INTERNATIONAL STANDARD

ISO 11119-3

Third edition
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Gas cylinders — Design, construction and testing of refillable composite gas cylinders and tubes —

Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with non-load-sharing metallic or non-metallic liners or without liners

Bouteilles à gaz — Conception, construction et essais des tubes et bouteilles à gaz rechargeables en matériau composite —

Partie 3: Tubes et bouteilles à gaz entièrement bobinés en matériau composite renforcés de fibres d'une contenance allant jusqu'à 450 l avec liners non métalliques ou métalliques non structuraux, ou sans liners

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This third edition cancels and replaces the second edition (ISO 11119-3:2013), which has been technically revised. The main changes compared to the previous edition are as follows:

— References updated.

— 7.1.4 Minimum fibre stress ratios added.

— 8.5.9 Drop/impact test. Addition of new alternative test for cylinders up to and including 50 l water capacity with dedicated compressed gas service. Addition of alternative impact test for tubes 150 l and above.

— 8.5.11 Fire resistance test. Changes to the procedure to make the test more consistent. Adding a criteria for tubes above 150 l to be tested for 5 min.

— 8.5.12 Torque test is now only required for taper threads.

— References updated

— 8.5.16 Pneumatic cycle test. New procedure for the test to have a lower number of cycles but, with a significant hold time at pressure.

A list of all parts in the ISO 11119 series can be found on the ISO website.

Introduction

The purpose of this document 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.

This document 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 document has been written so that it is suitable to be referenced in the UN Model Regulations[1].

This document addresses the general requirements on design, construction and initial inspection and testing of pressure receptacles of the *Recommendations on the transport of dangerous goods: Model regulations* developed by the United Nations[2].

Gas cylinders — Design, construction and testing of refillable composite gas cylinders and tubes —

Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with non-load-sharing metallic or non-metallic liners or without liners

1 Scope

This document specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes, examination and testing at time of manufacture for:

— type 4 composite fully wrapped cylinders or tubes with a non-load sharing liner and composite reinforcement on both the cylindrical portion and the dome ends;

— type 5 fully wrapped cylinders or tubes without liners and with a test pressure of less than 60 bar and composite reinforcement on both the cylindrical portion and the dome ends;

— water capacities up to 450 l;

— for the storage and conveyance of compressed or liquefied gases;

— cylinders and tubes with composite reinforcement of carbon fibre, aramid fibre or glass fibre (or a mixture thereof) within a matrix;

— a minimum design life of 15 years.

Cylinders and tubes manufactured and tested according to this document are not intended to contain toxic, oxidizing or corrosive gases.

This document does not address the design, fitting and performance of removable protective sleeves.

NOTE 1 References to cylinders in this document 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 are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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*

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

ISO 7225, *Gas cylinders — Precautionary labels*

ISO 7866, *Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing*

ISO 9809-1, *Gas cylinders — Design, construction and testing of refillable seamless steel gas cylinders and tubes — Part 1: Quenched and tempered steel cylinders and tubes with tensile strength less than 1 100 MPa*

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

ISO 9809-3, *Gas cylinders — Design, construction and testing of refillable seamless steel gas cylinders and tubes — Part 3: Normalized steel cylinders and tubes*

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

ISO 10286, *Gas cylinders — Terminology*

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 11114-4, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 4: Test methods for selecting steels resistant to hydrogen embrittlement*

ISO 13769, *Gas cylinders — Stamp marking*

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

EN 12165, *Copper and copper alloys. Wrought and unwrought forging stock*

ASTM E1356–08, *Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 10286 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

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

3.2
batch
set of homogeneous items or material

Note 1 to entry: 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 from the same material family and similar properties to a fibre 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
equivalent matrix
resin matrix from the same chemical family and similar properties to the resin matrix used in a previously prototype tested cylinder

3.14
glass fibre
continuous filaments of glass laid up in tow form

3.15
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

3.16
matrix
material used to bind and hold the fibres in place

3.17
non-load-sharing liner
liner that has a burst pressure less than 5 % of the nominal burst pressure of the finished composite cylinder

3.18
thermoplastic
plastics capable of being repeatedly softened by increase of temperature and hardened by decrease of temperature

