INTERNATIONAL STANDARD

ISO 11119-2

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

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

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

Partie 2: Tubes et bouteilles à gaz entièrement bobinés en matériau composite renforcés de fibres et d'une contenance allant jusqu'à 450 l avec liners métalliques structuraux

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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 11119-2:2012), which has been technically revised. It also incorporates the Amendment ISO 11119-2:2012/Amd.1:2014.

The main changes compared to the previous edition are as follows:

— References updated.

— 7.1.3 Minimum fibre stress ratios added.

— 8.5.8 Drop 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.

— 8.5.10 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.

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 worldwide 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[15].

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

Part 2: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with load-sharing metal 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 3 fully wrapped cylinders or tubes with a load-sharing metal liner and composite reinforcement on both the cylindrical portion and the dome ends;

— water capacities up to 450 l;

— 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.

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

This document does not apply to cylinders with welded liners.

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 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 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 9809-4, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 4: Stainless steel cylinders with an Rm value of less than 1 100 MPa*

ISO 10286, *Gas cylinders — Terminology*

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

ISO 11114-1, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: 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 13341, *Gas cylinders — Fitting of valves to gas cylinders*

ISO 13769, *Gas cylinders — Stamp marking*

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

ASTM D7269, *Standard test methods for tensile testing of aramid yarns*

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

3.3
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.

3.4
batch of liners
production quantity of up to 200 finished liners successively produced (plus units required for destructive testing) of the same nominal diameter, length, thickness and design, from the same material cast and heat treated to the same conditions of temperature and time

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 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 used in a previously prototype tested cylinder

3.11
equivalent liner
liner of the same alloy family, and that has certified properties and performance so as to be a directly comparable to a liner used in an already approved cylinder

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 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
load-sharing liner
liner which has a burst pressure greater than or equal to 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
working pressure
p_w
settled pressure, in bar, of a compressed gas at a reference temperature of 15 °C in a full gas cylinder

3.21
nominal outside diameter
diameter of the cylinder specified by the manufacturer for the type approval including tolerances (e.g. ±1 %)

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 finished 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 materials shall conform in all relevant respects to the appropriate standard:

a) seamless steel liners: ISO 9809-1, ISO 9809-2 or ISO 9809-3, as appropriate;

b) seamless stainless steel liners: ISO 9809-4;

c) seamless aluminium alloy liners: ISO 7866.

Relevant clauses are those covering materials, thermal treatments, neck design, construction and workmanship, and mechanical tests. This excludes the design requirements since these are specified by the manufacturer for the design of the composite cylinder (see 7.2.2).

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. They shall also maintain records so that the cast of material and the heat treatment batch (where applicable) used for the manufacture of each cylinder can be identified.

6.1.3 The liner shall be manufactured from a metal or alloy suitable for the gas to be contained in accordance with ISO 11114-1. For compatibility with hydrogen see ISO 11114-4.

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, environment, and intended life of the product.

6.2.3 The supplier of the filament material and the matrix system 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 conformity from the material manufacturer is considered acceptable for the purposes of verification.

6.2.5 Batches of materials shall be identified and documented.

7 Design and manufacture

7.1 General

7.1.1 A type 3 fully-wrapped composite gas cylinder with load-sharing liner shall comprise:

a) an internal metal liner, which carries part of the longitudinal and circumferential load;

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

c) 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 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.

The cylinder can also include additional parts (e.g. neck rings, bases).

7.1.3 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 calculated 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 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.

7.1.4 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 shall include (but not be limited to):

a) material, 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 including minimum mechanical properties and hardness ranges, where applicable;

g) minimum design burst pressure;

h) dimensional details of valve threads and any other permanent features.

7.2.3 Documentation for the 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, layer orientation, and tensioning of the fibre at wrapping (where applicable);

f) curing process, temperatures, duration, and tolerances, where applicable.

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

a) nominal water capacity, in litres, under ambient conditions;

b) dimensions with tolerances

c) list of intended contents, if intended for dedicated gas service;

d) test pressure, p_h;

e) working pressure, p_w (if applicable), that shall not exceed 0,67 × p_h;

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

g) minimum design burst pressure;

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

i) autofrettage pressure and approximate duration (where applicable);

j) nominal mass of the finished composite cylinder, including tolerances;

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

7.3 Manufacturing

7.3.1 The liner shall be manufactured in accordance with the manufacturer's design (see 7.2.2) and the International Standard for the relevant metallic material (as listed in 6.1.1).

7.3.2 The composite cylinder shall be fabricated from a load-sharing liner fully overwrapped with layers of continuous fibres in a matrix applied under a controlled tension to develop the design composite thickness 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 7.2.3. The maximum temperature shall be such that the mechanical properties of the liner material are not adversely affected.

7.3.4 If cylinders are subjected to an autofrettage operation, the autofrettage pressure and duration shall be as specified in 7.2.4. The manufacturer shall demonstrate the effectiveness of the autofrettage by appropriate measurement technique(s) acceptable to the inspector.

7.3.5 If cylinders are subjected to a prestressing or fibre tensioning during wrapping in order to actively change the final stresses in the finished cylinder, the level of stress shall be as specified in the documentation in 7.2.4 and levels of stress of 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 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, sufficient cylinders shall be made to complete the prototype tests required, in addition to the production quantity. In this case, the approval validity is 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) liner burst test, in accordance with 8.5.3;

c) cylinder burst test, in accordance with 8.5.4;

d) ambient temperature cycle test, in accordance with 8.5.5;

e) environmental cycle test, in accordance with 8.5.6;

f) flaw test, in accordance with 8.5.7;

g) drop/impact test, in accordance with 8.5.8;

h) high velocity impact (gunfire) test, in accordance with 8.5.9;

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

a) fire resistance test, in accordance with 8.5.10;

b) salt water immersion test, in accordance with 8.5.11 (mandatory for underwater uses);

c) environmentally assisted stress rupture test, in accordance with 8.5.13 (mandatory for cylinders with load sharing glass or aramid fibre;

d torque test, in accordance with 8.5.12.

