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Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing

Bouteilles à gaz — Bouteilles à gaz sans soudure en alliage d'aluminium destinées à être rechargées — 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.

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 7866 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, and by Technical Committee CEN/TC 23, *Transportable gas cylinders* in collaboration.

This second edition cancels and replaces the first edition (ISO 7866:1999), which has been technically revised.

The following significant technical changes have been carried out:

— a new subclause (11.7) has been added to address unacceptable manufacturing defects and unacceptable surface features at the time of manufacture and changes have been made to other subclauses to compliment the new subclause;

— terms and definitions and the symbols have been revised;

— terminology changes included: “stress” changed to “strength”;

— various editorial errors were corrected;

— equipment calibration requirements were added;

— defining "defect" as a feature caused by the manufacturing/manufacturer; and

— defining "imperfection" as damage or feature not caused by manufacturing/manufacturer.

Introduction

The purpose of this International Standard is to provide a specification for the design, manufacture, inspection and testing of a seamless aluminium alloy gas cylinder for worldwide usage. The objective is to balance design and economic efficiency against international acceptance and universal utility.

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

Following publication, this International Standard will be submitted for reference in the UN Recommendations on the Transport of Dangerous Goods – Model Regulations.

Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing

1 Scope

This International Standard specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes and tests at time of manufacture of refillable seamless aluminium alloy gas cylinders of water capacities up to and including 150 litres for compressed, liquefied and dissolved gases for worldwide use (normally up to +65 °C).

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 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

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

ISO 7438, *Metallic materials — Bend test*

ISO 7539-6:2011, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of pre-cracked specimens for tests under constant load or constant displacement*

ISO 10461, *Gas cylinders — Seamless aluminium-alloy gas cylinders — Periodic inspection and testing*

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

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

ISO 13769, *Gas cylinders — Stamp marking*

3 Terms and definitions

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

3.1
artificial ageing
heat treatment process in which the solute phase is precipitated to give an increased yield strength and tensile strength

3.2
bar·litres
product of the test pressure (in bars) and the water capacity (in litres)

3.3
batch
quantity of gas cylinders, plus gas cylinders for destructive testing, of the same nominal diameter, wall thickness, length and design, made successively from the same cast of aluminium alloy and subjected to the same heat treatment on the same equipment for the same duration of time

NOTE See Table G.1 for batch size requirements.

3.4
design stress factor (variable)
F
ratio of equivalent wall stress at test pressure, p_h, to the guaranteed minimum yield strength, R_{eg}

3.5
IAA
registration record of international alloy designations and chemical composition limits for wrought aluminium and wrought aluminium alloys as published by the Aluminum Association[1)]

NOTE Such aluminium alloys are designated by the prefix “AA”.

3.6
mass of a gas cylinder
combined mass of the gas cylinder and all permanently attached parts (e.g. foot ring, neck ring), but without the valve

NOTE Mass is expressed in kilograms.

3.7
quenching
controlled rapid cooling in a suitable medium to retain the solute phase in solid solution

3.8
solution heat treatment
thermal treatment which consists of heating products to a suitable temperature and holding them at that temperature long enough to allow constituents to enter into solid solution

3.9
stabilizing heat treatment
non-ageing heat treatment applied to 5 000-series aluminium alloys in order to minimize changes in mechanical properties and structure under service conditions

3.10
yield strength
value corresponding to the 0,2 % proof strength (0,2% non-proportional elongation), $R_{p0,2}$, for aluminium alloys

4 Symbols

a calculated minimum wall thickness, in millimetres, of the cylindrical shell (see Figure 1)

a′ guaranteed minimum wall thickness, in millimetres, of the cylindrical shell

A percentage elongation after fracture

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

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1) Aluminum Association Inc., 900, 19th Street N.W., Washington D.C., 20006-2168, USA.

d' positive circular development of fracture

d'' negative circular development of fracture

D nominal outside diameter, in millimetres, of the cylinder (see Figure 1 and Figure 2)

D_1 nominal outside diameter, in millimeters, of the cylinder neck (see Figure 2)".

