INTERNATIONAL STANDARD

ISO 7866

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

Bouteilles à gaz — Bouteilles 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 3.

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.

International Standard ISO 7866 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

Annexes A and B form a normative part of this International Standard. Annexes C and D are for information only.

Introduction

The purpose of this International Standard is to provide a specification for the design, manufacture, inspection and testing of a seamless aluminium 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 practices of any nation or region.

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 manufacture of refillable seamless aluminium alloy gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied and dissolved gases for worldwide use (normally up to + 65 °C).

NOTE If so desired, cylinders of water capacity less than 0,5 l may be manufactured and certified to this International Standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 6506:1981[1)], *Metallic materials — Hardness test — Brinell test.*

ISO 6508:1986[2)], *Metallic materials — Hardness test — Rockwell test (scales A - B - C - D - E -F - G - H - K).*

ISO 6892:1998, *Metallic materials — Tensile testing at ambient temperature.*

ISO 7438:1985, *Metallic materials — Bend test.*

ISO 7539-6:1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of pre-cracked specimens.*

ISO 11114-1:1997, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials.*

ISO 13341:1997, *Transportable gas cylinders — Fitting of valves to gas cylinders.*

ISO 13769[3)], *Gas cylinders — Stamp marking.*

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1) To be withdrawn and replaced by ISO 6506-1, ISO 6506-2 and ISO 6506-3.

2) To be withdrawn and replaced by ISO 6508-1, ISO 6508-2 and ISO 6508-3.

3) To be published.

3 Terms and definitions

For the purpose of this International Standard the following terms and definitions apply.

3.1
yield stress
value corresponding to the 0,2 % proof stress (non-proportional elongation), $R_{p0,2}$

3.2
solution heat treatment
thermal treatment which consists of heating the products to a suitable temperature and holding at that temperature long enough to allow constituents to enter into solid solution

3.3
quenching
controlled rapid cooling in a suitable medium to retain the solute phase in solid solution

3.4
artificial ageing
heat treatment process in which the solute phase is precipitated to give an increased yield stress and tensile strength

3.5
batch
quantity of up to 200 cylinders, plus cylinders for destructive testing, of the same nominal diameter, thickness and design, made successively from the same cast of aluminium alloy and subjected to the same heat treatment for the same duration of time

NOTE The lengths of the cylinders in a batch may vary by up to 12 %.

3.6
design stress factor (F)(variable)
ratio of equivalent wall stress at test pressure (p_h) to the guaranteed minimum yield stress (R_e)

3.7
IAA
registration record of international alloy designations and chemical composition limits for wrought aluminium and wrought aluminium alloys as published by the Aluminum Association[4)]

4 Symbols

a	Calculated minimum thickness, in millimetres, of the cylindrical shell (see Figure 1)
a'	Guaranteed minimum thickness, in millimetres, of the cylindrical shell
A	Percentage elongation
b	Guaranteed minimum thickness, in millimetres, at the centre of a convex base (see Figure 1)
D	Nominal outside diameter, in millimetres, of the cylinder (see Figure 1)
D_f	Diameter, in millimetres, of former (see Figure 5)
E	Modulus of elasticity in MPa
F	Design stress factor (variable) (see 3.6)

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

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

L_o Original gauge length, in millimetres, as defined in ISO 6892 (see Figure 4)

n Ratio of the diameter of the bend test former to the actual thickness of the test piece (t)

p_b Actual burst pressure, in bar[5] above atmospheric pressure

p_h Hydraulic test pressure, in bar, above atmospheric pressure

p_y Observed pressure when cylinder starts yielding during hydraulic bursting test, in bar, above atmospheric pressure

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

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

R_e Minimum guaranteed value of yield stress (see 3.1), in MPa

R_{ea} Actual value of the yield stress, in MPa, as determined by the tensile test specified in 10.2

R_g Minimum guaranteed value of tensile strength, in MPa

R_m Actual value of the tensile strength, in MPa, as determined by the tensile test specified in 10.2

S_o Original cross-sectional area of tensile test piece, in square millimetres, in accordance with ISO 6892

t Actual thickness of the test specimen, in millimetres

t_m Average cylinder wall thickness, in millimetres, at the position of test (see Table 2)

u Ratio of the distance between knife edges to the average cylinder wall thickness t_m at the position of test

w Width, in millimetres, of the tensile test piece (see Figure 4)

5 Inspection and testing

Evaluation of conformity is required to be performed in accordance with the relevant regulations of the country(ies) where the cylinders are used.

