INTERNATIONAL STANDARD

ISO 4706

First edition
2008-04-15

Corrected version
2008-07-01

Gas cylinders — Refillable welded steel cylinders — Test pressure 60 bar and below

Bouteilles à gaz — Bouteilles en acier soudées rechargeables — Pression d'essai de 60 bar et moins

Reference number
ISO 4706:2008(E)

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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.

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 4706 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 4706:1989), which has been technically revised.

ISO 4706 has been prepared to address the general requirements in Chapter 6.2 of the UN model regulations for the transportation of dangerous goods ST/SG/AC.10/1Rev.15. It is intended to be used under a variety of regulatory regimes but has been written so that it is suitable for use with the conformity assessment system in 6.2.2.5 of ST/SG/AC.10/1/Rev.15.

This corrected version incorporates the following corrections:

— following the cancellation of a proposed ISO 4706-2, the reference number has been changed from ISO 4706-1 to ISO 4706, therefore

  — reference to individual parts of ISO 4706 has been removed from the foreword,

  — references to ISO 4706-1 have been replaced by ISO 4706, and

  — the page headers have been changed to read “ISO 4706:2008”;

— the term “proof stress” has been replaced by the term “proof strength”;

— Subclause 7.4, Design of openings, has been moved to Clause 6, Design, and renumbered 6.3;

— the title of Figure 5 now relates to longitudinal welds, not circumferential welds;

— the graphics in Figure 5 have been modified to depict a longitudinal weld.

Introduction

The purpose of this International Standard is to facilitate agreement on the design and manufacture of welded-steel gas cylinders in all countries. The requirements are based on knowledge of, and experience with, materials, design requirements, manufacturing processes and controls in common use for the manufacture of gas cylinders.

With respect to those aspects concerning construction materials, approval of design rules and inspection during manufacture, which are subject to national or international regulations, it is necessary for interested parties to ensure that in the practical application of this International Standard, the requirements of the relevant authority are also satisfied.

Gas cylinders — Refillable welded steel cylinders — Test pressure 60 bar and below

1 Scope

This International Standard specifies the minimum requirements concerning material selection, design, construction and workmanship, procedure and test at manufacture of refillable welded-steel gas cylinders of a test pressure not greater than 60 bar[1)], and of water capacities from 0,5 l up to and including 500 l exposed to extreme worldwide temperatures (−50 °C to +65 °C) used for compressed, liquefied or dissolved gases.

Transportable large cylinders of water capacity above 150 l and up to 500 l may be manufactured and certified to this International Standard provided handling facilities are provided (see 8.6.4).

This International Standard is primarily intended to be used for industrial gases other than Liquefied Petroleum Gas (LPG), but may also be applied for LPG. For specific LPG applications see ISO 22991.

2 Normative references

The following referenced documents are indispensable for the application 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 5817, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

ISO 6892, *Metallic materials — Tensile testing — Method of testing at ambient temperature*

ISO 7438, *Metallic materials — Bend test*

ISO 9606-1, *Qualification test of welders — Fusion welding — Part 1: Steels*

ISO 10297:2006, *Transportable gas cylinders — Cylinder valves — Specification and type testing*

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

ISO 13769, *Gas Cylinders — Stamp marking*

ISO 11622, *Gas cylinders — Conditions for filling gas cylinders*

ISO 15613, *Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test*

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*

1) 1 bar = 10^5 Pa = 10^5 N/m^2.

ISO 17636, *Non-destructive testing of welds — Radiographic testing of fusion-welded joints*

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*

ISO 22991, *Gas Cylinders — Transportable refillable welded steel cylinders for liquefied petroleum gas (LPG) — Design and construction*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
yield strength
value corresponding to the upper yield strength, R_{eH}, or, for steels when yielding does not occur at tensile testing, the 0,2 % proof strength (non-proportional elongation), $R_{p0,}2$

3.1.2
normalizing
heat treatment in which a cylinder is heated to a uniform temperature above the upper critical point (Ac3) of the steel to regenerate or homogenize the metallurgical structure of the steel, to a sufficient degree to achieve the desired mechanical properties, and then cooled in a controlled or still air atmosphere

3.1.3
stress relieving
heat treatment given to the cylinder, the object of which is to reduce the residual stresses without altering the metallurgical structure of the steel, by heating it to a uniform temperature below the lower critical point (Ac1) of the steel, then cooling it in a controlled or still air atmosphere

3.1.4
stabilizing
heat treatment given to the cylinder, the object of which is to stabilize the structure of the steel by heating it to a uniform temperature above the lower critical point (Ac1) of the steel and subsequently cooling it to obtain the desired mechanical properties

3.1.5
batch
quantity of cylinders made consecutively by the same manufacturer using the same manufacturing techniques, to the same design, size and material specifications using the same type of welding machines, welding procedures and to the same heat treatment conditions

NOTE 1 In this context, “consecutively” need not apply to continuous production (start to finish).