D_f diameter, in millimetres, of the bend test former (see Figure 5)

E modulus of elasticity

F design stress factor (variable) (see 3.4)

H outside height, in millimetres, of the domed part (convex head or base end) (see Figure 1)

L' length of short branch of fracture, in millimeters

L'' length of long branch of fracture, in millimeters

L_o original gauge length, in millimetres, as defined in ISO 6892-1 (see Figure 4)

n ratio of the diameter of the bend test former to the actual thickness of the test specimen, t

p_b actual burst pressure, in bars above atmospheric pressure

p_f failure pressure, in bars

p_h hydraulic test pressure, in bars above atmospheric pressure

p_u upper cycling pressure, in bars

p_y observed pressure when gas cylinder starts yielding during hydraulic bursting test, in bars above atmospheric pressure

r inside knuckle radius, in millimetres (see Figure 1)

r_c tip radius, in millimeters

r_i inside crown radius, in millimetres (see Figure 1)

R maximum stress value, in MPa

R_{ea} actual value of the yield strength, in megapascals, as determined by the tensile test specified in 10.2 for the finished gas cylinder

R_{eg} minimum guaranteed value of the yield strength (see 3.10), in megapascals, for the finished gas cylinder

R_{ma} actual value of the tensile strength, in megapascals, as determined by the tensile test specified in 10.2 for the finished gas cylinder

R_{mg} minimum guaranteed value of the tensile strength, in megapascals, for the finished gas cylinder

$R_{p0,2}$ 0,2 % proof strength (0,2% non-proportional elongation), for aluminium alloys

S_o original cross-sectional area, in square millimetres, of the tensile test specimen in accordance with ISO 6892-1

t actual wall thickness, in millimetres, of the test specimen

t_m average cylinder wall thickness, in millimetres, in the position of testing during the flattening test

T titre of hydrogen peroxide in g per litre

u ratio of distance between knife edges at the end of test to the average cylinder wall thickness

w width, in millimetres, of the narrow, parallel-sided section of a tensile test specimen (see Figure 4)

z correction factor

5 Inspection and testing

NOTE Evaluation of conformity can be performed in accordance with the regulations recognized by the country(ies) where the gas cylinders are intended to be used.

To ensure that the gas cylinders conform to this International Standard, they shall be subjected to inspection and testing in accordance with Clauses 9, 10 and 11 by an inspection body, hereafter referred to as the “Inspection Body”, authorized to do so.

Equipment used for measurement, testing and examination during production shall be maintained and calibrated within a documented quality managment system.

6 Materials

6.1 General requirements

6.1.1 Aluminium alloys and their chemical composition limits shall be as specified in Table 1. Other aluminium alloys may be used to produce gas cylinders provided they satisfy all the requirements of this International Standard and are approved by the relevant authority for cylinder use.

6.1.2 The gas cylinder manufacturer shall identify the gas cylinders with the particular casts of the alloy from which they are made, and shall obtain and provide certificates of the analysis of the casts used. If check analysis is required, they shall be carried out either on test specimens taken from material in the form supplied by the producer of the aluminium alloy or from finished gas cylinders.

6.1.3 Some aluminium alloys are not compatible with certain gases and gas mixtures, e.g. corrosive gases (see ISO 11114-1). The manufacturer shall use materials compatible with the intended gas service when the purchaser indicates the intended gas.

