in accordance with 8.5.14;

e) for linerless cylinders comprised of two halves joined together, the water boil test in accordance with 8.5.17.

8.2.7 For approval of a design variant as specified in 8.4, it is only necessary to carry out the tests as prescribed in Table 1. Under supervision of the inspector A cylinder, approval by a reduced series of tests shall not be used as a basis for a second design variant approval with a reduced set of tests (i.e. multiple changes from an approved design are not permitted) although individual test results can be used as applicable (see 8.4.2).

8.2.8 Tests can be combined such that one cylinder can be used for more than one test. For example the cylinder burst test in 8.5.9 Drop test can be used to satisfy the requirement of 8.5.3 Burst test.

8.2.9 If the results of the above prototype tests are satisfactory, the inspector shall issue a design approval certificate a typical example of which is given in Annex A.

8.2.10 After completion of the tests the cylinders shall be destroyed or made incapable of holding pressure.

8.3 New design

8.3.1 After approval, no alteration shall be made to the design or the method of manufacture without requalification.

8.3.2 A new cylinder design requires full type approval testing. A cylinder shall be considered to be of a new design compared with an existing approved design when:

a) It is manufactured in a different factory. A relocation of a factory does not require a new cylinder design approval provided all equipment and procedures remain the same as for the original design approval.

b) It is manufactured by a process that is significantly different from the process used in the design type approval. A significant change is regarded as a change that would give rise to a measurable change in the performance of the liner and/or finished cylinder. The inspector determines when a change in process or design or manufacture is significantly different from the original qualified design.

c) The nominal outside diameter has changed more than 50 % from the qualified design.

d) A fibre of the same specification classification and mechanical properties but with a different linear density shall not be considered a new fibre type. Minor changes in the wrapping pattern shall not be considered to be a new design.

e) The cylinder is manufactured with a new fibre type. A fibre shall be considered to be of a new fibre type when:

   1) The fibre is of a different classification (e.g. glass, aramid or carbon);

   2) The fibre is produced from a different precursor [e.g. Polyacrylonitrile (PAN) or pitch for carbon];

   3) The fibre is not equivalent [see 8.4.1 (i)] to the fibre in the original design.

f) The matrix materials (i.e. resin, curing agent, accelerator) are different and not chemically equivalent to the original design (e.g. a change from an epoxy to a polyester);

g) The test pressure has increased more than 60 % from the qualified design.

8.3.3 A cylinder shall also be considered to be of a new design compared with an existing approved design if the method of liner manufacture or liner design has changed and when

a) It is manufactured from a material of different composition or composition limits from that used in the original type tests.

b) The material properties are outside the original design limits.

c) It is manufactured by a different process.

8.4 Design variants

8.4.1 For cylinders that are variants of another design, a reduced type approval testing programme is required as specified in Table 1. A cylinder shall be considered to be a design variant if changes are limited to:

a) the nominal length of the cylinder has changed by more than 5 %;

b) the nominal outside diameter has changed by 50 % or less;

c) there is a change in the design test pressure up to and including 60 %. Where a cylinder is to be used and marked for a lower test pressure than that for which design approval has been given, it is not deemed to be of a new design or design variant;

d) there have been changes to the composite thickness or wrap pattern other than the changes necessary to accommodate the changes of diameter and/or length;

e) the minimum wall thickness of the liner has changed by more than 10 %;

f) matrix materials (i.e. resin, curing agent, accelerator) are chemically equivalent to the original design;

g) the design or method of joining the neck boss to the liner has changed;

h) when equivalent overwrapping fibres are used:

   1) Equivalent fibres are manufactured from the same nominal raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties, and where the average tensile strength and modulus is within $\pm$ 5 % of the fibre properties in an approved cylinder design. Carbon fibres made from the same precursor can be equivalent, Aramid, carbon and glass fibres are not equivalent.

   2) 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;

i) when an equivalent liner is used:

   1) Equivalent liners are manufactured from the same nominal raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties as in an approved cylinder design.

   2) The equivalent liner material shall be subjected to the material tests specified in 9.1.2 for metal liners and 9.1.3 for polymer liners and the liner burst test specified in 8.5.18 and shall meet the minimum requirements specified in 7.2.2 and the criteria of 8.5.18.

   3) Where a new equivalent liner has been prototype tested for an existing design, 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.

j) when the cylinder thread has changed;

   1) When a cylinder design has only a different thread compared to an approved design only the torque test, in accordance with 8.5.13, shall be performed.

8.4.2 A cylinder approval by a reduced series of tests (a design variant) shall not be used as a basis for a second design variant approval with a reduced set of tests, i.e. multiple changes from an approved design are not permitted. If a test has been conducted on a design variant (A) that falls within the testing requirements for a second variant (B) then the result for (A) can be applied to the new design variant (B) test programme. However design variant (A) shall not be used as the reference for determining the testing required for any new design variant.

8.4.3 Where a design variant involves more than one parameter change all the tests required by those parameter changes shall be performed once only.

8.4.4 The inspector shall determine the level of reduced testing if not defined in Table 1, but a fully approved design shall always be used as a reference for the new design variant (i.e. new design variants shall not be approved by reference only to a previous design variant).

Table 1 — Type approval tests

Test No.	Test	New design	Design variant changes											
			Length		Diameter		Liner thickness >10%	Equi-valent fibre	Test pressure		Composite thickness or pattern or Liner base form	Neck boss	Equi-valent matrix	Thread
			> 5% ≤ 50 %	> 50 %	≤ 20 %	> 20 % ≤ 50 %			≤ 20 %	> 20 % ≤ 60 %				
9.1	Liner material test	×												
8.5.19	Resin shear test	X											X	
9.3	Composite material tests	×						×		×			×	
8.5.1/2	Hydraulic pressure	×	×	×	×	×	×	×	×	×	×	×	×	
8.5.3	Cylinder burst	×	×	×	×	×	×	×	×	×	×	×	×	
8.5.4	Ambient cycle	×	×	×	×	×	×	×	×	×	×	×	×	
8.5.5	Vacuum (c)(e)	×				×	×(d)					×		
8.5.6	Environmental cycle	×										×	×	
8.5.7	Stress rupture test (c)	×				×					×	×		
8.5.8	Flaw	×				×								
8.5.9	Drop	×		×		×						×		
8.5.10	High velocity impact	×				× (a)								
8.5.11	Fire resistance	×		×		×						×(b)		
8.5.12	Permeability (c)(e)	×				×	×					×		
8.5.13	Torque (f)	×										×		×
8.5.14	Salt water (c)	×										×	×	
8.5.15	Leak	×			×	×	×					×		
8.5.16	Pneumatic cycle	×		×		×	×							
8.5.17	Water boil test (c)	×				×		×		×	×		×	
8.5.18	Liner Burst test	X		X		X	X							

[a] Test to be conducted for reduction in diameter only or if an increase in diameter requires a larger calibre bullet.

[b] Only if cylinder in previous fire test leaked at the neck boss.

[c] Optional test required according to the design and intended use of the cylinder.

[d] For liner thickness decrease only.

[e] For non-metallic liners only.

[f] When a cylinder design has only a different thread compared to an approved design only the torque test, in accordance with 8.5.13, shall be performed.

