INTERNATIONAL STANDARD

ISO 11515

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Gas cylinders — Refillable composite reinforced tubes of water capacity between 450 L and 3000 L — Design, construction and testing

Bouteilles à gaz — Bouteilles tubulaires en composite renforcé rechargeables d'une capacité de 450 L à 3000 L — Conception, construction et essais

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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. www.iso.org/directives

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

The committee responsible for this document is ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

Introduction

The purpose of ISO 11515 is to provide a specification for the design, manufacture, inspection and testing of composite tubes for worldwide usage. The objective is to balance design and economic efficiency against international acceptance and universal utility.

ISO 11515 aims to eliminate the concern about climate, duplicate inspection and restrictions currently existing because of lack of definitive International Standards and should not be construed as reflecting on the suitability of the practice of any nation or region.

ISO 11515 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*.

Annexes A and B of ISO 11515 are for information only.

Gas cylinders — Refillable composite reinforced tubes of water capacity between 450 L and 3000 L — Design, construction and testing

1 Scope

This International Standard specifies minimum requirements for the design, construction and performance testing of composite reinforced tubes between 450 l and 3 000 l water capacity, for transport, storage and use of compressed or liquefied gases with test pressures up to and including 1600 bar with a design life of at least 15 years and less than or equal to 30 years. The expected service temperatures are between −40 °C and +65 °C.

The tubes defined are one of three types:

Type 2: a hoop wrapped tube with a load sharing metal liner and composite reinforcement on the cylindrical portion only.

Type 3: a fully wrapped tube with a load sharing metal liner and composite reinforcement on both the cylindrical portion and the dome ends.

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

The Type 4 tubes manufactured and tested to this International Standard are not intended to contain toxic, oxidizing or corrosive gases.

This International Standard is limited to tubes with composite reinforcement of carbon fibre or aramid fibre or glass fibre (or a mixture thereof) in a matrix.

Composite tubes can be used alone or in batteries to equip trailers or skids (ISO modules) or multiple element gas containers (MEGC) for the transportation and distribution of gases. This International Standard does not include consideration of any additional stresses that can occur during service or transport, (e.g. torsional / bending stresses). However it is important that the stresses associated with mounting the tube are considered by the assembly manufacturer and the tube manufacturer.

NOTE The design life of tubes according to this International Standard for transport of dangerous goods can be limited by the applicable regulations.

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 306, *Plastics — Thermoplastic materials — Determination of Vicat softening temperature (VST)*

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 4624, *Paints and varnishes — Pull-off test for adhesion*

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 9227:2012, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

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*

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*

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

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

ISO 11120, *Gas cylinders — Refillable seamless steel tubes of water capacity between 150 l and 3000 l — Design construction and testing*

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

ISO 13769, *Gas cylinders — Stamp marking*

ASTM D 522-93a, *Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings*

ASTM D1308, *Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes*

ASTM D2794, *Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)*

ASTM D3170, *Standard Test Method for Chipping Resistance of Coatings*

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.

3.1
aramid fibre
continuous filaments of aramid laid up in tow form, used for reinforcement

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
collective term for a 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 load sharing liners
quantity of up to 30 liners of the same nominal diameter, length, thickness and design, made successively from the same material cast (heat) and processed in the same heat treatment equipment (i.e. a continuous furnace process or a single furnace charge) using the same heat treatment parameters

3.5
batch of non-metallic liners
quantity of non-metallic liners of the same nominal diameter, length, thickness and design, made successively and subjected to the same continuous manufacturing process

3.6
batch of non-load sharing metal liners or metal bosses
quantity of non-load sharing metal liners or metal bosses of the same nominal diameter, length, thickness and design, made successively from the same material cast (heat) and processed in the same heat treatment equipment using the same heat treatment parameters

3.7
batch of finished tubes
production quantity of up to 200 finished tubes successively produced (plus finished tubes required for destructive testing), of the same nominal diameter, length, thickness and design

Note 1 to entry: The batch of finished tubes can contain different batches of liners, fibres and matrix materials.

3.8
burst pressure
highest pressure reached in a tube or liner during a burst test

3.9
carbon fibre
continuous filaments of carbon laid up in tow form, used for reinforcement

3.10
composite overwrap
combination of fibres and matrix used to reinforce the tube, including any barrier or protective layers that are a permanent part of the design

3.11
dedicated gas service
service in which a tube is to be used only with specified gas or gases

3.12
equivalent fibre
fibre equivalent to a fibre used in a previously prototype tested tube

3.13
exterior coating
layers of material applied to the tube as protection or for cosmetic purposes

Note 1 to entry: The coating can be transparent or opaque.

3.14
equivalent liner
liner 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 (within ± 5 %) of the approved liner design

3.15
glass fibre
continuous filaments of glass laid up in tow form, used for reinforcement

3.16
leak
escape of gas at a rate greater than 5×10^{-3} mbar.l/s through a defect rather than permeation

3.17
liner
inner portion of the composite tube, whose purpose is both to contain the gas and transmit the gas pressure to the fibres

3.18
load sharing liner
liner that has a burst pressure greater than or equal to 5 % of the nominal burst pressure of the finished composite tube

3.19
non-load-sharing liner
liner which has a burst pressure less than 5 % of the nominal burst pressure of the finished composite tube

3.20
matrix
material that is used to bind and hold the fibres in place

3.21
minimum design burst pressure
minimum burst pressure specified by the manufacturer and that shall be achieved during a burst test

