INTERNATIONAL STANDARD

ISO 11513

Second edition
2019-06

Gas cylinders — Refillable welded steel cylinders containing materials for sub-atmospheric gas packaging (excluding acetylene) — Design, construction, testing, use and periodic inspection

Bouteilles à gaz — Bouteilles en acier soudées rechargeables contenant des matériaux pour le stockage des gaz à une pression sub-atmosphérique (à l'exclusion de l'acétylène) — Conception, fabrication, essais, utilisation et contrôle périodique

Reference number
ISO 11513:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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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*.

This second edition cancels and replaces the first edition (ISO 11513:2011), which has been technically revised. The main changes compared to the previous edition are as follows:

— references to packing instruction P200 of the UN Model Regulations have been replaced with packing instruction P208 as this document is referenced in only P208 of the UN Model Regulations;

— the prohibition on the use of ultrasonic testing during periodic inspection and test has been removed from Annex B;

— the unit “weight” has been replaced with “mass” to align with ISO 80000.

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.

Introduction

This document provides a specification for the design, manufacture, use and periodic inspection and testing of a welded steel cylinder necessary to facilitate sub-atmospheric pressure gas packaging technology on a worldwide basis. The specifications given are based on knowledge of, and experience with, materials, design requirements, manufacturing processes and control at manufacture of cylinders in common use in the countries of the ISO member bodies.

The pressure shell of the cylinder is fabricated by manufacturing a cylindrical shape with a base and welding a machined plug (boss) or semi-ellipsoidal or torispherical shape onto the open end of the shell to form the cylinder. This method of fabrication allows for insertion of material prior to sealing the cylinder.

A further objective of this document is to balance design and economic efficiency against international acceptance and universal utility. It aims to eliminate the concerns about climate, duplicate inspections and restrictions currently existing because of lack of definitive International Standards.

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

Gas cylinders — Refillable welded steel cylinders containing materials for sub-atmospheric gas packaging (excluding acetylene) — Design, construction, testing, use and periodic inspection

1 Scope

This document specifies minimum requirements for the material, design, construction, workmanship, examination and testing at manufacture of refillable welded steel cylinders for the sub-atmospheric pressure storage of liquefied and compressed gases. It only applies to the cylinders themselves, irrespective of the materials contained therein (e.g. adsorbents, media, materials and/or gases) and other related applications. The cylinders have a test pressure not greater than 42 bar and a water capacity from 0,5 l up to and including 12 l exposed to ambient temperatures for the purpose of facilitating the sub-atmospheric pressure storage of liquefied and compressed gases as adsorbed gases.

Minimum requirements for inspection at the time of fill and periodic inspection and testing are also specified.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitute 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 4136, *Destructive tests on welds in metallic materials — Transverse tensile test*

ISO 4978, *Steel sheet and strip for welded gas cylinders*

ISO 5817, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

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

ISO 7438, *Metallic materials — Bend test*

ISO 9809-3:2010, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 3: Normalized steel cylinders*

ISO 10286, *Gas cylinders — Terminology*

ISO 11117, *Gas cylinders — Valve protection caps and valve guards — Design, construction and tests*

ISO 13769, *Gas cylinders — Stamp marking*

ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 17636-1, *Non-destructive testing of welds — Radiographic testing — Part 1: X- and gamma-ray techniques with film*

ISO 17637, *Non-destructive testing of welds — Visual testing of fusion-welded joints*

ISO 17639, *Destructive tests on welds in metallic materials — Macroscopic and microscopic examination of welds*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

ISO and IEC maintain technological 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/

3.1.1
yield strength
value corresponding to the lower yield strength, R_{eL}, or 0,92 · the upper yield strength, R_{eH}, or for steels that do not exhibit a defined yield, the 0,2 % proof strength, $R_p0{,}2$

3.1.2
stress relieving
heat treatment given to the drawn pressure shell by heating to a uniform temperature below the lower critical point, AC_1, of the steel and cooling in a still atmosphere

Note 1 to entry: The object is to reduce the residual stresses without altering the metallurgical structure of the steel.

3.1.3
batch
quantity of finished cylinders made consecutively during the same or consecutive days to the same design, size and material specifications and cast for each pressure-containing part on the same equipment and subjected to the same heat-treatment conditions

Note 1 to entry: Different suppliers can be used for the different pressure-containing parts within a batch, e.g. one supplier for shells, another for plugs.

3.1.4
F
design stress factor
ratio of equivalent wall stress at test pressure, p_h, to guaranteed minimum yield strength, R_{eg}

3.1.5
sub-atmospheric gas packaging
gas source package that stores and delivers gas at sub-atmospheric pressure, which includes a container (e.g. gas cylinder and outlet valve) that stores and delivers gas at a pressure of less than 1 bar at normal conditions of temperature and pressure

Note 1 to entry: The container can incorporate a medium in order to reduce the pressure of the gas to sub-atmospheric levels.

