INTERNATIONAL STANDARD

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Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing —

Part 1:
Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa

Bouteilles à gaz — Bouteilles à gaz rechargeables en acier sans soudure — Conception, construction et essais —

Partie 1: Bouteilles en acier trempé et revenu ayant une résistance à la traction inférieure à 1 100 MPa

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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 9809-1 was prepared by Technical Committee ISO/TC58, *Gas cylinders,* Subcommittee SC 3, *Cylinder design*.

ISO 9809 consists of the following parts, under the general title *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing*:

— *Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa*

— *Part 2: Quenched and tempered steel cylinders with tensile strength greater than or equal to 1 100 MPa*

— *Part 3: Normalized steel cylinders*

Annex B forms an integral part of this part of ISO 9809. Annexes A, C and D are for information only.

Introduction

The purpose of ISO 9809 is to provide a specification for the design, manufacture, inspection and testing of a seamless steel cylinder for worldwide usage. The objective is to balance design and economic efficiency against international acceptance and universal utility.

ISO 9809 aims to eliminate the concern about climate, duplicate inspections and restrictions currently existing because of lack of definitive International Standards and should not be construed as reflecting on the suitability of the practice of any nation or region.

Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing —

Part 1:
Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa

1 Scope

This part of ISO 9809 specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes and tests at manufacture of refillable quenched and tempered seamless steel gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied and dissolved gases exposed to extreme world-wide ambient temperatures (normally between − 50 °C and + 65 °C). This part of ISO 9809 is applicable to cylinders with a maximum tensile strength R_m of less than 1 100 MPa.

NOTE 1 If so desired, cylinders of water capacity less than 0,5 l may be manufactured and certified to this part of ISO 9809.

NOTE 2 For quenched and tempered cylinders with maximum tensile strength greater than or equal to 1 100 MPa refer to ISO 9809-2. For normalized steel cylinders refer to ISO 9809-3.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 9809. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 9809 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 148:1983[1)], *Steel — Charpy impact test (V-notch).*

ISO 2604-2:1975, *Steel products for pressure purposes — Quality requirements — Part 2: Wrought seamless tubes.*

ISO 6506:1981[2)], *Metallic materials — Hardness test — Brinell test.*

ISO 6508:1986[3)], *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 9712:1999, *Non-destructive testing — Qualification and certification of personnel.*

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1) To be withdrawn and replaced by ISO 148-1, ISO 148-2 and ISO 148-3.

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

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

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

ISO 13769:—[4], *Gas cylinders — Stamp marking.*

3 Terms and definitions

For the purposes of this part of ISO 9809 the following definitions apply.

3.1
yield stress
value corresponding to the upper yield stress, R_{eH} or, for steels that do not exhibit a defined yield, the 0,2 % proof stress (non-proportional elongation), $R_{p0,2}$ (see ISO 6892)

3.2
quenching
hardening heat treatment in which a cylinder, which has been heated to a uniform temperature above the upper critical point, Ac_3, of the steel, is cooled rapidly in a suitable medium

3.3
tempering
softening heat treatment which follows quenching, in which the cylinder is heated to a uniform temperature below the lower critical point, Ac_1,of the steel

3.4
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 steel 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 ± 12 %.

3.5
test pressure (p_h)
pressure required applied during a pressure test.

NOTE It is used for cylinder wall thickness calculation.

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

4 Symbols

a Calculated minimum thickness, in millimetres, of the cylindrical shell.

a' Guaranteed minimum thickness, in millimetres, of the cylindrical shell.

a_1 Guaranteed minimum thickness, in millimetres, of a concave base at the knuckle (see Figure 2).

a_2 Guaranteed minimum thickness, in millimetres, at the centre of a concave base (see Figure 2).

A Percentage elongation.

[4] To be published.

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

c Maximum permissible deviation of burst profile, in millimetres (see Figures 10 and 11).

D Nominal outside diameter of the cylinder, in millimetres (see Figure 1).

D_f Diameter, in millimetres, of former (see Figure 6).

F Design stress factor (variable) (see 3.6).

h Outside depth (concave base end), in millimetres (see Figure 2).

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

L_o Original gauge length, in millimetres, of tensile test piece as defined in ISO 6892 (see Figure 5).

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

p_b Measured burst pressure, in bar[5)], above atmospheric pressure.

p_h Hydraulic test pressure, in bar, above atmospheric pressure.

p_w Working 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 Figures 1 and 2).

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

R_{ea} Actual value of the yield stress, in MPa, determined by the tensile test (see 10.2.)

R_g Minimum guaranteed value of tensile strength, in MPa.

R_m Actual value of tensile strength, in MPa, as determined by the tensile test (see 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.

u Ratio of distance between knife edges or platens in the flattening test to average cylinder wall thickness at the position of test.