Table 1 — Chemical composition of materials

Group	Type of alloy (IAA registered AA designation)		Chemical composition (% by mass)											Others		Al
			Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Zr	Pb	Each	Total	
1	6351A	min.	0,7	—	—	0,40	0,40	—	—	—	—	—	—	—	—	Remainder
		max.	1,3	0,50	0,10	0,8	0,8	—	—	0,20	0,20	—	0,003 0	0,05	0,15	
	6082A	min.	0,7	—	—	0,40	0,60	—	—	—	—	—	—	—	—	Remainder
		max.	1,3	0,50	0,10	1,0	1,2	0,25	—	0,20	0,10	—	0,003 0	0,05	0,15	
	6061A	min.	0,40	—	0,15	—	0,8	0,04	—	—	—	—	—	—	—	Remainder
		max.	0,8	0,7	0,40	0,15	1,2	0,35	—	0,25	0,15	—	0,003 0	0,05	0,15	
2	5283A	min.	—	—	—	0,50	4,5	—	—	—	—	—	—	—	—	Remainder
		max.	0,30	0,30	0,03	1,0	5,1	0,05	0,03	0,10	0,03	0,05	0,003 0	0,05	0,15	
3	7060	min.	—	—	1,8	—	1,3	0,15	—	6,1	—	—	—	—	—	Remainder
		max.	0,15	0,20	2,6	0,20	2,1	0,25	—	7,5	0,05	0,05	0,003 0	0,05	0,15	
	7032	min.	—	—	1,7	—	1,5	0,15	—	5,5	—	—	—	—	—	Remainder
		max.	0,10	0,12	2,3	0,05	2,5	0,25	0,05	6,5	0,1	0,05	0,003 0	0,05	0,15	
4	2001	min.	—	—	5,2	0,15	0,20	—	—	—	—	—	—	—	—	Remainder
		max.	0,20	0,20	6,0	0,50	0,45	0,10	0,05	0,10	0,20	0,05	0,003 0	0,05	0,15	

The bismuth content shall not exceed 0,0030 % (by mass).

NOTE The above materials are used extensively throughout the world in preference to the alloy compositions quoted in ISO 209. They are included in this International Standard quoting the IAA registered designations, but making reference to ISO 209 where it is considered applicable.

6.2 Thermal treatments

6.2.1 Heat-treatable alloys (see Table 1, groups 1, 3 and 4)

The manufacturer shall specify, in the type approval documentation, the solution heat treatment and artificial-ageing temperatures and the minimum times for which the gas cylinders have been held at those temperatures. The medium used for quenching after solution heat treatment shall be identified.

6.2.2 Non-heat-treatable alloys (see Table 1, group 2)

The manufacturer shall specify, in the type approval documentation, the type of metal-forming operation carried out (extrusion, drawing, ironing, head forming, etc.).

Unless the alloy is subjected to a temperature in excess of 400 °C during the forming process, a stabilizing heat treatment shall be carried out at a temperature above 220 °C, and the temperature and time at that temperature shall be identified by the manufacturer.

6.2.3 Control of specified heat treatment

During the heat treatment, the manufacturer shall comply with the following tolerances:

a) temperatures:

— solution temperature ±10 °C,

— artificial ageing temperature ±5 °C,

— stabilizing temperature ±10 °C;

b) time gas cylinders actually spend at this temperature during treatment:

— solution treatment ±30 %,

— ageing treatment ±20 %,

— stabilizing treatment ±10 %.

6.3 Test requirements

The material of the finished gas cylinders shall conform to Clauses 9, 10 and 11.

6.4 Failure to meet test requirements

6.4.1 In the event of failure to meet test requirements, retesting or reheat treatment and retesting shall be carried out as follows:

a) If there is evidence of a fault in carrying out a test, or an error of measurement, a second test shall be performed, on the same gas cylinder if possible. If the result of this test is satisfactory, the first test shall be ignored.

b) If the test has been carried out in a satisfactory manner and the failure is in a test representing the prototype or batch gas cylinders, the procedure detailed in either 6.4.2 or 6.4.3 shall be followed.

c) If the test has been carried out in a satisfactory manner and the failure is in a test applied to every gas cylinder, then only those gas cylinders which failed the test require retesting or reheat treatment and retesting, provided the cause of the failure is well identified. If the failure is due to the heat treatment applied, the failed gas cylinders shall be subjected to the procedure in 6.4.3. If the failure is due to a cause other than the heat treatment applied, all defective gas cylinders shall be rejected.

6.4.2 Two further gas cylinders selected at random from the same batch shall be subjected to the tests specified in 10.1.3 a) and 10.1.3 b). If both gas cylinders meet the specified requirements, the batch shall be accepted. Should either gas cylinder fail to meet the specified requirements, the batch shall

a) be rejected,

or

b) be treated in accordance with 6.4.3.

6.4.3 The batch of gas cylinders shall be reheat-treated and two further gas cylinders shall be tested in accordance with 10.1.3 a) and 10.1.3 b). If both gas cylinders meet the specified requirements, the batch shall be accepted. Should either gas cylinder fail to meet the specified requirements, the batch shall be rejected.