3.22
tube
transportable pressure receptacle of a water capacity exceeding 150 litres

3.23
representative composite tube
a shorter tube with the same nominal diameter, and manufactured using the same materials and manufacturing technique, and using a representative wrapping pattern (same number of strands and same number of layers) so as to represent an equivalent stress compared to a full scale prototype

3.24
tubing
hollow cylindrical body of metal or other material, used for conveying or containing liquids or gases

3.25
Type 2 tube
hoop wrapped tube with a load sharing metal liner and composite reinforcement on the cylindrical portion only

3.26
Type 3 tube
fully wrapped tube with a load sharing metal liner and composite reinforcement on both cylindrical portion and dome ends

3.27
Type 4 tube
fully wrapped tube with a non-load sharing liner and composite reinforcement on both cylindrical portion and dome ends

4 Symbols

p_b	Burst pressure of finished tube	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 11515 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 tubes are intended to be used that might override the requirements given in this International Standard. To ensure that the tubes conform to this International Standard, 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.

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 Load sharing liner materials shall conform in all relevant respects to the appropriate International Standards:

a) seamless steel liners: ISO 9809-1, ISO 9809-2, ISO 9809-3 or ISO 11120 as appropriate;

b) seamless aluminium alloy liners: ISO 7866.

Relevant sections are those covering materials, thermal treatments, neck design, construction and workmanship, mechanical tests. Design requirements are excluded since these are specified by the manufacturer for the design of the composite tube (see 7.2.2).

6.1.1.1 The composite tube manufacturer shall verify that each new batch of materials has the specified properties and qualities, and shall maintain records so that the cast of material and the heat treatment batch (where applicable) used for the manufacture of each tube can be identified. A certificate of conformance from the liner material manufacturer is considered acceptable for the purposes of verification.

6.1.1.2 The liner shall be manufactured from a metal or alloy suitable for the gas to be contained in accordance with ISO 11114-1.

6.1.1.3 When a neck ring is provided, it shall be of a material compatible with that of the tube, and shall be securely attached by a method appropriate to the liner material.

Non-load sharing liner materials shall conform in all relevant respects to the appropriate standards, as follows:

a) The liner (including metal boss) shall be manufactured from a material suitable for the gas to be contained in accordance with ISO 11114-1 and ISO 11114-2.

b) Metal bosses attached to a non-metallic liner shall fulfil the performance requirements of this International Standard.

c) The tensile yield strength and ultimate elongation of plastic liner material shall be determined at −50 °C in accordance with ISO 527-2.The test results shall demonstrate the ductile properties of the plastic liner material at temperatures of −50 °C or lower by meeting the values specified by the manufacturer.

d) Polymeric materials from finished liners shall be tested in accordance with a method described in ISO 306. The softening temperature shall be at least 100 °C.

6.2 Composite overwrap

6.2.1 The overwrap filament materials shall be carbon fibre or aramid fibre or glass fibre (or any mixture thereof).

6.2.2 The resin matrix shall be a polymer suited to the application, environment and intended life of the product, e.g. epoxy or modified epoxy with amine or anhydride curing agent, vinyl esters and polyesters.

6.2.3 The supplier of the filament material and the resin matrix system component materials shall provide sufficient documentation for the composite tube manufacturer to be able to identify fully the batch of materials used in the manufacture of each tube.

6.2.4 The composite tube 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 tube 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.

6.2.6 The manufacturer shall ensure there is no adverse reaction between the liner and the reinforcing fibre, e.g. by the application of a suitable protective coating to the liner prior to the wrapping process (if necessary).

NOTE Glass fibre reinforced composite tubes can be susceptible to chemical attack and degradation after being in contact with aggressive acids (e.g. battery acid).

7 Design and manufacture

7.1 General

7.1.1 A Type 2 composite tube shall comprise:

a) an internal metal liner with one or two openings along the central axis only, which carries all the longitudinal load and part of the circumferential load;

b) the liner, designed to withstand a burst pressure greater than 0,85 of the test pressure of the finished tube.

c) a composite overwrap formed by layers of continuous fibres in a matrix along the parallel portions of the tube sidewall;

d) an optional exterior coating to provide external protection. When this is an integral part of the design it shall be permanent.

7.1.2 A Type 3 composite tube shall comprise:

a) an internal metal liner with one or two openings along the central axis only, 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 exterior coating to provide external protection. When this is an integral part of the design it shall be permanent.

7.1.3 A Type 4 composite tube shall comprise:

a) an internal metal or non-metallic non-load sharing liner with one or two openings along the central axis only;

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;

d) an optional exterior coating to provide external protection. When this is an integral part of the design it shall be permanent.

7.2 Design submission

7.2.1 The design submission for each new design of tube 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.

The design submission will cover a design family of composite tubes of the same diameter and pressure with different cylindrical lengths from 2× diameter and up to 5× the length of the representative composite tube and with a water capacity between 450 and 3 000 litre.

7.2.2 Documentation for the liner and/or metal boss(es) shall include:

a) Material details, 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 (where applicable);

e) inspection procedures (minimum requirements);

f) material properties (including hardness for Type 2 and Type 3 tubes);

g) minimum design burst pressure (for Type 2 and Type 3 tube liners);

h) dimensional details of valve threads;

i) method of sealing boss to liner for Type 4 tubes.

7.2.3 Documentation for the composite overwrap shall include:

a) fibre material, specification and mechanical properties requirements;

b) minimum composite thickness;

c) resin system - main components and resin bath temperature where applicable;