V Water capacity of cylinder, in litres.

w Width, in millimetres, of the tensile test piece (see Figure 5).

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 part of ISO 9809 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.

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

6 Materials

6.1 General requirements

6.1.1 Materials for the manufacture of gas cylinders intended for international service shall fall within one of the following categories.

a) internationally recognized cylinder steels;

b) nationally recognized cylinder steels;

c) new cylinder steels resulting from technical progress.

For all categories, the requirements of 6.2.1, 6.2.2 and relevant conditions of 6.2.3 shall be satisfied.

6.1.2 The material used for the fabrication of gas cylinders shall be steel, other than rimming quality, with non-ageing properties, and shall be aluminium and/or silicon killed.

In cases where examination of this non-ageing property is required by the customer, the criteria by which it is to be specified shall be agreed with the customer and inserted in the order.

6.1.3 The cylinder manufacturer shall establish means to identify the cylinders with the cast of steel from which they are made.

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

6.2 Controls on chemical composition

6.2.1 The chemical composition of all steels shall be defined at least by:

— the carbon, manganese and silicon contents in all cases;

— the chromium, nickel and molybdenum contents or other alloying elements intentionally added to the steel;

— the maximum sulfur and phosphorus contents in all cases.

The carbon, manganese and silicon contents and, where appropriate, the chromium, nickel and molybdenum contents shall be given, with tolerances, such that the differences between the maximum and minimum values of the cast do not exceed the values shown in Table 1.

The combined content of the following elements: Vanadium, Niobium, Titanium, Boron and Zirconium, shall not exceed 0,15 %.

The actual content of any element deliberately added shall be reported and their maximum content shall be representative of good steelmaking practice.

Table 1 — Chemical composition tolerances

Element	Maximum content %	Permissible range %
Carbon	$<$ 0,30 $\geqslant$ 0,30	0,06 0,07
Manganese	All values	0,30
Silicon	All values	0,30
Chromium	$<$ 1,50 $\geqslant$ 1,50	0,30 0,50
Nickel	All values	0,40
Molybdenum	All values	0,15

6.2.2 Sulfur and phosphorus in the cast analysis of material used for the manufacture of gas cylinders shall not exceed the values shown in Table 2.

Table 2 — Maximum sulfur and phosphorus limits

	R_m < 950 MPa	950 ≤ R_m < 1 100
Sulfur	0,020 %	0,010 %
Phosphorus	0,020 %	0,020 %
Sulfur + phosphorus	0,030 %	0,025 %

6.2.3 The cylinder manufacturer shall obtain and provide certificates of cast (heat) analyses of the steels supplied for the construction of gas cylinders.

Should check analyses be required, they shall be carried out either on specimens taken during manufacture from the material in the form as supplied by the steelmaker to the cylinder manufacturer, or from finished cylinders. In any check analysis, the maximum permissible deviation from the limits specified for the cast analyses shall conform to the values specified in ISO 2604-2.

6.3 Typical steels

Two typical internationally recognized steel types which have provided safe performance over many years are:

a) chromium molybdenum steel (quenched and tempered);

b) carbon manganese steel (quenched and tempered).

The chemical compositions of these steels, subject to the controls specified in 6.2.1, are given in table 3.

Table 3 — Internationally recognized steel compositions

Element	Steel grade and conditions	
	CrMo (Q & T)	CMn (Q & T)
Carbon	0,25 to 0,38 %	0,38 max. %
Silicon	0,1 to 0,4 %	0,1 to 0,35 %
Manganese	0,4 to 1,0 %	1,35 to 1,75 %
Phosphorus	0,020 max. %	0,020 max. %
Sulfur	0,020 max. %	0,020 max. %
Chromium	0,8 to 1,2 %	
Molybdenum	0,15 to 0,40 %	

NOTE The actual range for each element shall be in accordance with 6.2.1 and 6.2.2, and good steel-making practice. In particular the limits specified in Table 2 take precedence over the ranges given in this table.

6.4 Heat treatment

6.4.1 The cylinder manufacturer shall certify the heat treatment process applied to the finished cylinders.

6.4.2 Quenching in media other than mineral oil is permissible provided that the method produces cylinders free of cracks.

If the average rate of cooling in the medium is greater than 80 % of that in water at 20 °C without additives, every production cylinder shall be subjected to a method of non-destructive testing to prove freedom from cracks.

6.4.3 The tempering process shall achieve the required mechanical properties.

The actual temperature to which a type of steel is subjected for a given tensile strength shall not deviate by more than 30 °C from the temperature specified by the cylinder manufacturer.

6.5 Testing requirements

The material of the finished cylinders shall satisfy the requirements of clauses 9, 10 and 11.