3.19
thermosetting
plastics that, when cured by the application of heat or chemical means, harden permanently into a substantially infusible and insoluble product

3.20
nominal outside diameter
diameter of the cylinder specified by the manufacturer for the type approval including tolerances (e.g. ±1 %)

3.21
working pressure
p_w
settled pressure of a compressed gas at a reference temperature of 15 °C in a full gas cylinder

3.22
glass transition temperature
Tg
the temperature where a polymer substrate changes from a rigid glassy material to a soft (not melted) material, and is usually measured in terms of the stiffness, or modulus

4 Symbols

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

5 Inspection and testing

To ensure that the cylinders conform to this document, 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 boss assembly) shall be manufactured from materials suitable for the gas to be contained as specified in ISO 11114-1 and ISO 11114-2 where applicable. For compatibility with

hydrogen see ISO 11114-4. Materials used to manufacture the components of boss assemblies attached to non-metallic liners shall fulfil the material performance requirements of this document.

6.1.2 The metallic liner or metallic boss component materials shall conform to the following material performance tests in the appropriate standard:

a) seamless steel liners or bosses: the material tests in ISO 9809-1, ISO 9809-2 or ISO 9809-3;

b) seamless stainless steel liners or bosses: the material tests in ISO 9809-4;

c) seamless aluminium alloy liners or boss components: Sustained load cracking test and stress corrosion cracking test (if size permits sample extraction) in line with ISO 7866**;**

d) brass boss components: material composition as defined in EN 12165.

Testing carried out on material sample coupons is acceptable for metallic boss components; where coupons are to be used, the coupons shall be produced from a representative sample of raw material. (i.e. if a component is manufactured from bar stock, the coupon shall be manufactured from bar stock).

6.1.3 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.

6.1.4 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 material.

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 shall be a polymer suited to the application, local environmental conditions and to the intended life of the product.

6.2.3 The suppliers of the filament material and the matrix component materials 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:

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 without liner with a test pressure of less than 60 bar shall comprise:

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

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

c) an optional external protection system.

Type 5 cylinders and tubes made from two or more parts joined together are not permitted under this document.

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 The cylinders shall be designed for high reliability under sustained load and cyclic loading. Therefore, it is necessary to take account of the properties of the individual composite fibres and to establish their respective minimum fibre stress ratios.

The fibre stress ratio is defined as the fibre stress at design minimum burst pressure divided by the fibre stress at 2/3 test pressure.

The minimum fibre stress ratios shall be as follows:

— for glass: 3,6;

— for aramid: 3,1;

— for carbon: 2,4;

The fibre stress ratio for type 4 and type 5 cylinders can be confirmed by burst testing. The strength of the individual types of fibres used in hybrid construction may be verified by testing of containers reinforced with a single type of fibre. In a hybrid construction, the applicable stress ratio requirements shall be met in one of the two following ways:

a) if load sharing between the various fibre reinforcing materials is considered a fundamental part of the design, each fibre shall meet the stated stress ratio requirements;

b) if load sharing between fibres is not considered as a fundamental part of the design, then one of the reinforcing fibres shall be capable of meeting the stress ratio requirements even if all other fibre reinforcing materials are removed.

7.1.5 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, curing agent, accelerator, materials and specifications where applicable.

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 overwrapped if it has been damaged or scored by the stripping process.

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 is 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 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 elastic 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/impact test, in accordance with 8.5.9;

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

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

i) leak test in accordance with 8.5.15;

j) pneumatic cycle test in accordance with 8.5.16;

k) resin shear strength in accordance with 8.5.18.

l) glass transition test in accordance with 8.5.14;

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 (mandatory if a cylinder is to be exposed to a vacuum in service);

b) environmentally assisted stress rupture test in accordance with 8.5.7 (mandatory for cylinders with load sharing glass or aramid fibre);

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

d) fire resistance test in accordance with 8.5.11;

e) salt water immersion test in accordance with 8.5.14 (mandatory for cylinders used in underwater applications).

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/impact 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 This clause specifies when a composite cylinder is a new design for the purposes of this document. Subclause 8.4 specifies when a composite cylinder is a design variant.