8.5 Type approval test procedures and criteria

8.5.1 Proof pressure test

8.5.1.1 Procedure

When carrying out the pressure test, a suitable fluid (e.g. normally water) shall be used as the test medium. This test requires that the pressure in the cylinder be increased gradually and regularly until the test pressure, p_h, is reached. The cylinder test pressure shall be held for at least 30 s with the cylinder isolated from the pressure source, during which time there shall be no decrease in the recorded pressure or evidence of any leakage. Adequate safety precautions shall be taken during the test.

If leakage occurs in the piping or fittings, the cylinders shall be re-tested after repairing such leakages.

The limit deviation on attaining test pressure shall be test pressure +3 % / -0 or +10 bar whichever is the lower. Pressure gauges with the appropriate accuracy shall be used.

All internal surfaces of cylinders shall be dried (to ensure no free water) immediately after testing.

Alternatively a pneumatic pressure test can be used provided that appropriate measures are taken to ensure safe operation and to contain any energy that can be released, which is considerably more than in the hydraulic test.

8.5.1.2 Criteria

The cylinder shall be rejected if there are leaks, failure to hold pressure or visible permanent deformation after the cylinder is depressurised.

NOTE Cracking of resin is not necessarily a sign of permanent deformation.

8.5.2 Hydraulic elastic expansion test

8.5.2.1 Procedure

When carrying out the pressure test, a suitable fluid (e.g. normally water) shall be used as the test medium. This test requires that the pressure in the cylinder be increased gradually and regularly until the test pressure, p_h, is reached. The cylinder test pressure shall be held for at least 30 s with the cylinder isolated from the pressure source, during which time there shall be no decrease in the recorded pressure or evidence of any leakage. Adequate safety precautions shall be taken during the test.

If leakage occurs in the piping or fittings, the cylinders shall be re-tested after repairing such leakages.

The elastic expansion shall be determined from the difference in volume measured at 10 % test pressure, p_h, and at the test pressure, p_h, and recorded.

The limit deviation on attaining test pressure shall be test pressure +3 % / -0 or +10 bar whichever is the lower.

All internal surfaces of cylinders shall be dried (to ensure no free water) immediately after testing.

8.5.2.2 Criteria

The cylinder shall be rejected if either:

a) it shows an elastic expansion in excess of 110 % of the average elastic expansion for the batch at manufacture, or

b) if there are leaks or failure to hold pressure.

8.5.3 Cylinder burst test

8.5.3.1 Procedure

Three cylinders shall be tested hydraulically, to destruction, by pressurizing at a rate of no more than 10 bar/s. The test shall be carried out under ambient conditions. Prior to the commencement of the test, it shall be ensured that no air is trapped within the system.

The parameters that shall be monitored and recorded are:

a) burst pressure;

b) mode of failure for cylinders without liners;

c) pressure/time curve or pressure/volume curve.

8.5.3.2 Criteria

a) The burst pressure shall exceed the minimum design burst pressure specified by the cylinder manufacturer (see 7.2.4).

b) The burst pressure, pb, for cylinders with carbon fibre reinforcement shall be not less than the test pressure, ph $\times$ 2.0.

c) The burst pressure, pb, for cylinders with aramid fibre reinforcement shall be not less than the test pressure, ph $\times$ 2.1.

d) The burst pressure, pb, for cylinders with glass fibre reinforcement shall be not less than the test pressure, ph $\times$ 2.4.

e) For cylinders without liners manufactured from two parts joined together, the burst shall not result in failure at the joint below a pressure 1.2 $\times$ the burst pressure for the appropriate fibre above.

8.5.4 Ambient cycle test

8.5.4.1 For cylinders with test pressure equal to, or greater than, 60 bar

8.5.4.1.1 General

Where a cylinder is intended for use only with one or more specific gases the design can be designated for dedicated gas use. The gases permitted in the cylinder shall be identified clearly on the cylinder label (see 10.2).

8.5.4.1.2 Procedure

Two cylinders shall be subjected to a hydraulic pressure cycle test to test pressure, p_h, for unspecified gas service or maximum developed pressure at 65 °C, p_{max}, for the dedicated gas which has the greatest developed pressure.

The test shall be carried out using a non-corrosive fluid under ambient conditions, subjecting the cylinders to successive reversals at an upper cyclic pressure that is equal to the hydraulic test pressure, p_h or maximum developed pressure at 65 °C, p_{max}, as appropriate.

The value of the lower cyclic pressure shall not exceed 10 % of the upper cyclic pressure, but shall have an absolute maximum of 30 bar. The frequency of reversals shall not exceed 0,25 Hz (15 cycles/min). The temperature on the outside surface of the cylinder shall not exceed 50 °C during the test.

The parameters that shall be monitored and recorded are:

a) temperature of the cylinder;

b) number of cycles achieving upper cyclic pressure;

c) minimum and maximum cyclic pressures;

d) cycle frequency;

e) test medium used;

f) mode of failure, if appropriate.

8.5.4.1.3 Criteria

Both cylinders shall withstand N pressurization cycles to test pressure, p_h, or N_d pressurization cycles to maximum developed pressure, p_{max}, without failure by burst or leakage

where

$N = y \times 250$ cycles per year of design life;

$N_d = y \times 500$ cycles per year of design life;

y is the number of years of design life.

y shall be a whole number which is not less than 15 years.

The test shall continue for a further N, or N_d, cycles, or until the cylinder fails by leakage, whichever is the sooner. In either case the cylinder shall be deemed to have passed the test. However, if failure during this second part of the test is by burst, then the cylinder shall have failed the test. See Table 2.

Table 2 — Criteria for ambient cycle test

	1st part	2nd part
Number of cycles	0 to N	N *to* $2N$ but $2N$ no more than 12 000
	0 to N_d	N_d to $2N_d$ but $2N_d$ no more than 24 000
Criteria	No leakage/burst = Pass	
	No leakage or burst	Leakage = Pass
	Pass 1st part	Burst = Fail

If the cylinder is designed to pass 12 000 hydraulic cycles to test pressure or 24 000 cycles to maximum developed pressure and achieves this level consistently in the test it shall not be necessary to limit the design life of the cylinder.

8.5.4.2 For cylinders with test pressure less than 60 bar

8.5.4.2.1 Procedure

Two cylinders shall be subjected to a hydraulic pressure cycle test to test pressure.

The test shall be performed using a non-corrosive fluid under ambient conditions, subjecting the cylinders to successive reversals at an upper cyclic pressure which is equal to the hydraulic test pressure, p_h.

The value of the lower cyclic pressure shall not exceed 10 % of the upper cyclic pressure. The frequency of reversals of pressure shall not exceed 0,25 Hz (15 cycles/min). The temperature on the outside surface of the cylinder shall not exceed 50 °C during the test.

The parameters that shall be monitored and recorded are:

a) temperature of the cylinder;

b) number of cycles achieving upper cyclic pressure;

c) minimum and maximum cyclic pressures;

d) cycle frequency;

e) test medium used;

f) mode of failure, if appropriate.

8.5.4.2.2 Criteria

Both cylinders shall withstand 12 000 pressurization cycles to test pressure, ph. If the cylinder is designed to pass 12 000 hydraulic cycles to test pressure and achieves this level consistently in the test it shall not be necessary to limit the design life of the cylinder.

8.5.5 Vacuum test

8.5.5.1 General

When this test is carried out, one cylinder shall be subjected to a vacuum test prior to the environmental cycle test (see 8.5.6). When this test is not carried out a warning shall be permanently marked on the cylinder label (see 10.2).