3.2 Symbols

a calculated minimum thickness, in millimetres, of the cylindrical shell

a' guaranteed minimum thickness, in millimetres, of the cylindrical shell (including any corrosion allowance, see 8.1)

a_1 guaranteed minimum thickness, in millimetres, of a concave base at the knuckle (see Figure 1 a)

a_2 guaranteed minimum thickness, in millimetres, at the centre of a concave base (see Figure 1 a)

b calculated minimum thickness, in millimetres, of the cylinder end

A percentage elongation after fracture

D outside diameter of the cylinder, in millimetres

d internal diameter of the cylinder, in millimetres

h outside height, in millimetres, of domed part (convex base end) (see Figure 1 a)

L length of the cylinder, in millimetres

P_b measured burst pressure, in bars, above atmospheric pressure, in the burst test

NOTE 1 bar = 10^5 Pa = 0,1 MPa.

p_h test pressure above atmospheric pressure, in bars

P_y observed pressure when cylinder starts yielding during hydraulic bursting tests, in bars, above atmospheric pressure

r inside knuckle radius, in millimetres (see Figures 1 and 2)

R_{eg} guaranteed minimum yield strength in megapascals (yield strength as defined in 3.1.1), for the finished cylinder and used for design calculation

R_{ea} value of the actual yield strength in megapascals (yield strength as defined in 3.1.1), determined by the tensile test (see 9.4.2.2)

R_{ma} value of the actual tensile strength in megapascals as determined by the tensile test (see 9.4.2.2)

R_{mg} guaranteed minimum tensile strength in megapascals, for the finished cylinder and used for design calculations

4 Inspection and testing

To ensure that the cylinders conform to this document, they shall be subject to inspection and testing in accordance with Clauses 8, 9 and 10.

Inspection at the time of fill is specified in Annex A and periodic inspection and testing is specified in Annex B.

Tests and examinations performed to demonstrate compliance with this document shall be conducted using instruments calibrated before being put into service and thereafter according to an established programme.

5 Materials and stress relieving

5.1 Materials for shells and end pressings shall conform to either ISO 4978 or ISO 9809-3.

NOTE "Materials" refers to materials in the state before transformation with regard to the manufacturing process.

To conform to the state of the art for modern steel manufacturing and steel grades used for pressure purposes, the same limits on sulphur and phosphorous contents as noted in ISO 4706:2008, 5.9.1 for refillable welded steel cylinders and ISO 9809-3:2010, Table 3 shall apply in this document. The following limits are noted:

— carbon: 0,25 % max.;

— silicon: 0,45 % max.;

— manganese: 1,60 % max.;

— phosphorous: 0,040 % max.;

— sulphur: 0,040 % max.

5.2 All parts welded to the cylinder shall be made of compatible materials with respect to their weldability.

5.3 The welding consumables selected by the manufacturer shall be compatible with the base materials and shall produce welds which meet the minimum strength values used in the design of the cylinder and guaranteed by the manufacturer of the finished cylinder.

5.4 The cylinder manufacturer shall have certificates of the ladle analysis and mechanical properties of the steel supplied for the construction of the pressure-retaining parts of the cylinder.

5.5 The manufacturer shall maintain a system of identification for the materials used in fabrication so that all materials for pressure parts in the completed cylinder are traceable to their origin.

5.6 Grades of steel used for cylinder manufacture shall be compatible with the intended gas service, e.g. corrosive gases, embrittling gases. See ISO 11114-1.

5.7 The drawn pressure shell and plug shall be delivered in the stress-relieved condition. Localized stress relief of the drawn pressure shell and plug shall not be undertaken.

The quality of the welds shall be checked by non-destructive examination (NDE) or other equivalent means to demonstrate that the cylinder is fit for the intended service. See 9.7.4.

The actual temperature of stress relief to which a type of steel is subjected for a given tensile strength shall not deviate by more than 30 °C from the temperature specified by the manufacturer for the cylinder type.

5.8 The material properties of the finished cylinders shall be suitable to meet the requirements of Clause 8 and Clause 9.

Only steel pressure receptacles resistant to hydrogen embrittlement can be used for gases assigned the special packing provision “d” as per P208 of the UN Model Regulations[1].

6 Design

6.1 General

6.1.1 The calculation of the wall thickness of the pressure-containing parts shall be related to the guaranteed minimum yield strength, R_{eg}, for the parent material in the finished cylinder.

For certain gases, additional corrosion allowances may be applicable.

6.1.2 For calculation purposes, the value of the yield strength, R_{eg}, shall be limited to a maximum of 0,85 R_{mg}.

6.1.3 The internal pressure upon which the minimum sidewall thickness calculation of gas cylinders is based shall be the test pressure, p_h.