In order to ensure that the cylinders are in compliance with this International Standard they shall be subject to inspection and testing in accordance with clauses 9, 10 and 11 by an authorized inspection body (hereafter referred to as "the inspector") recognized in the countries of use. The inspector shall be competent for inspection of cylinders.

6 Materials

6.1 General requirements

6.1.1 The chemical composition limits for alloys for the fabrication of gas cylinders shall be as specified in Table 1.

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

Table 1 — Chemical composition of materials

Group	Type of alloy (IAA registered designation)	Marking code reference		Chemical composition (% m/m)														Remarks
				Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Zr	Pb	Others		Al	
															Each	Total		
1	6351A	A	min.	0,70	—	—	0,40	0,4	—	—	—	—	—	—	—	—	Remainder	Special precautions shall be taken for this alloy to prevent coarse grain structure in the neck of the cylinder
			max.	1,30	0,5	0,10	0,80	0,8	—	—	0,20	0,20	—	0,003	0,05	0,15		
	6082A	B	min.	0,70	—	—	0,40	0,6	—	—	—	—	—	—	—	—	Remainder	Special precautions shall be taken for this alloy to prevent coarse grain structure in the neck of the cylinder
			max.	1,30	0,5	0,10	1,00	1,2	0,25	—	0,20	0,10	—	0,003	0,05	0,15		
	6061A	C	min.	0,40	—	0,15	—	0,8	0,04	—	—	—	—	—	—	—	Remainder	
			max.	0,80	0,7	0,40	0,15	1,2	0,35	—	0,25	0,15	—	0,003	0,05	0,15		
2	5283A	D	min.	—	—	—	0,50	4,5	—	—	—	—	—	—	—	—	Remainder	
			max.	0,30	0,3	0,03	1,00	5,1	0,05	0,03	0,10	0,03	0,05	0,003	0,05	0,15		
3	7060	G	min.	—	—	1,80	—	1,3	0,15	—	6,10	—	—	—	—	—	Remainder	
			max.	0,15	0,2	2,60	0,20	2,1	0,25	—	7,50	0,05	0,05	0,003	0,05	0,15		

NOTE 1 The above materials are used extensively throughout the world in preference to the alloy compositions quoted in ISO 209-1. They are included in this standard quoting the IAA registered designations, but making reference to ISO 209-1 where it is considered applicable.

NOTE 2 When contamination is suspected, e.g. because of melting non-virgin material, the bismuth content shall be shown to not exceed 0,03 % (m/m).

NOTE Other aluminium alloy(s) may be used to produce gas cylinders provided that they satisfy the requirements of the corrosion resistance tests defined in annex A, meet all other requirements of this International Standard and are approved by the relevant statutory authorities of the countries in which the cylinders are to be used. Such new alloys may be used provided they have been used for the manufacture of either at least 20 000 cylinders in satisfactory service for two years, or at least 5 000 cylinders manufactured from not less than ten casts of aluminium and in satisfactory service for two years. Evidence of this satisfactory service is to be submitted to ISO for discussion by the appropriate Technical Committee. Once accepted by this committee, the new alloy will be added to Table 1 and the standard revised or amended. At this stage, cylinders manufactured from this alloy may be marked in accordance with this International Standard. Satisfactory service is defined as having no failures in service.

