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

Part 4: Stainless steel cylinders with an Rm value of less than 1 100 MPa

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

Partie 4: Bouteilles en acier inoxydable avec une valeur Rm inférieure à 1 100 MPa

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Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
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Contents

Page

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO 9809-4:2014
https://standards.iteh.ai/catalog/standards/sist/1e91e984-d6bb-42f0-8a30-38586b34b42a/iso-9809-4-2014

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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 documents 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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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

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ISO 9809-4:2014

The committee responsible for this document is ISO/TC 58, *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*

— *Part 4: Stainless steel cylinders with tensile strength less than 1 100 MPa*

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Introduction

The purpose of ISO 9809 is to provide a specification for the design, manufacture, inspection, and testing of a seamless stainless steel cylinder for worldwide usage. The objective is to balance the 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 the 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.

This part of ISO 9809 has been prepared to address the general requirements on the design, construction, and initial inspection and test of pressure receptacles of the UN model regulations for the transportation of dangerous goods.[6]

It is intended to be used under a variety of regulatory regimes but has been written so that it is suitable for use with the conformity assessment system in paragraph 6.2.2.5 of the above mentioned model regulations.

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

Part 4: Stainless steel cylinders with an Rm value of less than 1 100 MPa

1 Scope

This part of ISO 9809 specifies the minimum requirements for the material, design, construction and workmanship, manufacturing processes, examinations, and tests at manufacture of refillable seamless stainless steel gas cylinders of water capacities from 0,5 l up to and including 150 l for compressed, liquefied, and dissolved gases. This part of ISO 9809 is applicable to cylinders with a maximum actual tensile strength, R_{ma}, of less than 1 100 MPa.

NOTE If so desired, cylinders of water capacity less than 0,5 l and between 150 l and 500 l can be manufactured to be in full compliance with this part of ISO 9809.

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2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 3651-2, *Determination of resistance to intergranular corrosion of stainless steels — Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels — Corrosion test in media containing sulfuric acid*

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

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method*

ISO 7438, *Metallic materials — Bend test*

ISO 9329-1, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 1: Unalloyed steels with specified room temperature properties*

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel*

ISO 13769, *Gas cylinders — Stamp marking*

3 Terms and definitions

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

3.1
yield strength
stress value corresponding to the 0,2 % proof stress or for austenitic steels in the solution-annealed condition, 1 % proof stress

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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
toughening 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
solution annealing
softening heat treatment for austenitic and duplex stainless steels in which a cylinder is heated to a uniform temperature above the upper critical point (Ac_3, as defined in ISO 10052) of the steel followed by rapid cooling

3.5
cryoforming
process where the cylinder is subjected to a controlled low-temperature deformation treatment that results in a permanent increase in strength

3.6
batch
quantity of up to 200 cylinders plus cylinders for destructive testing of the same nominal diameter, thickness, length, and design made successively on the same equipment, from the same cast of steel, and subjected to the same heat treatment for the same duration of time

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3.7
test pressure
p_h
required pressure applied during a pressure test

ISO 9809-4:2014
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Note 1 to entry: It is used for the cylinder wall thickness calculation.

3.8
burst pressure
p_b
highest pressure reached in a cylinder during a burst test

3.9
design stress factor
F
ratio of the equivalent wall stress at test pressure (p_h) to guaranteed minimum yield strength (R_{eg})

3.10
working pressure
settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full gas cylinder

4 Symbols

A percentage elongation after the fracture for a gauge length of L_o

a calculated minimum thickness of the cylindrical shell, in millimetres

a' guaranteed minimum thickness of the cylindrical shell, in millimetres

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

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

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

c_1 maximum permissible deviation of burst profile for quenched and tempered cylinders, in millimetres (see Figure 11)

c_2 maximum permissible deviation of the burst profile for cryoformed or solution-annealed cylinders with less than 7,5 mm wall thickness, in millimetres (see Figure 12)

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

D_f diameter of former, in millimetres (see Figure 6)

F design stress factor (variable) (see 3.7)

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

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

L_o original gauge length as defined in ISO 6892, in millimetres (see Figure 5)

l overall length of the cylinder, in millimetres (see Figure 3)

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

p_b measured burst pressure above the atmospheric pressure, in bar

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

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p_h hydraulic test pressure above the atmospheric pressure, in bar

p_y observed pressure when the cylinder starts yielding during the hydraulic burst test above the atmospheric pressure, in bar