NOTE 2 See 10.2 for specific batch quantities.

3.1.6
base materials
steel used to manufacture the cylinder including the pressure and non-pressure retaining materials of construction

3.1.7
cylinder shell
cylinder after completion of all forming, welding and heat treatment operations

3.1.8
***F* Factor**
design stress factor

3.1.9
parent material
all pressure retaining materials used in the fabrication of the cylinder

3.1.10
overlap
placement of steel on top of or below a weld joint for the purpose of joint alignment or added joint strength

3.2 Symbols

Symbol	Definition	Unit
a	Calculated minimum thickness of the cylindrical shell	mm
a_1	Calculated minimum value of a used in the calculation of b (see 7.2.2) of the cylinder head	mm
a_b	Minimum thickness of the cylindrical shell (including any corrosion allowance) guaranteed by the manufacturer	mm
A	Percentage elongation after fracture	%
Y	Stabilized cylinder	—
b	Calculated minimum thickness of the end	mm
C	Shape factor	—
D	Outside diameter of the cylinder as given in the design drawing	mm
D_f	Outside diameter of a bend test former	mm
F	Design stress factor	—
h	Height of the cylindrical part of the end	mm
H	Outside height of the domed part of the end	mm
J	Stress reduction factor	—
K	Ellipsoidal Ratio	—
L	Length of the cylinder	mm
L_0	Original gauge length in accordance with ISO 6892	mm
n	Ratio of diameter of bend test former to the thickness of the test piece	—
N	Normalized cylinder	—
P_b	Maximum pressure attained during the burst test	bar
P_h	Actual test pressure applied to the cylinder by the manufacturer	bar
P_{tmin}	Minimum test pressure (see ISO 11622)	bar

r	Inside knuckle radius of the end	mm
R	Inside dishing radius of the end	mm
R_{eH}	Minimum value of yield strength (apparent) guaranteed by the cylinder manufacturer for the finished cylinder	N/mm^2
R_g	Guaranteed tensile strength by the manufacturer	N/mm^2
R_m	Actual value of tensile strength determined by the tensile test specified in 9.1.2.2	N/mm^2
$R_{p0,2}$	0,2 % proof strength (see ISO 6892)	N/mm^2
S	Stress relieved cylinder	—
S_0	Original cross-sectional area of tensile test piece in accordance with ISO 6892	mm^2

4 Inspection and testing

To ensure that the cylinders are in conformance with this International Standard, they shall be subject to inspection and testing in accordance with Clauses 7, 8, 9 and 10.

Some countries of use may require that cylinders be inspected and tested by an authorized body. The inspection body shall be recognized in the country of use and shall be competent for testing and inspecting cylinders in accordance with this International Standard.

5 Materials

5.1 The material used for the fabrication of the gas cylinder shall be steel, other than rimming quality, suitable for pressing or drawing and welding, and shall not deteriorate with time (i.e. non-ageing). The steel grades used shall have specified, guaranteed, mechanical properties that are possible to achieve for the finished cylinder after normalizing, stress relieving or stabilizing.

In cases where verification of the non-ageing property of the material is required, the criteria by which it is to be specified should be agreed by the manufacturer and purchaser, and included in the order.

5.2 Materials for shells and end pressings, excluding bosses (see 5.3), shall conform to the requirements of 5.8 and 5.9.1.

5.3 Bosses shall be manufactured from compatible weldable materials with a maximum carbon content of 0,25 %(m/m).

5.4 All items welded to the cylinder (e.g. shrouds and footrings) shall be made of compatible weldable material containing maximum values %(m/m) of:

a) carbon 0,250 %;

b) phosphorous 0,040 %;

c) sulphur 0,040 %.

5.5 The welding consumables shall be such that they are capable of giving consistent welds with a minimum tensile strength at least equal to that specified for the parent materials in the finished cylinder.

5.6 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. The cylinder manufacturer shall also have certificates of the ladle analysis for items welded to the cylinder (e.g. shrouds and footrings).

5.7 A system of identification shall be in place to determine the cast(s) of steel used for the construction of the pressure retaining parts of the cylinder.

5.8 Grades of steel used for cylinder manufacture shall be compatible with the intended gas service (e.g. corrosive or embrittling gases).