8.5.5.2 Procedure

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

The contents (inert gas or air) shall be reduced from atmospheric 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 be returned to atmospheric pressure. The total number of cycles shall be 50.

The parameters that shall be monitored and recorded are:

a) number of cycles achieving lower cyclic pressure;

b) minimum and maximum cyclic pressures;

c) cycle frequency;

d) results of visual inspection.

8.5.5.3 Criteria

After cycling, the interior of the liner shall be inspected for damage. Any evidence of disbonding, folding or other damage shall be noted. If the cylinder then passes the environmental cycle test (see 8.5.6) it shall also be deemed to have passed the vacuum test.

8.5.6 Environmental cycle test

8.5.6.1 General

When the vacuum test (see 8.5.5) is performed, the vacuum-tested cylinder shall be used for the environmental cycle test. When the vacuum test is not performed, a warning shall be permanently marked on the cylinder label (see 10.2).

The tests in this section will be performed in an environmental chamber.

8.5.6.2 Procedure

One cylinder, without paint or removable protective coating shall be tested as follows.

Condition cylinder and contained hydraulic pressurizing medium for 48 h at atmospheric pressure, at a temperature between 60 °C and 70 °C and at a relative humidity greater than or equal to 90 %. The intent of this requirement can be met by spraying with a continuous fine spray or mist of water in a chamber held between 60 °C and 70 °C.

The hydraulic pressurizing medium external to the cylinder under test shall commence the cycle testing at ambient temperature. Hydraulically apply 5 000 cycles from a pressure approximately equal to atmospheric pressure to 2/3 of the test pressure, p_h. The cylinder skin temperature shall be maintained at between 60 °C and 70 °C by regulating the environmental chamber and the cycling frequency. The cycling frequency shall not exceed 10 cycles/min.

Release the pressure and stabilize the cylinder at 20 °C approximately.

Stabilize the cylinder and the contained pressurizing medium until the temperature is between – 40 °C and – 50 °C. The hydraulic pressurizing medium external to the cylinder under test shall commence the cycle testing at ambient temperature. Apply 5 000 cycles from a pressure less than 10 % of working pressure to 2/3 of the test pressure, p_h. The cylinder skin temperature shall be maintained at between – 40 °C and – 50 °C by regulating the environmental chamber and the cycling frequency. The cycling frequency shall not exceed 10 cycles/min. The fluid shall also be selected to ensure that it functions at the temperatures specified in the various cycle tests.

Release the pressure and stabilize the cylinder at approximately 20 °C.

Type 4 cylinders shall be subjected to the leak test (see 8.5.15)

On completion of these tests the cylinder shall be subjected to the burst test (see 8.5.3)

Parameters to monitor and record:

a) temperatures during each part;

b) humidity during 1st part of test;

c) test medium used;

d) number of cycles, achieving upper cyclic pressure, at each stage;

e) minimum and maximum cyclic pressures;

f) cycle frequency;

g) the parameters specified in 8.5.3.

8.5.6.3 Criteria

a) The burst pressure shall be greater than 85 % of the minimum design burst pressure.

b) The burst pressure, p_b, for cylinders with carbon fibre reinforcement shall be not less than the test pressure, $p_h \times 1.7$.

c) The burst pressure, p_b, for cylinders with aramid fibre reinforcement shall be not less than the test pressure, $p_h \times 1.9$.

d) The burst pressure, p_b, for cylinders with glass fibre reinforcement shall be not less than the test pressure, $p_h \times 2.2$.

8.5.7 Environmentally assisted stress rupture test

8.5.7.1 Procedure

This test shall be conducted only on cylinders where glass or aramid fibre has a load sharing application.

For a design life of up to 20 years, two cylinders shall be hydraulically pressurized to test pressure, p_h, and shall be maintained at this pressure for 1 000 h. For a design life equal to or greater than 20 years, the test shall run for 2 000 h. The test shall be conducted at a minimum temperature of 70°C ± 5°C and a relative humidity equal to or greater than 95 %.

The use of a water spray or suspending the cylinder over a water bath are both methods that can be used to meet the requirements of this test.

After this test, the cylinders shall be subjected to the leak test (see 8.5.15) and the burst test (see 8.5.3).

The parameters that shall be monitored and recorded are:

a) temperature and relative humidity at least twice a day;

b) cylinder pressure at least twice a day;

c) parameters specified in 8.5.3.1.

8.5.7.2 Criteria

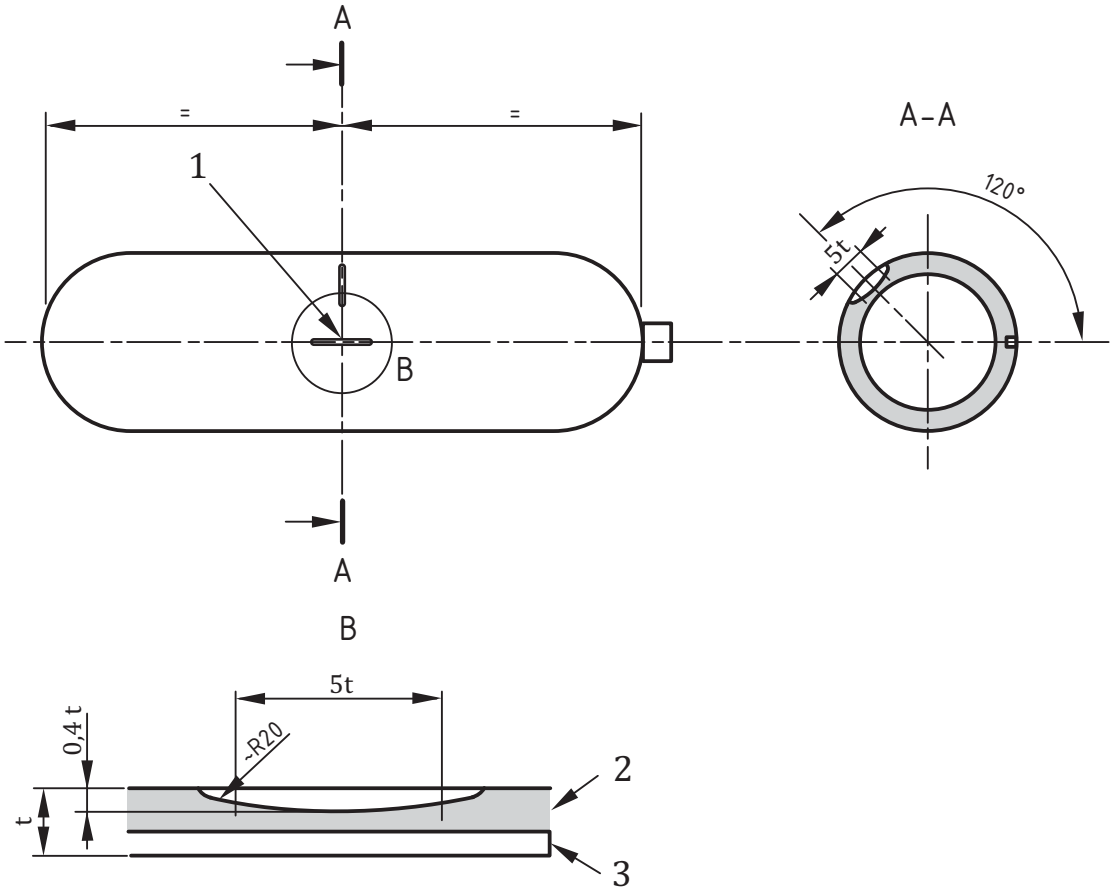
The cylinder shall not exhibit any visible deformation or loose fibres (unravelling) and shall satisfy the criteria of the leak test (see 8.5.15). The burst pressure burst shall be equal to or greater than 100 % of the minimum burst level required in the burst test (8.5.4) for the relevant fibre.

