

INTERNATIONAL
STANDARD

ISO
4706

Third edition

**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*

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Contents

	Page
Foreword.....	v
Introduction.....	vi
1 Scope.....	1
2 Normative references.....	1
3 Terms, definitions and symbols.....	2
3.1 Terms and definitions.....	2
3.2 Symbols.....	3
4 Inspection and testing.....	4
5 Materials.....	4
5.1 General.....	4
5.2 Chemical composition.....	5
6 Design.....	5
6.1 General requirements.....	5
6.2 Valve protection.....	6
6.3 Design of openings.....	6
7 Calculation of minimum wall thickness (sidewall and ends).....	6
7.1 Sidewall thickness.....	6
7.2 Design of ends concave to pressure.....	7
8 Construction and workmanship.....	10
8.1 Welding qualification.....	10
8.1.1 General.....	10
8.1.2 Base materials (pressure and non-pressure).....	11
8.1.3 Positions of welds.....	11
8.1.4 Welding materials.....	11
8.1.5 Retesting.....	11
8.1.6 Period of effectiveness.....	11
8.1.7 Changes to welding process requiring recertification.....	11
8.1.8 Welder qualification tests.....	12
8.1.9 Results of welder qualification.....	12
8.2 Plates and pressed parts.....	12
8.3 Welded joints.....	12
8.4 Tolerances.....	14
8.4.1 Out of roundness.....	14
8.4.2 Straightness.....	14
8.4.3 Verticality.....	15
8.5 Non-pressure-containing attachments.....	15
8.6 Valve protection.....	15
8.7 Closure of openings.....	15
8.8 Heat treatment.....	15
9 Testing.....	16
9.1 Mechanical testing.....	16
9.1.1 General requirements.....	16
9.1.2 Types of test and evaluation of test results.....	16
9.2 Burst test under hydraulic pressure.....	20
9.2.1 Test conditions.....	20
9.2.2 Interpretation of test.....	20
9.2.3 Volumetric expansion.....	20
9.3 Pressure test.....	21
9.4 Radiographic and macro examination.....	21
9.4.1 Radiographic examination.....	21
9.4.2 Macro examination.....	22

9.4.3	Examination of flange welding.....	22
9.4.4	Examination of welding of non-pressure containing attachments.....	22
9.4.5	Unacceptable imperfections at radiographic or macro examination.....	22
9.5	Visual examination of the surface of the weld.....	22
10	Acceptance criteria.....	23
11	Type approval.....	24
12	Batch tests.....	25
12.1	Inspection lots.....	25
12.2	Rate of sampling.....	25
12.3	Quantity ≤ 3 000 cylinders water capacity less than or equal to 35 l.....	26
12.4	Quantity over 3 001 cylinders water capacity greater than 35 l.....	26
12.5	Failure to meet batch test requirements.....	26
13	Test/examinations for all pressure cylinders.....	27
14	Markings.....	27
15	Certificate.....	27
Annex A (informative) New design type approval certificate.....		28
Annex B (informative) Acceptance certificate.....		30
Bibliography.....		32

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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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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 third edition cancels and replaces the second edition (ISO 4706:2008), which has been technically revised.

The main changes are as follows:

- references have been updated;
- x-ray is required on three-piece designs;
- x-ray frequency has been changed from 50 to 250;
- criteria for x-ray retesting requirements have been added.

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

The purpose of this document 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.

This document 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.10/1 Rev. 22.^[1]

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

1 Scope

This document specifies the minimum requirements concerning material selection, design, construction and workmanship, procedure, and test at manufacture of refillable welded-steel gas cylinders of water capacities from 0,5 l up to and including 150 l and drums of water capacities of 150 l to 500 l of a test pressure not greater than 60 bar¹⁾, exposed to extreme worldwide temperatures (–50 °C to +65 °C) used for compressed, liquefied or dissolved gases.

NOTE Unless specified in the text, for the purpose of this document, the word “cylinder” includes “pressure drums”.

This document is primarily intended to be used for industrial gases other than liquefied petroleum gas (LPG), and is also applicable to LPG.

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

ISO 7438, *Metallic materials — Bend test*

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

ISO 10286, *Gas cylinders — Vocabulary*

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

ISO 11363-1, *Gas cylinders — 17E and 25E taper threads for connection of valves to gas cylinders — Part 1: Specifications*

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*

ISO 14732, *Welding personnel — Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials*

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

ISO 17636-2, *Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors*

1) 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1 N/mm².

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 in ISO 10286 and the following apply.

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

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

— IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

yield strength

value corresponding to the upper yield strength, R_{eg} , 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 to entry: In this context, “consecutively” need not apply to continuous production (start to finish).

Note 2 to entry: See 12.1 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 (*F*)**

design stress factor

3.1.9**parent material**

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

3.1.11**embossed**

carve, mould or stamp a design on a surface or object so that it stands out in relief

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	minimum elongation after fracture	%
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_p	mandrel diameter	mm
e	thickness of metal which is offset (see Figure 4)	mm
e_1	thickness of metal which is not offset (see Figure 4)	mm
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 6892-1	mm
n	ratio of diameter of bend test former to the thickness of the test piece	—
N	normalized cylinder	—
P_b	highest pressure reached in the cylinder during the burst test (see ISO 10286)	bar
P_h	actual test pressure applied to the cylinder by the manufacturer	bar
r	inside knuckle radius of the end	mm

R	inside dishing radius of the end	mm
R_e	actual value of yield strength determined by tensile test specified in 9.1.2.2.1.2	MPa
R_{eg}	minimum value of yield strength guaranteed by the cylinder manufacturer for the finished cylinder	MPa
R_m	actual value of tensile strength determined by the tensile test specified in 9.1.2.2.1.2	MPa
R_{mg}	minimum value of tensile strength guaranteed by the cylinder manufacturer for the finished cylinder	MPa
$R_{p0,2}$	0,2 % proof strength (see ISO 6892-1)	MPa
S_0	original cross-sectional area of tensile test piece in accordance with ISO 6892-1	mm ²

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 7, 8, 9](#) and [10](#).