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

6.1.3 Grades of aluminium alloy used for cylinder manufacture shall be compatible with the intended gas service, e.g. corrosive gases, embrittling gases (see ISO 11114-1).

6.2 Thermal treatments

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

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

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

The manufacturer shall specify on 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 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 specified temperature for the solution, artificial ageing and stabilizing treatments within a range of 20 °C.

6.3 Testing requirements

The material of the finished cylinders shall satisfy the requirements of 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 re-heat 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 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 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 cylinder then only those cylinders which fail the test require retesting or re-heat treatment and retesting. If the failure is due to the heat treatment applied, then the failed cylinders shall be subject to the procedure in 6.4.3. If the failure is due to a cause other than the heat treatment applied, all defective cylinders shall be rejected.

6.4.2 Two further cylinders selected at random from the same batch shall be subjected to the tests specified in 10.1.2.a) and 10.1.2.b). If both cylinders meet the specified requirements, the batch shall be accepted. Should either 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 cylinders shall be reheat treated and two further cylinders shall be tested in accordance with 10.1.2.a) and 10.1.2.b). If both cylinders meet the specified requirements, the batch shall be accepted. Should either cylinder fail to meet the specified requirements, the batch shall be rejected.

6.4.4 Where it can be established that the heat treatment was at fault, the cylinders may be re-solution treated and artificially aged, or alternatively additional time at the ageing treatment temperature may be given. Cylinders that have been subject to re-heat treatment may only be presented to the inspector once more for testing.

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 stress (R_e) of the material.

7.1.2 For calculation purposes, the value of the yield stress (R_e) is limited to a maximum of 0,90 R_g for aluminium alloys.

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

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 equations (1) and (2), and additionally condition (3) shall be satisfied:

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

Where the value of F is the lesser of $\frac{0{,}65}{R_e / R_g}$ or 0,85

R_e/R_g shall not exceed 0,90.

NOTE Regional international agreements may limit the magnitude of the 'F' factor used for design.

The wall thickness shall also satisfy the formula

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

with an absolute minimum of 1,5 mm

The burst ratio shall be satisfied by test

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

NOTE It is generally assumed that p_h = 1,5 × service pressure for permanent gases for cylinders designed and manufactured to this Internatioinal Standard.

7.3 Design of convex ends (heads and bases)

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

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

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

The base shall have a hemispherical, torispherical or semi-ellipsoidal profile.

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

Where these conditions are not fulfilled, the cylinder manufacturer shall prove by the prototype tests as required in 9.1 that the design is satisfactory.

7.4 Neck design

7.4.1 The external diameter and thickness of the formed neck end of the cylinder shall be adequate for the torque applied in fitting the valve to the cylinder. The torque may vary according to the diameter of thread, the form and the sealant used in fitting the valve. The torques specified in ISO 13341 shall not be exceeded, since this would result in permanent damage to the cylinder.

7.4.2 In establishing the minimum thickness, consideration shall be given to obtaining a thickness of the wall in the cylinder neck that will prevent permanent expansion of the neck during the initial and subsequent fittings of the valve into the cylinder without support of an attachment, such as a neck ring.

7.5 Foot-rings

When a foot-ring is provided, it shall be sufficiently strong and made of material compatible with that of the cylinder. The shape should preferably be cylindrical and shall give the cylinder sufficient stability. The foot-ring shall be secured to the cylinder by a method other than welding, brazing or soldering. in order to prevent ingress of water, any gaps which may form water traps shall be sealed by a method other than welding or brazing.

7.6 Neck-rings

When a neck-ring is provided, it shall be sufficiently strong and made of material compatible with that of the cylinder, and shall be securely attached by a method other than welding, brazing or soldering.

The manufacturer shall ensure that the axial load to remove the neck-ring is greater than 10 × the weight of the empty cylinder and that the minimum torque to rotate the neck ring is 100 Nm.

7.7 Design

A fully dimensioned drawing shall be prepared which includes the specification of the material and makes reference to this International Standard.