8.5.8 Flaw test

8.5.8.1 Procedure

Two cylinders shall be tested. One longitudinal flaw shall be cut into each cylinder, in the mid-length of the cylindrical wall of the cylinder in accordance with Figure 1. The flaw shall be made with a 1 mm thick cutter to a depth equal to at least 40 % of the composite thickness but no greater than 2.5 mm deep and to a length between the centres of the cutter equal to five times the cylinder thickness.

A second transverse flaw of the same dimensions shall be cut into each cylinder in the mid-length of the cylindrical wall approximately 120° around the circumference from the other flaw in accordance with Figure 1.



Key

1 1mm wide
2 wrap
3 liner

Figure 1 — Flaw test procedure

One cylinder shall be subjected to the burst test specified in 8.5.3.

The other cylinder shall be subjected to the ambient cycle test specified in 8.5.4, but the upper cyclic pressure shall be 2/3 of the test pressure, p_h, and the test shall be suspended after 5 000 cycles if the cylinder has not failed.

a) The parameters that shall be monitored and recorded are dimensions of flaws;

b) temperature of the cylinder;

c) number of cycles achieving upper cyclic pressure;

d) minimum and maximum cyclic pressures;

e) cycle frequency;

f) test medium used;

g) mode of failure, if appropriate.

8.5.8.2 Criteria

First cylinder: burst pressure, p_b, shall be equal to or greater than the test pressure, $p_h \times 4/3$.

Second cylinder: the cylinder shall withstand at least 1 000 pressure cycles to 2/3 of the test pressure, p_h, without leakage. If the cylinder fails by leakage after 1 000 cycles it shall be deemed to have passed the test. However, if failure during this second half of the test is by burst, then the cylinder shall have failed the test.

8.5.9 Drop test

8.5.9.1 For cylinders up to and including 50 l water capacity

8.5.9.1.1 Procedure

Two cylinders shall be filled with water to 50 % capacity and fitted with a plug, flush with the end of each cylinder.

Both cylinders shall 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 of a minimum of 5 mm thickness. The protective plate shall be sufficiently flat so that the difference in level between any two points on the surface is no more than 2 mm.

One cylinder shall be subjected to the burst test specified in 8.5.3.

The other cylinder shall be subjected to the pressure cycling test specified in 8.5.4.

The parameters that shall be monitored and recorded are:

a) visual appearance after each drop – record position and dimensions of impact damage;

b) parameters specified in test 8.5.3;

c) parameters specified in test 8.5.4.

Dimension in metres

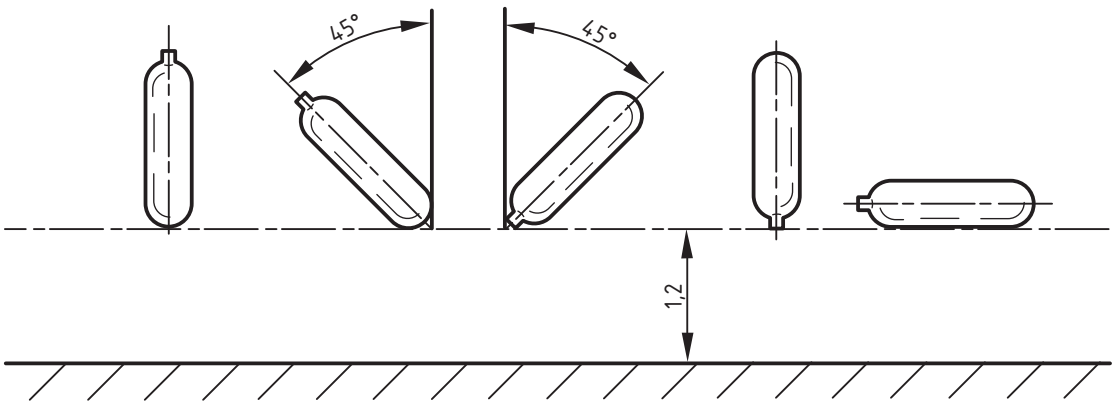


Figure 2 — Drop test

8.5.9.1.2 Criteria

First cylinder: burst pressure, p_b, shall be equal to or greater than 100 % of the minimum burst level required in the burst test (see 8.5.3).

Second cylinder: the cylinder shall satisfy the requirements of the ambient cycle test (see 8.5.4).

8.5.9.2 For cylinders over 50 l water capacity

8.5.9.2.1 Procedure

a) One or more empty cylinders, with sealing device to protect threads and sealing surfaces, shall be drop tested at ambient temperature. The surface onto which the cylinders are dropped shall be a smooth, horizontal concrete pad or flooring.

b) One cylinder shall be dropped in a horizontal position with the lowest point of the cylinder no less than 1.8 m above the surface onto which it is dropped. One cylinder shall be dropped vertically on one end at a sufficient height above the floor or pad so that the potential energy is 1 220 joules, but in no case shall the height of the lower end be greater than 1.8 m. One cylinder shall be dropped at a 45 degree 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. The cylinder(s) shall be allowed to bounce on the concrete pad or flooring after the initial impact. No attempt shall be made to prevent this secondary impacting, but the cylinder may be prevented from toppling during the vertical drop test.

8.5.9.2.2 Criteria

The cylinders shall withstand 3 000 pressurization cycles to 2/3 of the test pressure, p_h, without failure by burst or leakage. The test shall continue for a further 9 000 cycles, or until the cylinder fails by leakage, whichever is the sooner. In either case the cylinder shall be deemed to have passed the test. However if failure during this second part of the test is by burst, then the cylinder shall have failed the test.

8.5.10 High velocity impact (gunfire) test

8.5.10.1 Procedure

One cylinder shall be filled to 2/3 of the test pressure, p_h, with air or nitrogen or the gas to be contained.

WARNING — Appropriate measures shall be taken to ensure safe operation and to contain any energy that can be released.

The cylinder shall be positioned in such a way that the point of impact of the projectile shall be in the cylinder side wall at a nominal angle of 45° and such that the bullet would also exit through the cylinder side wall.

Cylinders with diameter of above 120 mm shall be impacted by a 7,62 mm armour-piercing projectile (of length between 37 mm and 51 mm) with a nominal speed of about 850 m/s. The bullet shall be fired from a distance of not more than 45 m. The cylinder shall be safely vented before removing from the test.

Cylinders with diameter of 120 mm and below shall be impacted by a 5,6 mm armour piercing (or similar) bullet with a nominal speed of 850 m/s. The bullet shall be fired from a distance of not more than 45 m.

The cylinder shall be safely vented before removing from the test.

The dimensions of the entrance and exit openings shall be measured and recorded.

After the test the cylinder shall be rendered unserviceable.

The parameters that shall be monitored and recorded are:

a) type of projectile;

b) initial pressure;

c) description of failure;

d) approximate size of the entrance and exit openings.