6.1.4 A fully dimensioned drawing including the specification of the material shall be produced.

6.2 Calculation of cylindrical wall thickness

The guaranteed minimum thickness of the cylindrical shell shall be not less than that calculated by:

$$a = \frac{D}{2} \times \left(1 - \sqrt{\frac{10 \times F \times R_{eg} - \sqrt{3} \times p_h}{10 \times F \times R_{eg}}} \right)$$

where F is the lesser of $\frac{0{,}65}{\frac{R_{eg}}{R_{mg}}}$ or 0,77.

$\frac{R_{eg}}{R_{mg}}$ shall not exceed 0,85.

The guaranteed minimum thickness of the cylinder shell shall also conform to 6.4.

6.3 Design of cylinder ends

NOTE Examples of typical cylinder ends are shown in Figure 1. Figure 1 a) is a typical base end concave to pressure and Figure 1 b) is a typical end plug used to seal the top of the cylinder.

6.3.1 General

The thickness in the base of a cylinder with a convex base end shall not be less than the guaranteed minimum wall thickness of the cylindrical shell specified in 6.2.

6.3.2 Design of base concave to pressure

When concave base ends [see Figure 1 a)] are used, the following design values are recommended:

— $a_1 \geq 2a$

— $a_2 \geq 2a$

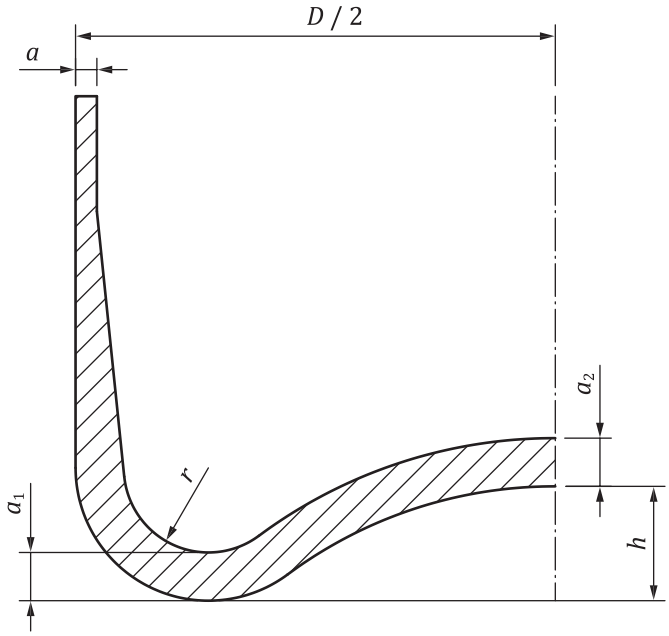
— $h \geq 0{,}12\ D$

— $r \geq 0{,}075\ D$

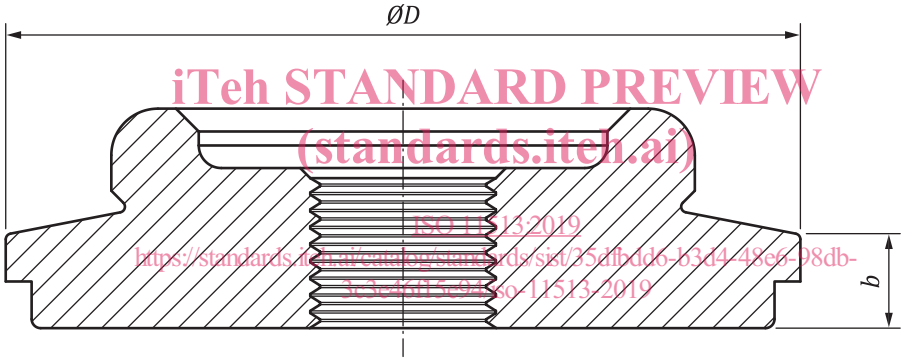
The design drawing shall at least show values for a_1, a_2, h and r.

The cylinder manufacturer shall in all cases prove by the pressure cycling test given in 8.3.2 that the design is satisfactory.

NOTE 1 An example of a typical end is shown in Figure 1 a).



a) Illustration of cylinder base end concave to pressure



b) Boss style end plug with inlet threads

Figure 1 — Typical cylinder ends

6.4 Minimum wall thickness

6.4.1 The minimum wall thickness of the cylindrical shell including the base, a, shall be not less than the value derived from the appropriate formula:

— for $D \leq 100$ mm, $a = 1{,}1$ mm;

— for 100 mm $< D \leq 150$ mm, $a = 1{,}1 + 0{,}008(D - 100)$ mm;

— for $D > 150$ mm, $a = \frac{D}{250} + 0{,}7$ mm, with an absolute minimum of 1,5 mm.

6.4.2 The minimum thickness, b, of end plugs (bosses) used to seal the top of the cylinder shall be at least twice the thickness of the cylinder sidewall, a, i.e. $b \geq 2a$.

The adequacy of the end plug design shall be demonstrated by the pressure cycling test in accordance with 8.3.2.

NOTE 1 An example of a typical end plug to seal the top of the cylinder is shown in Figure 2.