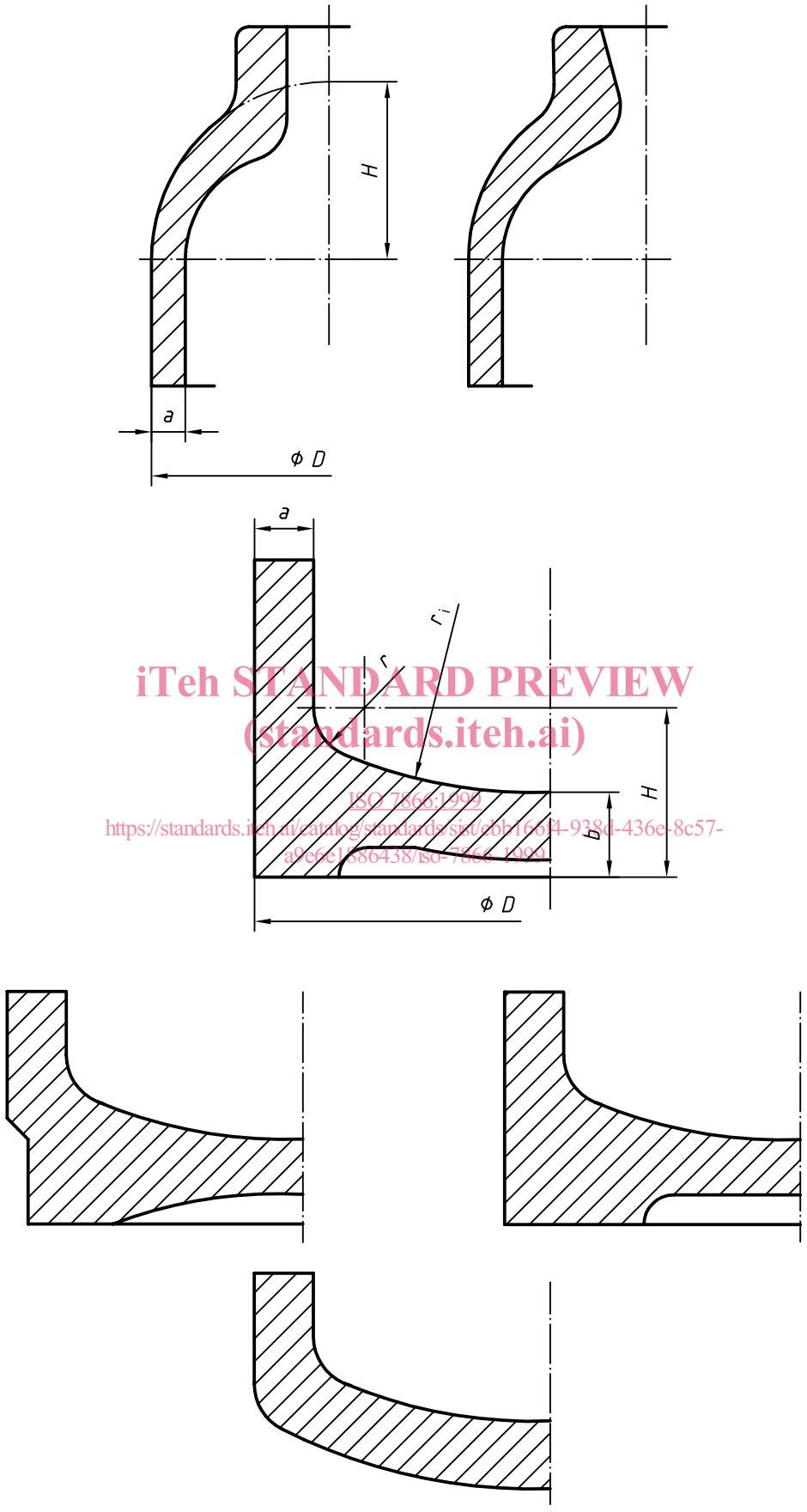

Figure 1 — Typical convex ends