6.4.4 For heat-treatable alloys, where it can be established that the heat treatment was at fault for failure of a test, the batch of gas cylinders may additionally (more than once) be re-solution heat-treated and/or aged. However, the batch may only be submitted to the Inspection Body one more time for testing after the initial submission. If the batch presented to the Inspection Body for the second test or tests fails one or more tests, the batch shall be condemned.

7 Design

7.1 General requirements

7.1.1 The calculation of the wall thickness of the pressure-containing parts shall be related to the yield strength, R_{eg}, of the material.

7.1.2 For calculation purposes, the value of the yield strength, R_{eg}, is limited to a maximum of $0{,}90R_{mg}$ for seamless aluminium alloy gas cylinders.

7.1.3 The internal pressure upon which the calculation of wall thickness is based shall be the hydraulic test pressure, p_h.

7.1.4 Wherever any exposure to heat is necessary (e.g. for gas cylinders for dissolved acetylene, where the process by which the porous material is manufactured can modify the characteristics of the aluminium alloy used; see Annex H), this shall be considered when designing the shell.

7.2 Calculation of cylindrical shell thickness

The guaranteed minimum thickness of the cylindrical shell, a', shall not be less than the thickness calculated using relationships (1) and (2), and additionally condition (3) shall be satisfied:

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

where

the value of F is the lesser of $\frac{0{,}65}{R_{eg}/R_{mg}}$ and 0,85;

R_{eg}/R_{mg} shall not exceed 0,90.

The wall thickness shall also satisfy the relationship:

$$a \geq \frac{D}{100} + 1\ \text{mm} \quad (2)$$

with an absolute minimum of 1,5 mm.

The burst ratio shall be satisfied by test. The following condition shall be met:

$$p_b/p_h \geq 1{,}6 \quad (3)$$

When choosing the minimum guaranteed value of the thickness of the cylindrical shell, a', the manufacturer shall ensure that the thickness is sufficient to satisfy both the calculations and the required verification testing.

NOTE It is generally assumed that $p_h = 1{,}5 \times$ the service pressure for compressed gases for gas cylinders designed and manufactured to this International Standard.

7.3 Design of ends (heads and bases)

7.3.1 The thickness and shape of the base and head of the gas cylinders shall be such as to meet the requirements of the tests specified in 10.4 (hydraulic burst test) and 9.2.3 (pressure-cycling test).

To achieve satisfactory stress distribution, the gas cylinder wall thickness shall increase progressively in the transition zone between the cylindrical shell and the ends, particularly the base. Examples of typical shapes of convex heads and base ends are shown in Figure 1.

7.3.2 The thickness at any part of a convex end shall be not less than the minimum wall thickness of the cylindrical part.

7.3.3 The inside crown radius, r_i, shall be not greater than 1,2 × the inside diameter of the shell, and the knuckle radius, r, shall be not less than 10 % of the inside diameter of the shell.

7.3.4 Where the conditions of 7.3.3 are not fulfilled, the gas cylinder manufacturer shall prove by the prototype tests as required in 9.2 that the design is satisfactory.

7.4 Neck design

7.4.1 The external diameter and thickness of the formed neck end of the gas cylinder shall be adequate for the stresses resulting from the fitting of the valve to the gas cylinder. The stresses can vary according to the thread diameter, its form and the sealant used in fitting the valve. The requirements specified in ISO 13341 (or as recommended by the manufacturer where that International Standard does not apply) shall be applied, since permanent damage to the gas cylinder could otherwise result.

7.4.2 In establishing the minimum thickness, consideration shall be given to obtaining a thickness of the wall in the gas cylinder neck which will prevent permanent expansion of the neck during the initial and subsequent fittings of the valve into the gas cylinder.

In specific cases (e.g. very thin walled cylinders), where the stresses resulting from the initial and subsequent fittings of the valve to the gas cylinder cannot be supported by the neck itself, the neck may be designed to require reinforcement, such as a neck ring or shrunk-on collar, provided the reinforcement material and dimensions are clearly specified by the manufacturer and this configuration is part of the type approval procedure.