6.6 Failure to meet test requirements

In the event of failure to meet test requirements, re-testing or re-heat treatment and retesting shall be carried out as follows to the satisfaction of the inspector:

a) If there is evidence of a fault in carrying out a test, or an error of measurement, a further test shall be performed. 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, the cause of test failure shall be identified.

   1) If the failure is considered to be due to the heat treatment applied, the manufacturer may subject all the cylinders implicated by the failure to a further heat treatment i.e. if the failure is in a test representing the prototype or batch cylinders, test failure shall require re-heat treatment of all the represented cylinders prior to re-testing; however, if the failure occurs sporadically in a test applied to every cylinder, then only those cylinders which fail the test shall require re-heat treatment and re-testing.

   This re-heat treatment shall consist of re-tempering or re-quenching and tempering.

   Whenever cylinders are re-heat treated, the minimum guaranteed wall thickness shall be maintained.

   Only the relevant prototype or batch tests needed to prove the acceptability of the new batch shall be performed again. If one or more tests prove even partially unsatisfactory, all cylinders of the batch shall be rejected.

   2) If the failure is due to a cause other than the heat treatment applied, all defective cylinders shall be either rejected, or repaired by an approved method. Provided that the repaired cylinders pass the test(s) required for the repair, they shall be re-instated as part of the original batch.

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 guaranteed minimum yield stress (R_e) of the material.

7.1.2 For calculation purposes, the value of R_e shall not exceed 0,9 R_g.

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 Limitation on tensile strength

7.2.1 Where there is no risk of hydrogen embrittlement the maximum value of the tensile strength is limited by the ability of the steel to pass the requirements of clause 9 and clause 10, but in no case shall the actual maximum tensile strength R_m exceed 1 100 MPa for chrome-molybdenum steels or 1 030 MPa for carbon-manganese steels.

7.2.2 Where there is a risk of hydrogen embrittlement (see ISO 11114-1) the maximum value of the tensile strength as determined in 10.2 shall either be 880 MPa or, where the ratio R_{ea}:R_m does not exceed 0,9, shall be 950 MPa.

NOTE Test methods to optimize the strength levels of steels for hydrogen service are under consideration.

7.3 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.

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

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 0,9.

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

The wall thickness shall also satisfy the formula

$$a \geqslant \frac{D}{250} + 1 \quad (2)$$

with an absolute minimum of a = 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 in accordance with this part of ISO 9809.

7.4 Calculation of convex ends (heads and bases)

7.4.1 The thickness, b, at the centre of a convex end shall be not less than that required by the following criteria: where the inside knuckle radius, r, is not less than 0,075 D

$b \geqslant 1{,}5\,a$ for $0{,}40 > H/D \geqslant 0{,}20$

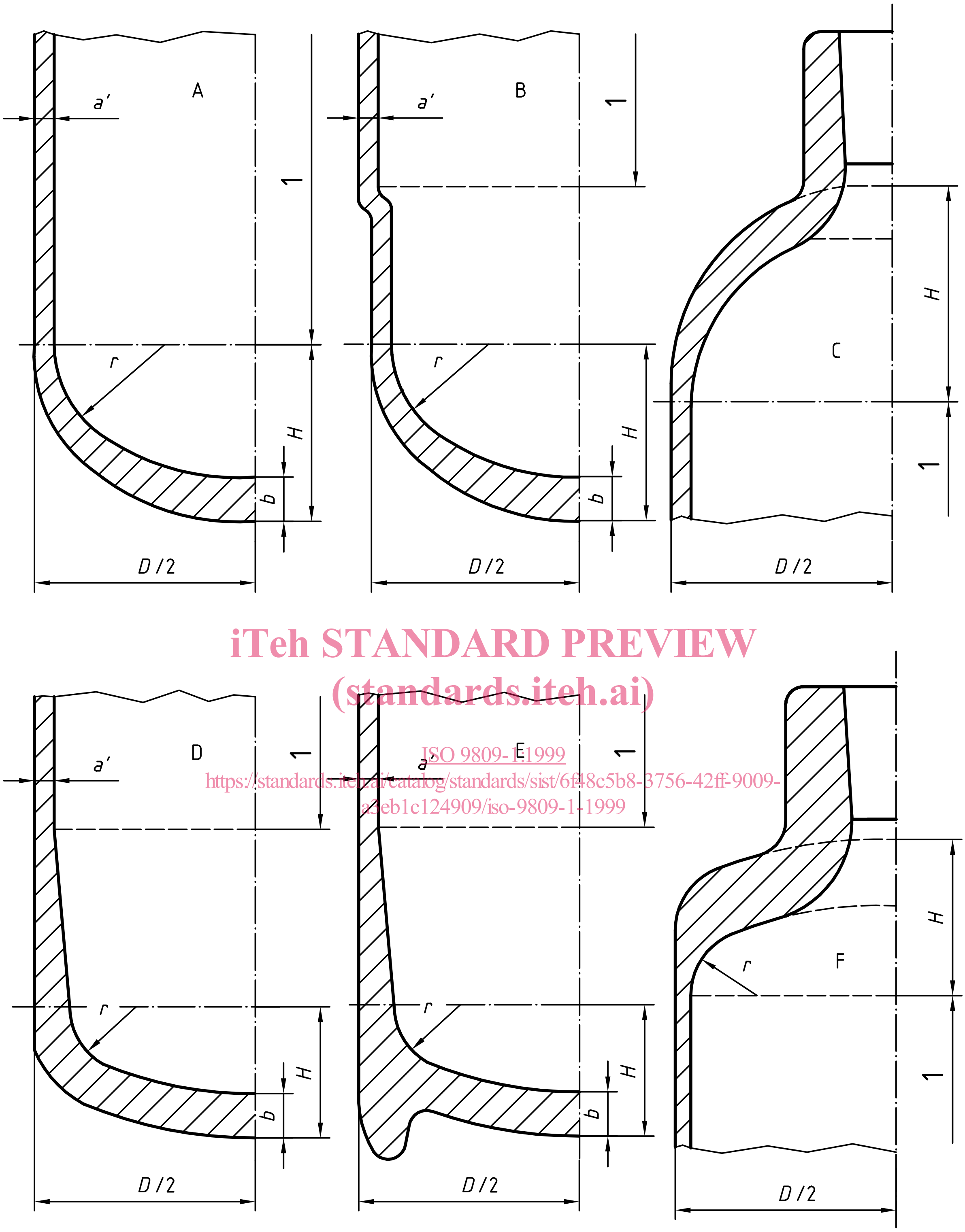
$b \geqslant a$ for $H/D \geqslant 0{,}40$