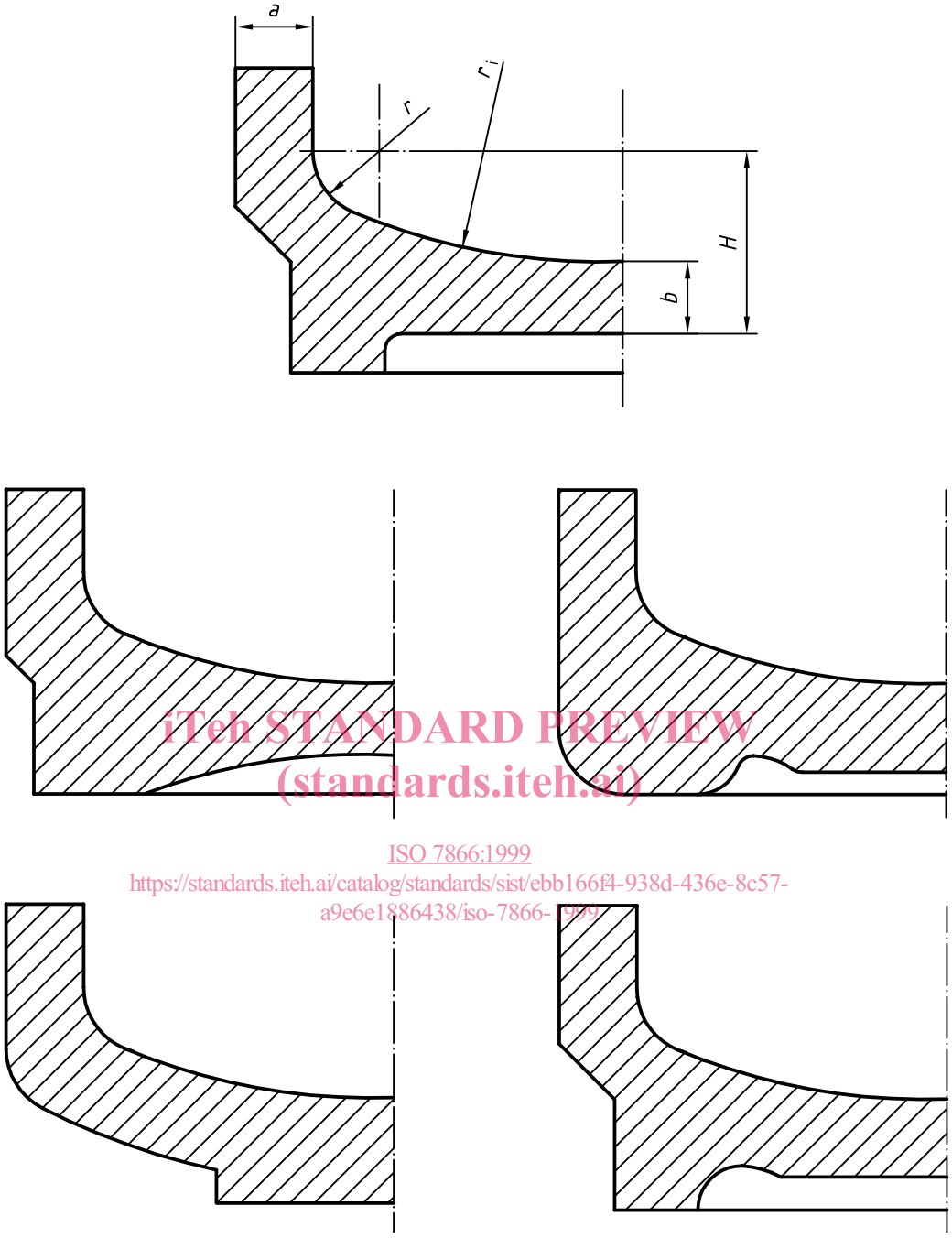

Figure 1 — Typical convex ends (concluded)