5.9 Chemical composition.

5.9.1 Materials used for the fabrication of gas cylinders shells and end pressings shall be of weldable quality and values %(m/m) of:

a) carbon 0,25 %;

b) silicon 0,45 %;

c) manganese 1,60 %;

d) phosphorus 0,040 %;

e) sulphur 0,040 %;

shall not be exceeded in the cast analysis.

The use of micro-alloying elements such as niobium (columbium), titanium and vanadium shall not exceed:

a) niobium 0,05 %;

b) titanium 0,03 %;

c) vanadium 0,10 %;

d) niobium plus vanadium 0,12 %.

Where other micro-alloying elements are used, their presence and amounts shall be reported, together with those already described in 5.9.1, in the steel manufacturer's certificate.

5.9.2 When the country of use of the cylinder requires a check analysis on the steel, the analysis shall be carried out either on specimens taken during manufacture from material in the form as supplied by the steel maker to the cylinder manufacturer, or from the cylinder shell, or from finished cylinders. In any check analysis, the maximum tolerance for cast analyses shall conform to the values specified in 5.9.1.

6 Design

6.1 General requirements

6.1.1 The calculation of the wall thickness of the pressure parts to resist the internal pressure in the gas cylinders is related to the yield strength of the material for the finished cylinder.

6.1.2 For calculation purposes, the value of the yield strength i.e. R_{eH} is limited to a maximum value of:

a) 0,75 R_g for finished cylinders with a guaranteed tensile strength (R_g) $<$ 490 N/mm^2;

b) 0,85 R_g for finished cylinders with a guaranteed tensile strength (R_g) $\geqslant$ 490 N/mm^2.

6.1.3 The internal pressure, on which the wall thickness calculation of the gas cylinder is based, shall be the minimum test pressure P_{tmin}.

A minimum pressure of 30 bar shall be used in the design of LPG cylinders.

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

6.2 Valve protection

The design of the cylinder shall provide protection for valves against damage in order to avoid release of contents. When the requirements of 8.7 are not met then the cylinders shall be conveyed in crates or cradles or shall be provided during transportation with some other effective valve protection, unless it can be demonstrated that the valve can withstand damage without leakage of product.

6.3 Design of openings

6.3.1 The location of all openings shall be restricted to the ends of the cylinder.

6.3.2 Each opening in the cylinder shall be reinforced, either by a valve boss or pad, of weldable and compatible steel, securely attached by welding and so designed as to be of adequate strength and to result in no harmful stress concentrations. Compliance shall be confirmed by calculation or performing a fatigue test in accordance with the requirements of 9.6.

6.3.3 The welds of the openings shall be clear of circumferential and longitudinal joints.

6.3.4 If the leak-tightness between the valve and the cylinder is assured by a metallic seal (e.g. copper), a suitable internal valve boss can be fitted to the cylinder by a method that need not independently assure leak-tightness.

7 Calculation of minimum wall thickness (sidewall and ends)

7.1 Sidewall thickness

7.1.1 The wall thickness of the cylindrical shell shall not be less than that calculated using Equation (1).

$$a = \frac{D}{2}\left(1 - \sqrt{\frac{10\,JF\,R_{eH} - \sqrt{3}P_h}{10\,JF\,R_{eH}}}\right) \quad (1)$$

where

F = 0,77 for water capacities 0,5 l to 150 l;

F = 0,72 for water capacities 151 l to 250 l;

F = 0,68 for water capacities 251 l to 500 l;

and for longitudinal welds:

J = 1.0 for completely radiographed seams;

J = 0,9 for spot-radiographed seams;

J = 0,7 for seams that are not radiographed (carbon steels only);

J = 1,0 for cylinders without a longitudinal weld.

In no case shall the actual thickness be less than that specified in 7.3.

7.2 Design of ends concave to pressure

7.2.1 Unless otherwise specified in 7.4, the shape of ends of gas cylinders shall be such that:

a) for torispherical ends $R \leqslant D$; $r \geqslant 0{,}1\ D$; $h \geqslant 4b$ [see Figure 1 a)];

b) for semi-ellipsoidal ends $H \geqslant 0{,}192\ D$; $h \geqslant 4b$ [see Figure 1 b)].

7.2.2 The head thickness of all other end shapes shall be not less than that calculated using Equation (2).

$$b = a_1 C \tag{2}$$

where

a_1 is the value of a calculated in accordance with 7.1.1 using $J = 1{,}0$;

C is a shape factor, the value of which depends on the ratio H/D.

The value of C shall be obtained from the graph shown in Figure 2 or 3, as applicable.