In order to obtain a satisfactory stress distribution in the region where the end joins the shell any thickening of the end that may be required shall be gradual from the point of juncture, particularly at the base. For the application of this rule the point of juncture between the shell and the end is defined by the horizontal line indicating dimension H in Figure 1.

Shape B shall not be excluded from this requirement.

7.4.2 The cylinder manufacturer shall prove by the pressure cycling test detailed in 9.2.3 that the design is satisfactory.

The shapes shown in Figure 1 are typical of convex heads and base ends. Shapes A, B, D and E are base ends and shapes C and F are heads.



Key

1 Cylindrical part

Figure 1 — Typical convex ends

7.5 Calculation of concave base ends

When concave base ends (see Figure 2) are used the following design values are recommended:

$a_1 \geqslant 2a$

$a_2 \geqslant 2a$

$h \geqslant 0{,}12\, D$

$r \geqslant 0{,}075\, D$

The design drawing shall at least show values for a_1, a_2, h and r.

In order to obtain a satisfactory stress distribution, the thickness of the cylinder shall increase progressively in the transition region between the cylindrical part and the base.

The cylinder manufacturer shall in any case prove by the pressure cycling test detailed in 9.2.3 that the design is satisfactory.

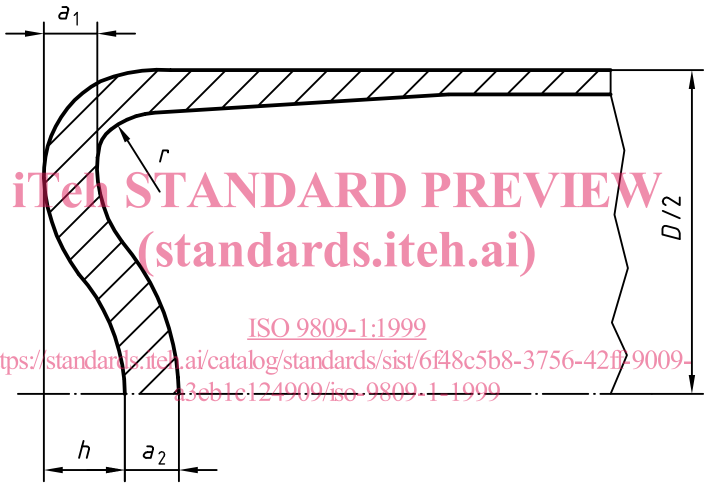


Figure 2 — Concave base ends

7.6 Neck design

7.6.1 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 of thread and the sealant used in the fitting of the valve. (For guidance on torques see ISO 13341).

7.6.2 In establishing the minimum thickness, consideration shall be given to obtaining a thickness of wall in the cylinder neck which 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.

7.7 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. Any gaps which may form water traps shall be sealed by a method other than welding, brazing or soldering.

7.8 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.