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

5 Materials

5.1 General

5.1.1 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.

5.1.2 Materials for shells and end pressings, excluding bosses (see [5.1.3](#)), shall conform to the requirements of [5.1.8](#) and [5.2.1](#).

5.1.3 Bosses shall be manufactured from compatible weldable materials with a maximum carbon content of mass fraction of 0,25 %.

5.1.4 All items welded to the cylinder (e.g. shrouds and footrings) shall be made of compatible weldable material containing the maximum values in % (mass fraction) given in [Table 3](#).

5.1.5 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.

5.1.6 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).

5.1.7 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.

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

5.2 Chemical composition

5.2.1 Materials used for the fabrication of gas cylinders shells and end pressings shall be of weldable quality and contain the values in % (mass fraction) given in [Table 1](#).

Table 1 — Cylinder shell and ends chemistry allowable limits

Element	Maximum content % (mass fraction)
Carbon	0,250
Silicon	0,450
Manganese	1,600
Phosphorus	0,040
Sulfur	0,040

The use of micro-alloying elements such as niobium, titanium and vanadium shall not exceed the values given in [Table 2](#).

Table 2 — Micro alloying chemistry allowable limits

Element	Maximum content % (mass fraction)
Niobium	0,05
Titanium	0,03
Vanadium	0,10
Niobium plus Vanadium	0,12

Table 3 — Attachments welded to the cylinder chemistry allowable limits

Element	Maximum content % (mass fraction)
Carbon	0,250
Phosphorus	0,040
Sulfur	0,040

Where other micro-alloying elements are used, their presence and amounts shall be reported, together with those already described in [5.2.1](#), in the steel manufacturer's certificate.

5.2.2 In any check analysis, the maximum permissible deviation from the limits specified for the cast analyses shall conform to the values in [5.2.1](#).

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_{eg} , is limited to a maximum value of:

- a) $0,75 R_{mg}$ for finished cylinders with a guaranteed tensile strength (R_{mg}) < 490 MPa;
- b) $0,85 R_{mg}$ for finished cylinders with a guaranteed tensile strength (R_{mg}) \geq 490 MPa.

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_h .

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 8.6 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. Conformity shall be confirmed by calculation or performing a fatigue test in accordance with the requirements of 11.3.

6.3.3 The welds of the openings shall be separated from circumferential and longitudinal joints by a distance not less than $3a$.

6.3.4 Particular care shall be taken to ensure that neck threads are accurately cut, are of full form and are free from any sharp profiles, e.g. burrs (see ISO 11363-1).

6.3.5 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

The guaranteed minimum sidewall thickness of the cylindrical shell, a , shall not be less than the thickness calculated using [Formula \(1\)](#):

$$a = \frac{D}{2} \left(1 - \sqrt{\frac{10 J F R_{eg} - \sqrt{3} P h}{10 J F R_{eg}}} \right) \quad (1)$$

where

the value of F is the lesser of:

$$\frac{0,65}{R_{eg} / R_{mg}} \text{ or } 0,85$$

and for longitudinal welds:

- J 1,0 for completely radiographed seams;
- J 0,9 for spot-radiographed seams;
- J 1,0 for cylinders without a longitudinal weld.

The value of J shall be selected in accordance with [9.4](#).

[Formula \(1\)](#) is not applicable where the length of the cylindrical portion of the cylinder, measured between the beginning of the domed parts of the two ends, is not more than $\sqrt{2bD}$. In this case, the wall thickness shall be not less than that of the domed part (see [7.2.2](#)).

The sidewall thickness shall also satisfy the following:

- for $D \leq 100$ mm: $a = 1,1$ mm;
- for $D > 100$ and $D \leq 150$ mm: $a = 1,1 + 0,008(D - 100)$ mm;
- for $D > 150$ mm: $a = (D/250) + 0,7$ mm (with an absolute minimum of 2,0 mm);

For acetylene cylinders with $D > 300$ mm, the minimum wall thickness shall be 3,0 mm.

The burst pressure ratio shall be demonstrated as follows:

- $P_b \geq P_h \times 2$ and ≥ 50 bar.

7.2 Design of ends concave to pressure

7.2.1 Unless otherwise specified in [6.3](#), the shape of ends of gas cylinders shall be such that:

- a) for torispherical ends $R \leq D$; $r \geq 0,1 D$; $h \geq 4b$ [see [Figure 1 a](#)];
- b) for semi-ellipsoidal ends $H \geq 0,192 D$; $h \geq 4b$ [see [Figure 1 b](#)].

7.2.2 The head thickness of all other end shapes shall be not less than that calculated using [Formula \(2\)](#).

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

where

a_1 is the value of a calculated in accordance with [7.1](#) using $J = 1,0$;

C is a shape factor, the value of which depends on the ratio H/D , and shall be obtained from the graph shown in [Figure 2](#) or [Figure 3](#), as applicable.

7.2.3 Heads that do not contain markings may be 90 % of the minimum sidewall thickness as indicated in [7.1](#).

Ends shaped other than those specified in [7.2](#) may be used provided that the adequacy of their design is demonstrated by fatigue testing in accordance with the requirements of [11.3](#).