8.5.10.2 Criteria

The cylinder shall remain in one piece. If a cylinder is not penetrated by the above projectile then the cylinder will have passed the test.

8.5.11 Fire resistance test

8.5.11.1 General

The purpose of the test is to demonstrate that the cylinder design has adequate safety when exposed to a fire.

a) Where a pressure-relief device to be used in service is specified.

b) Others.

8.5.11.2 Procedure

Two cylinders shall be fitted with either:

a) the specified valves and PRD's or

b) a suitable method for pressure release (e.g. a valve fitted with bursting disc set to operate at between p_h and 1,15 p_h).

If the test is conducted with the PRD's and valve intended for use in service (i.e. option a), the specification of the valve and PRD's shall be marked on the design drawing and the approval certificate.

The cylinders shall be charged with air or nitrogen or the gas intended for use to the working pressure ($p_h \times 2/3$).

Surface temperatures shall be monitored by thermocouples located along the bottom of the cylinder and spaced not more than 0,75 m apart and shielded from direct flame impingement with metallic shielding of a minimum 0,4 mm thickness. Thermocouple temperatures and the cylinder pressure shall be recorded at intervals of every 30 s or less during the test.

A uniform fire source of 1,65 m length shall be used that is capable of enveloping the entire diameter of the cylinder, when in the horizontal position, and producing a temperature $\geq$ 590 °C, measured within 2 min on the bottom surface of the cylinder.

The timing of the fire test shall start when the thermocouple temperature reaches 590 °C and all thermocouples must register a temperature $\geq$ 590 °C for the remainder of the test.

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

The cylinders shall be tested in both the vertical or horizontal position as follows:

Vertical — One cylinder shall be placed in an upright position (valve uppermost for cylinders with one valve and PRD), with the lowest part of the cylinder approximately 0,1 m from the top of the firewood, in the case of a wood fire, or 0,1 m from the surface of the liquid in a fuel-based fire. The relief device shall be shielded from direct flame impingement.

Horizontal — One cylinder shall be placed in a horizontal position with the centre of the fire at the mid-point of the cylinder and with the lowest part of the cylinder approximately 0,1 m from the top of the firewood, in the case of a wood fire, or 0,1 m from the surface of the liquid in a fuel-based fire. The relief device shall be shielded from direct flame impingement.

The cylinder shall be exposed to the fire until it has vented to a pressure less than 7 bar.

The parameters that shall be monitored and recorded are:

a) type and characteristics of pressure relief device;

b) initial pressure;

c) location of leak;

d) temperature;

e) time.

8.5.11.3 Criteria

a) For cylinders intended to be fitted with a specified pressure-relief devices the cylinders shall vent through the pressure-relief devices. (This test shall be repeated if another design of pressure-relief device is specified and used). For cylinders intended for liquefied gases a leak through the cylinder wall is acceptable.

b) For others the cylinder shall not burst during a period of two minutes from the start of the fire test. Cylinders may leak through the cylinder wall or other surfaces.

8.5.12 Permeability test

8.5.12.1 General

This test shall be performed for composite cylinders with non-metallic liners and for cylinders without liners.

8.5.12.2 Procedure

One finished cylinder shall be filled with either air, nitrogen, compressed natural gas or hydrogen, or for specialized applications, the gas to be contained.

The cylinder shall be pressurised to working pressure and placed in an enclosed sealed chamber at ambient temperature, and monitored for leakage for up to 500 h, to establish a steady state permeation rate.

The permeation shall be monitored by any suitable measurement techniques including gas chromatography, mass spectrometry, and weight loss.

8.5.12.3 Criteria

The permeation rate of the stored gas shall be determined. The maximum rate of permeation shall be less than X ml/h/l water capacity, where X is as follows:

a) Where the test was conducted with air or nitrogen or compressed natural gas the permeability rate shall be and X = 0,25;

b) Where the test was conducted with hydrogen permeability rate shall be X = 2,00;

c) for specialized applications, the value of X shall be chosen according to the application.

8.5.13 Torque test on cylinder neck boss

8.5.13.1 Procedure

The body of the cylinder shall be held in such a manner as to prevent it rotating except where the manufacturer specifies that the cylinder is to be held by the neck for valve insertion. In this case the manufacturer's directions shall be used.

The cylinder shall be fitted with a suitable valve or plug and tightened to 150 % of the maximum torque recommended in ISO 13341 for the relevant boss material or as recommended by the manufacturer where this International Standard does not apply.

The valve shall be removed after the first installation and the neck thread and boss inspected. The valve shall then be re-installed as specified above.

The cylinder shall be held at 2/3 test pressure for not less than 2 h and then the leak test in 8.5.15 shall be conducted.

The following parameters shall be monitored and recorded:

a) type of valve/plug material;

b) valving procedure;

c) applied torque.

8.5.13.2 Criteria

The neck thread and boss shall remain within drawing and gauge tolerance. Leakage greater than that specified in 8.5.15 shall constitute a failure of the test.

8.5.14 Salt water immersion test

8.5.14.1 General

This test is mandatory for all cylinders intended for underwater applications and is not required for other applications.

8.5.14.2 Procedure

The cylinders shall be unpainted but otherwise finished as for the intended application. The liner can be painted or protected from corrosion in any manner that is included in the design submission.

a) Immersion period

Two closed unpressurized cylinders shall be immersed for a period of between 1 h and 2 h in an aqueous solution containing 35 g of sodium chloride/l at a temperature of not less than 20 °C.

After 2 h the hydraulic pressure of the cylinder shall be increased to and maintained at 2/3 of the test pressure for not less than 22 h.

b) Drying period

The pressurized cylinders shall then be taken out from salt water immersion and subjected to natural drying conditions in ambient atmosphere for not less than 22 h.

During this drying-out period, the cylinders shall be pressurized. The hydraulic pressure of the cylinder shall be increased to and maintained at the test pressure × 2/3 for not less than 2 h. Pressure shall then be released.

Repeat the cycle consisting of these two periods a) and b) 45 times.

On completion of these 45 cycles:

a) one of the two cylinders shall be submitted to the burst test in accordance with 8.5.3;

b) the other cylinder shall be submitted to pressure cycling in accordance with 8.5.4.

The parameters that shall be monitored and recorded are:

a) temperature of the solution, at least once a day;

b) filling pressure;

c) duration of immersion;

d) parameters specified in test 8.5.3;

e) parameters specified in test 8.5.4.

8.5.14.3 Criteria

The burst pressure, p_b, shall be not less than the burst pressure in 8.5.4 for the relevant fibre. The second cylinder shall satisfy the criteria for the ambient cycle test, 8.5.4.

8.5.15 Leak test

8.5.15.1 Procedure

Leak testing shall be performed at a minimum of the test pressure, p_h, $\times$ 2/3.

Acceptable methods for leak testing include, but are not limited to, bubble testing using dry air or gas or measurement of trace gases using a mass spectrometer.

8.5.15.2 Criteria

Leakage greater than 10^{-3} mbar/litre/sec i.e. approximately 1 visible bubble in 2 min or 6 cc/hour in the bubble leak test shall constitute a failure of the test.

8.5.16 Pneumatic cycle test

8.5.16.1 General

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

Prior to conducting this test, cylinders shall be preconditioned by having successfully passed the test requirements of 8.5.15 (leak test), 8.5.1 (hydrostatic proof test), and 8.5.4 (ambient temperature pressure cycling test) except for the number of cycles is reduced by half.

