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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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Foreword

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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).

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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]

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 bar[1)], 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 = 10^5 Pa; 1 MPa = 1 N/mm^2.

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), $R_{po,2}$

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
$R_{po,2}$	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}) ≥ 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 3*a*.

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):

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