7.4.3 Gas cylinders may be designed with one or two openings but both shall be along the central gas cylinder axis.

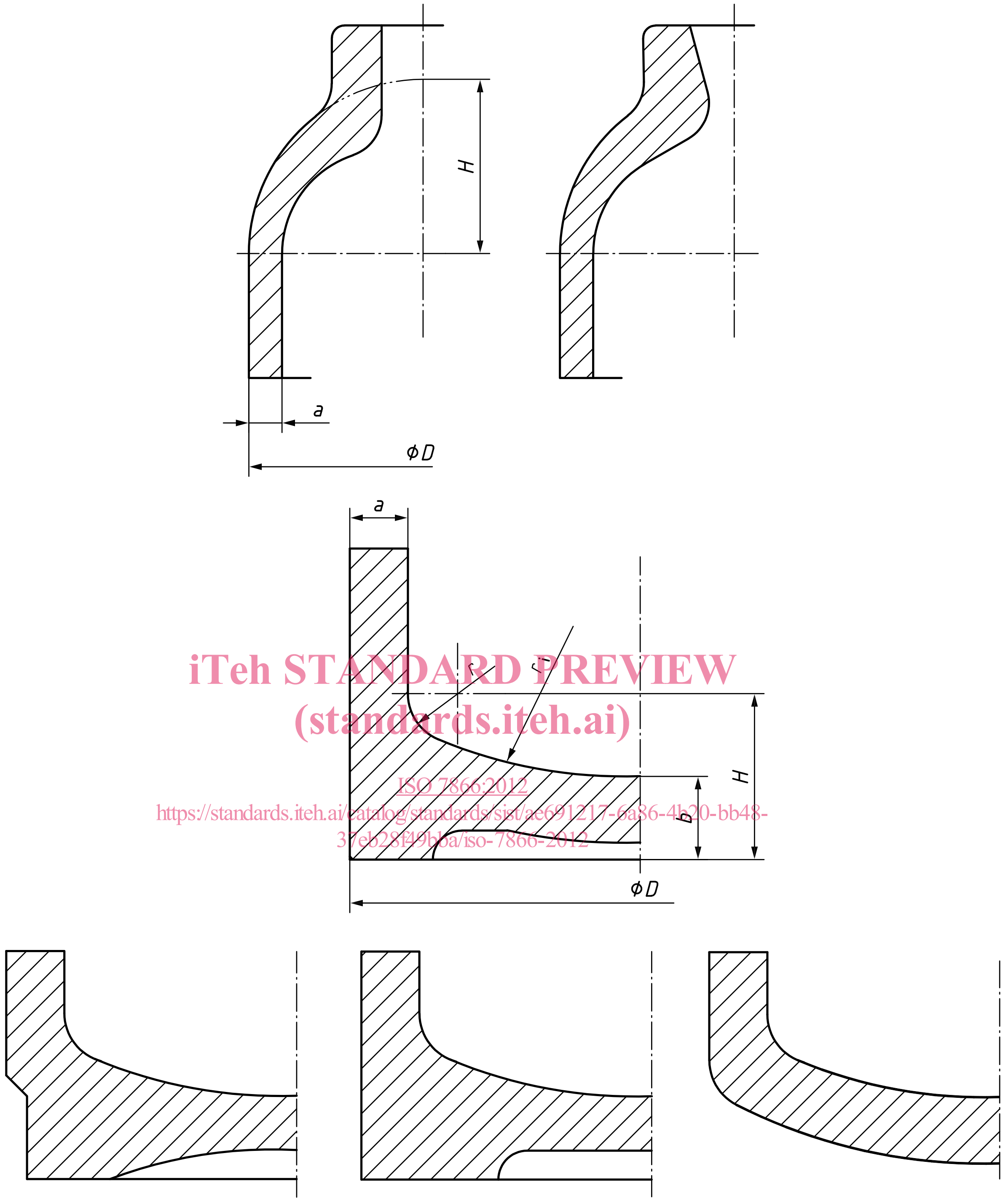

Figure 1 — Typical ends