8.5.16.2 Procedure

One cylinder shall be charged to the test pressure, p_h, $\times$ 2/3 with the same gas as used in 8.5.12, (permeability test).

The cylinder pressure shall be held at the test pressure, p_h, $\times$ 2/3 for 72 h.

The cylinder shall then be subjected to 1 000 pneumatic pressure cycles between 10 % of working pressure and the working pressure, p_w. Unless otherwise specified by the manufacturer, care shall be taken to ensure that temperatures during filling and venting do not exceed the defined service conditions.

After cycling, the cylinder pressure shall be held at the test pressure, p_h, x 2/3 for 72 h.

The vessel shall then be subjected to 8.5.4 (ambient temperature pressure cycle test) except the number of cycles is reduced by half.

The liner and liner/end boss interface shall be visually inspected for evidence of any deterioration, such as fatigue cracking or electrostatic discharge.

Parameters to monitor and record:

a) temperature of the cylinder;

b) number of cycles achieving upper cyclic pressure;

c) minimum and maximum cyclic pressures;

d) cycle frequency;

e) test medium used;

f) visual appearance of the liner after the pneumatic hold and cycle;

g) parameters specified in test 8.5.4;

h) mode of failure, if appropriate.

8.5.16.3 Criteria

The vessel shall have successfully passed the 8.5.15 (leak test) and it must not display excessive deterioration (such as fatigue cracking, blistering or electrostatic discharge) that would prevent it from completing its intended service life.

A vessel that demonstrates three successive pneumatic hold and cycle tests as provided in 8.5.16.1 and meeting the requirements of the 8.5.15 leak test and the 8.5.4 (ambient temperature pressure cycle test) except for the number of cycles is reduced by half shall have been deemed to meet the requirements of 8.5.16.

NOTE The ambient cycle testing in this section can be used to demonstrate compliance to 8.5.4 (ambient temperature pressure cycling test).

8.5.17 Water boil test

8.5.17.1 General

This test shall be performed for cylinders without liners and which are manufactured from two parts joined together.

8.5.17.2 Procedure

One closed unpressurized cylinder shall be subjected to boiling water for 100 h. The cylinder shall be entirely covered by the water. The temperature shall be at least 97, 5 °C.

NOTE The water can be ordinary tap water.

On completion of the test the cylinder shall be submitted to hydraulic pressure to burst, in accordance with 8.5.3.

The following parameters shall be monitored and recorded:

a) burst pressure;

b) number of pieces;

c) description of failure;

d) pressure/time curve or pressure/volume curve;

e) water temperature.

8.5.17.3 Criteria

The burst pressure, p_v, or pressure at failure shall meet the applicable requirement specified in 8.5.3.2.

8.5.18 Liner burst test

8.5.18.1 Procedure

The burst pressure, p_b, or pressure at failure shall meet the applicable requirement specified in 8.5.3.2.

One liner shall be tested hydraulically to destruction by pressurizing at a rate of no more than 5 bar/s. The test shall be carried out under ambient conditions.

The parameters that shall be monitored and recorded are

a) burst pressure,

b) pressure/time curve or pressure/volume curve.

8.5.18.2 Criteria

The burst pressure of the liner p_{bl}, shall be less than 5 % of the – minimum burst pressure of the finished composite cylinder as stated in 7.2.4.

8.5.19 Resin shear strength

Prototype matrix materials shall be tested on a sample coupon representative of the composite overwrap in accordance with ISO 14130 or an equivalent standard acceptable to the competent authority. This test shall be repeated when matrix materials are changed and are not chemically equivalent to those used in the original design.

8.6 Failure of type approval tests

In the event of failure to meet test requirements, an investigation into the cause of failure and re-testing shall be performed in accordance with 9.5.

9 Batch inspection and testing

9.1 Liner

9.1.1 Each batch of liners shall be examined and dimensionally checked to ensure compliance with the design specifications. The inspections to be carried out in accordance with the manufacturer's quality assurance procedures are

a) visual inspection of external and internal surface finish,

b) dimensions,

c) minimum wall thickness,

d) water capacity,

e) weight, and

f) thread conformity.

9.1.2 Each batch of non-load-sharing metal liners and metallic bosses shall be tested to confirm that the proper materials have been used and that the required minimum properties specified in 7.2.2 have been achieved. The mechanical properties shall be tested in accordance with ISO 6892-1. Manufacturer's certification (mechanical properties, chemical analysis) shall demonstrate compliance.

9.1.3 One liner from every batch of non-metallic liners shall be tested to confirm that the proper materials have been used and to verify that the required mechanical minimum properties have been achieved and meet the minimum design requirements. On every test liner two tensile specimens shall be tested. The tensile strength and the elongation shall be tested in accordance with ISO 527-1 and ISO 527-2. Acceptance of non-metallic liners shall be made taking into account the following verifications:

a) the properties of the material (raw material as granulate etc.) shall be within the tolerances set by the material manufacturer for melt flow index, density and glass transition temperature;

b) the process parameters during liner manufacturing shall be within the tolerances agreed during type approval of the process;

c) the material properties of the liner shall be within the tolerances required by the design requirements laid down in 7.2.2.

Manufacturer's certification (mechanical properties, melt flow index, density, glass transition temperature) shall demonstrate compliance.

9.1.4 The liners shall be checked for homogeneity by means of a non-destructive test, specified by the manufacturer, to ensure that the material(s) have been processed correctly.

After heat treatment 5 % of the liners or liner bosses shall be checked for hardness in accordance with either ISO 6506-1 or ISO 6508-1 and shall achieve the limits specified in 7.2.2.

9.1.5 A record of the tests carried out shall be kept by the cylinder manufacturer.

NOTE Suitable forms of test certificates are shown in Annex B.

9.2 Failure of liner batch tests

9.2.1 If any of the test results is not satisfactory, and if the inspector is satisfied that this was due to an error in performing the test, a re-test shall be authorized using the same liner or if that is not possible either:

a) the test in question shall be repeated on a liner or test ring from the same batch, and if the results are satisfactory the batch shall be accepted or:

b) the batch shall be re-heat treated (if appropriate) and re-tested in accordance with 9.1.2, 9.1.3 and 9.1.4, and if the results are satisfactory the batch shall be accepted.

9.2.2 Where heat treatment has been shown to be inadequate, liners shall be subjected to re-treatment, once only.

9.2.3 Where heat treatment furnace records show artificial ageing has been inadequate, additional time at the ageing temperature shall be given.

9.2.4 If the test results, having allowed for re-testing or re-heat treatment, are not satisfactory, liners in the batch shall be rendered unserviceable.

9.3 Overwrap materials

9.3.1 Supplier's certification of the material properties shall serve as verification of compliance. The strength of fibres shall be not less than specified in the documentation listed in 7.2.3.

9.3.2 If certification is not available each batch of filament materials shall be subjected to an impregnated strand test in accordance with ISO 3341 for glass fibre, ASTM D7269 for aramid and ISO 10618 for carbon fibre, or an appropriate equivalent standard. The strength of fibres shall be not less than specified in the documentation listed in 7.2.3.

9.4 Composite cylinder

9.4.1 The inspector shall certify that the design, manufacture, inspections and testing have been carried out in accordance with this part of ISO 11119. An example form of certificate is shown in Annex A.

9.4.2 Each batch of composite cylinders shall be examined and checked to ensure compliance with the design standard. The batch of finished cylinders can contain different batches of liners, fibres and matrix materials. The inspections that shall be carried out in accordance with the manufacturer's quality assurance procedures are

a) visual inspection of external and internal surface finish,

b) dimensions,

c) markings,

d) water capacity,

e) weight,

f) cleanness, and

g) fibre tension (if applicable).

9.4.3 The internal and external surfaces of the finished cylinder shall be free from defects and residues from the manufacturing process which would adversely affect the safe working of the cylinders.

NOTE See ISO 9809-1, ISO 9809-2, ISO 9809-3 and ISO 7866 for guidance on possible defects in metallic liners.

9.4.4 Each completed cylinder shall be subjected to either a hydraulic proof test (in accordance with 8.5.1) or a volumetric expansion test (in accordance with 8.5.2) at the design test pressure specified in 7.2.4 c) as specified in the manufacturer's quality assurance procedures.

9.4.5 A pressure cycling test shall be conducted on no less than one finished cylinder per five batches (a maximum of 1 000 pieces produced sequentially). The cylinder to be tested shall be selected at random from the five batches. If the cylinder fails the test all five batches shall not be released until the investigation carried out in accordance with 9.5 is completed.

The cylinder shall be subjected to a hydraulic pressure cycle test to test pressure, p_h, for unspecified gas service or maximum developed pressure at 65 °C, p_{max}, for dedicated gas service.

The procedure shall be in accordance with 8.5.4, except that the test can be suspended, as appropriate to the design, either after 12 000 hydraulic cycles to test pressure or 24 000 cycles to maximum developed pressure, or after N or N_d cycles where

N = $y \times$ 250 cycles per year of design life,

N_d = $y \times$ 500 cycles per year of design life,

y = is the number of years of design life.

Cylinders with a test pressure of 60 bar and above shall withstand N pressurization cycles to test pressure, p_h, (up to a maximum of 12 000 cycles), or N_d pressurization cycles to maximum developed pressure, p_{max}, (up to a maximum of 24 000 cycles), without failure by burst or leakage. Cylinders with test pressure below 60 bar shall withstand 12 000 pressurization cycles to test pressure, p_h, without failure by burst or leakage.

9.4.6 One cylinder per batch of finished cylinders shall be subjected to a burst test in accordance with 8.5.3.

The cylinder subjected to the pressure cycle test (see 9.4.5) can be used for this test.

The burst pressure, p_b, shall be in accordance with the criteria for the cylinder burst test specified in 8.5.3.

9.4.7 All cylinders incorporating welded or non-metallic liners or bonded bosses shall be tested for leakage in accordance with 8.5.15.

Leak testing shall be conducted on the completed cylinder and shall be performed at 2/3 of the test pressure, p_h.

9.5 Cylinder failure during type approval or batch testing

9.5.1 In the event of failure to meet test requirements either during a production run (batch test) or when design type approval tests do not give satisfactory results, an investigation into the cause of failure and re-testing shall be carried out.

9.5.2 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 this is not possible then a second test shall be performed on a cylinder selected at random from the batch. If the results of this test are satisfactory, the first test shall be ignored.

9.5.3 If the test has been carried out in a satisfactory manner, either:

a) the cause of failure shall be identified and the procedure detailed in 9.5.4 or 9.5.5 shall be followed or

b) the batch shall be rejected and made unserviceable.

9.5.4 If the cause of failure is identified, the defective cylinders can be reclaimed by an approved method or shall be rejected. All cylinders from the batch represented by the failed cylinder shall be tested and the passed and failed cylinders shall be separated into two batches. The failed test shall be repeated with the quantities required in 8.5.4 or 8.5.5 (as applicable) for both batches. For failures found during 100 % batch testing only the repaired cylinders need to be re-tested. If one or more tests prove even partially unsatisfactory, all the cylinders of the batch(es) covered by the tests shall be rejected.

9.5.5 Alternatively the cause of failure can be investigated and if this is identified the defective cylinders in the batch shall be removed from the batch and the failed test repeated with the quantities required in 8.5.3 or 8.5.4 (as applicable) for the original batch.

9.5.6 If a batch fails the second series of tests, the batch of cylinders shall be rendered unserviceable for holding gas under pressure. The manufacturer shall ensure that the cylinders do not enter service.

10 Cylinder marking

10.1 General

Each finished composite cylinder which satisfies the requirement of this part of ISO 11119 shall be permanently and legibly marked in accordance with ISO 13769 and ISO 7225 or the relevant marking regulations of the countries of use except that the empty weight shall be the nominal weight.

NOTE Attention is drawn to requirements for marking in relevant regulations that might override the requirements given in this International standard.

10.2 Additional marking

10.2.1 When applicable, the cylinder shall be permanently and legibly marked using a label which is either attached to the cylinder surface, in the resin or under a glass fibre layer. The applicable information to be included on the label is dependent upon cylinder use, but shall be selected from

a) **"WARNING – THIS CYLINDER MUST BE FILLED ONLY WITH <<Named Gas(es)>>"** where a cylinder is to be used for dedicated gas service;

b) **"WARNING – THIS CYLINDER MUST BE USED WITH A <<Named>> PRESSURE RELIEF DEVICE"** where a cylinder is approved with a specific pressure relief device (see 8.5.11);

c) **"Maximum torque <<manufacturer's recommended torque>>"** where fitting torque does not correspond to the values given in ISO 13341 or where the thread is not listed in ISO 13341;

d) **"WARNING – THIS CYLINDER MUST BE CLAMPED BY THE NECK FOR VALVE INSERTION AND REMOVAL"** where the cylinder is not designed for clamping on the body.

e) **"WARNING – THIS CYLINDER MUST NOT BE SUBJECTED TO A VACUUM"**, where a prototype representative of the cylinder design has not been subjected to the vacuum test in accordance with 8.5.5.1.

f) Details of components that are permanently attached to the cylinder and form part of the qualified design (e.g. neck rings, protective boots etc) with instructions that they shall not be removed at periodic inspection.

g) Other additional markings such as re-test dates (in accordance with national legislation), customer names etc.

10.2.2 All labels shall be clearly marked with letters not less than 3 mm high.

Annex A
(informative)

Examples of design approval certificate

Design approval certificate — Composite gas cylinders and tubes with non-load-sharing metallic or non-metallic liners

Issued by (*Relevant authority*) on the basis of applying ISO 11119-3, *Gas cylinders – Refillable composite gas cylinders and tubes – Design, construction and testing — Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450L with non-load-sharing metallic or non-metallic liners*

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 .....

Liner heat treatment ..... Details .....

Finished cylinder		Liner	Liner	Boss	Composite material	
Capacity	l	Material			Fibre(s)	
Test pressure	bar	Minimum thickness, mm			Fibre(s) tensile strength	MPa
Diameter	mm	Minimum yield strength, MPa			Fibre(s) modulus	GPa
Length	mm	Minimum tensile strength, MPa			Matrix components	
Thread		Elongation, %			Shear strength	MPa

Compatible gases .....

Manufacturer or agent ..... (*Name and address of manufacturer or his agent*) .....

.....

.....

Type of approval mark .....

Details of the results of the examination of the design for design approval are detailed in Type approval Test Report.

.....

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

.....

.....

Date ..... Place .....

Signature .....

Annex B
(informative)

Specimen test reports

VERIFICATION BODIES REPORT ON:

THE MANUFACTURE OF FULLY WRAPPED FIBRE REINFORCED COMPOSITE GAS CYLINDERS AND TUBES WITH NON-LOAD-SHARING METALLIC OR NON-METALLIC LINERS

Inspection Body ____________________

The inspector's mark ____________________

Certificate No. ____________________

Place ____________________ Date ____________________

Cylinders manufactured by ____________________

Manufacturer's mark ____________________

Manufactured for ____________________

Consigned to ____________________

Quantity __________ Overall size (mm) __________Outside diameter by __________ long

Serial numbers __________ to __________ inclusive

Standard

Drawing No. ____________________

Date of hydraulic pressure test ____________________

Test pressure (bar) ____________________

Water capacity (l) ____________________

Gas __________ Filling pressure (permanent) (bar) ____________________

Filling ratio (liquefied) (bar) ____________________

Mass of container (kg) Minimum __________ Maximum __________ Without valve

Minimum __________ Maximum __________ With valve

NOTE Items in parentheses below refer to the clauses of this part of ISO 11119.

Each liner was produced by over-wrapping a seamless liner with resin-impregnated filament reinforcement.

Liner material designated as ____ was supplied by _____ and the analysis was within the required limits.

Each liner was produced by an approved process. The results of the mechanical tests have been found satisfactory (see 9.1.3).

Overwrap was applied by wrapping under controlled tension.

Glass Carbon Aramid

designated _____

supplied by _____

impregnated with resin designated _____

manufactured by _____

Identified by package number and cured after wrapping to the manufacturer's standard.

Filaments strand strength and reinforcement were verified and found satisfactory.

Calculated stress levels on the reinforcement filaments satisfy design requirements.

Each cylinder was subjected to a hydraulic proof pressure test (see 8.5.1) or volumetric expansion test (see 8.5.2) at the test pressure stated above.

The results of the batch pressure cycle and burst tests were satisfactory.

Each cylinder has been marked as required by ISO 11119-3 (Clause 10).

WE HEREBY CERTIFY that each of the above cylinders meets, in full, the requirements of ISO 11119-3.

For and on behalf of the manufacturer _____

For and on behalf of the Inspection Body_____

Specimen test reports (continued)

1. Mechanical tests on liners

Batch No.	Code	Test piece dimensions (mm)	0,2 % yield strength (MPa)	Tensile strength (MPa)	Elongation (%)

For and on behalf of the manufacturer _____

2. Hydraulic volumetric expansion test certificate for composite cylinders

Customer Order No. _____ Tested to a pressure _____ and conforming to

Manufacturer's No. _____

Container No.	Cast No.	Expansion at 10 %	Expansion at p_h	Expansion at p_h — expansion at 10 %	Mass full (kg)	Mass empty (kg)	Water capacity (l)	Test date

Certified by _____ on behalf of _____ Date _____
(for manufacturer)

Certified by _____ Date _____
(Inspection Body)

Annex C
(informative)

Test report for equivalency

VERIFICATION BODIES REPORT ON:

THE TESTING OF LINER MATERIALS AND/OR COMPOSITE MATERIALS TO PROVE EQUIVALENCY WITH APPROVED MATERIALS FROM A PREVIOUS TYPE APPROVAL

_____

Inspection Body _____

The inspector's mark _____

Certificate No. _____

Place _____ Date _____

Cylinders manufactured by _____

Manufacturer's mark _____

Manufactured for _____

Consigned to _____

LINER MATERIALS

Documentation for the liner and metal boss(es) shall include (but not be limited to)

— Equivalent liners are manufactured from the same nominal raw materials, using the same process of manufacture and having the same physical structure and the same nominal physical properties as in an approved cylinder design.

— The equivalent liner material shall be subjected to the material tests specified in 9.1.3 and the liner burst test specified in 8.5.18 and shall meet the minimum requirements specified in 7.2.2 and the criteria of 8.5.18.

DESIGN CRTERIA	APPROVED DESIGN	EQUIVALENT DESIGN
Liner materials including limits of chemical analysis		
Process of manufacture		
Physical structure and nominal physical properties		
Material Tests in 9.1.2 or 9.1.3		
Liner Burst Test in 8.5.18		

COMPOSITE MATERIALS

Documentation for composite overwrap shall include (but not be limited to):

DESIGN CRITERIA	APPROVED DESIGN	EQUIVALENT DESIGN
Fibre material, raw materials, process of manufacture physical structure		
Average tensile strength and modulus		

WE HEREBY CERTIFY that each of the above liner materials and/or fibre materials are equivalent to liner materials and/or fibre material in a previously approved cylinder design according to the requirements of ISO 11119-3.

For and on behalf of the manufacturer _____

For and on behalf of the Inspection Body_____

Specimen test reports (continued)

1. Mechanical tests on liners

Batch No.	Code	Test piece dimensions (mm)	0,2 % yield strength (MPa)	Tensile strength (MPa)	Elongation (%)

For and on behalf of the manufacturer _____

2. Hydraulic volumetric expansion test certificate for composite cylinders

Customer Order No. _____ Tested to a pressure _____
and conforming to

Manufacturer's No. _____

Container No.	Cast No.	Expansion at 10 %	Expansion at p_h	Expansion at p_h — expansion at 10 %	Mass full (kg)	Mass empty (kg)	Water capacity (l)	Test date

Certified by _____ on behalf of _____ Date _____
(for manufacturer)

Certified by _____ Date _____
(Inspection Body)

Bibliography

[1] ISO 7438:2005, *Metallic materials — Bend test*

[2] ISO 7866:2012, *Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing*

[3] ISO 9809-1, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa*

[4] ISO 9809-2, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 2: Quenched and tempered steel cylinders with tensile strength greater than or equal to 1 100 MPa*

[5] ISO 9809-3, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 3: Normalized steel cylinders*

[6] ISO 10156:2010, *Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets*

[7] ISO 11114-3:2010, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 3: Autogenous ignition test in oxygen atmosphere*

[8] ISO 11439, *Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles*

[9] ISO 11623:2002, *Transportable gas cylinders — Periodic inspection and testing of composite gas cylinders*

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

[11] EN 144-1, *Respiratory protective devices — Gas cylinder valves — Part 1: Thread connections for insert connector*

[12] EN 720-2, *Transportable gas cylinders — Gases and gas mixtures — Part 2: Determination of flammability and oxidizing ability of gases and gas mixtures*

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

[14] EN 12245, *Transportable gas cylinders — Fully wrapped composite cylinders*

[15] EN 12257, *Transportable gas cylinders — Seamless, hoop-wrapped composite cylinders*

[16] ASTM D 2290-00, *Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method*

[17] ASTM D 2291-98, *Standard Practice for Fabrication of Ring Test Specimens for Glass-Resin Composites*

[18] ASTM D 2344-00, *Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates*

[19] CGA Pamphlet C-6.2, *Guidelines for Visual Inspection and Requalification of Fibre Reinforced High Pressure Cylinders*

[20] CGA C14:1992, *Procedures for Fire Testing of DOT Cylinder Pressure Relief Device Systems*

[21] ISO 13341, *Gas cylinders — Fitting of valves to gas cylinders*

ICS 23.020.30

Price based on 40 pages