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r inside knuckle radius, in millimetres (see Figures 1 and 2)

R_{ea} actual value of the yield strength as determined by the tensile test, in MPa (see 10.2)

R_{eg} minimum guaranteed value of the yield strength (see 7.1.1) for the finished cylinder, in MPa

R_{ma} actual value of the tensile strength as determined by the tensile test, in MPa (see 10.2)

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

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

t actual thickness of the test specimen, in millimetres

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

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

V water capacity of the cylinder, in litres

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

5 Inspection and testing

To ensure that the cylinders conform to this part of ISO 9809, they shall be subject to inspection and testing in accordance with Clauses 9, 10, and 11 by an inspection body (hereafter referred to as "the inspector") authorized to do so.

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

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

6 Materials

6.1 General requirements

6.1.1 Materials for the manufacture of gas cylinders 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 relevant conditions specified in 6.2 and 6.3 shall be satisfied.

6.1.2 There is a risk of sensitization to the intergranular corrosion resulting from the hot processing of austenitic and duplex stainless steels. Intergranular corrosion testing shall be carried out for such materials in accordance with 10.6.

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

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

ISO 9809-4:2014
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6.1.5 Some grades of stainless steel can be susceptible to environmental stress corrosion cracking. Special precautions shall be taken in such cases, such as appropriate coating.

6.1.6 Some grades of stainless steel can be susceptible to phase transformation at low temperatures resulting in a brittle alloy. Special precautions shall be taken in such cases, i.e. not using the cylinder below the minimum acceptable temperature.

6.2 Controls on chemical composition

6.2.1 The following are the four broad categories of stainless steels:

— ferritic;

— martensitic;

— austenitic;

— austenitic/ferritic (duplex).

Recognized steels are listed in ISO 15510. Other grades of stainless steel can also be used provided that they fulfil all the requirements of this part of ISO 9809.

6.2.2 The cylinder manufacturer shall obtain and make available 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 the specimens taken during the manufacture from the material in the form as supplied by the steel maker to the cylinder manufacturer,

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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 9329-1.

6.3 Heat treatment

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

6.3.2 The finished cylinders made from the ferritic or martensitic steel categories shall be quenched and tempered, except if they are cold worked (see 6.4).

6.3.3 For the ferritic and martensitic steels, the heat treatment process shall achieve the required mechanical properties.

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

6.4 Cold working or cryoforming

Cold working or cryoforming is used to enhance the finished mechanical properties in certain stainless steel materials.

For cylinders that are subjected to cold working or to the cryoforming process, all the heat treatment requirements refer to the cylinder preform operations. Cold worked or cryoformed cylinders shall not be subjected to any subsequent heat treatment.

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6.5 Failure to meet test requirements

ISO 9809-4:2014
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In the event of failure to meet the test requirements, retesting or reheat 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 can subject all the cylinders implicated by the failure to a further heat treatment, e.g. if the failure is in a test representing the prototype or batch cylinders. Test failure shall require reheat treatment of all the represented cylinders prior to retesting.

      Whenever the cylinders are reheat 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 the cylinders of the batch shall be rejected.

   2) If the failure is due to a cause other than the heat treatment applied, all the cylinders with imperfections shall be either rejected or repaired such that the repaired cylinders pass the test(s) required for the repair. They shall then be reinstated as part of the original batch.

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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 strength (R_{eg}) of the material in the finished cylinder.

7.1.2 Cylinders can be designed with one or two openings along the central cylinder axis only.

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 Formulae (1) and (2), and additionally, Formula (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 equal to 0,77.

The wall thickness shall also satisfy Formula (2).

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

with an absolute minimum of a = 1,5 mm.

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The burst ratio shall be satisfied by Formula (3).

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

NOTE It is generally assumed that p_h = 1,5 × the working pressure for compressed gases for the cylinders designed and manufactured to this part of ISO 9809.

7.3 Calculation of convex ends (heads and bases)

7.3.1 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, then

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

— $b \geq a$ for $H/D \geq 0{,}40$.

To obtain a satisfactory stress distribution in the region where the end joins the shell, any thickening of the end that can 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 lines indicating the dimension H in Figure 1.

Shape b) shall not be excluded from this requirement.

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7.3.2 The design shall be verified and considered satisfactory by the application of the pressure cycling test given in 9.2.2.

The shapes shown in Figure 1 are typical of the convex heads and base ends. Shapes a), b), d), and e) are base ends and shapes c) and f) are heads.

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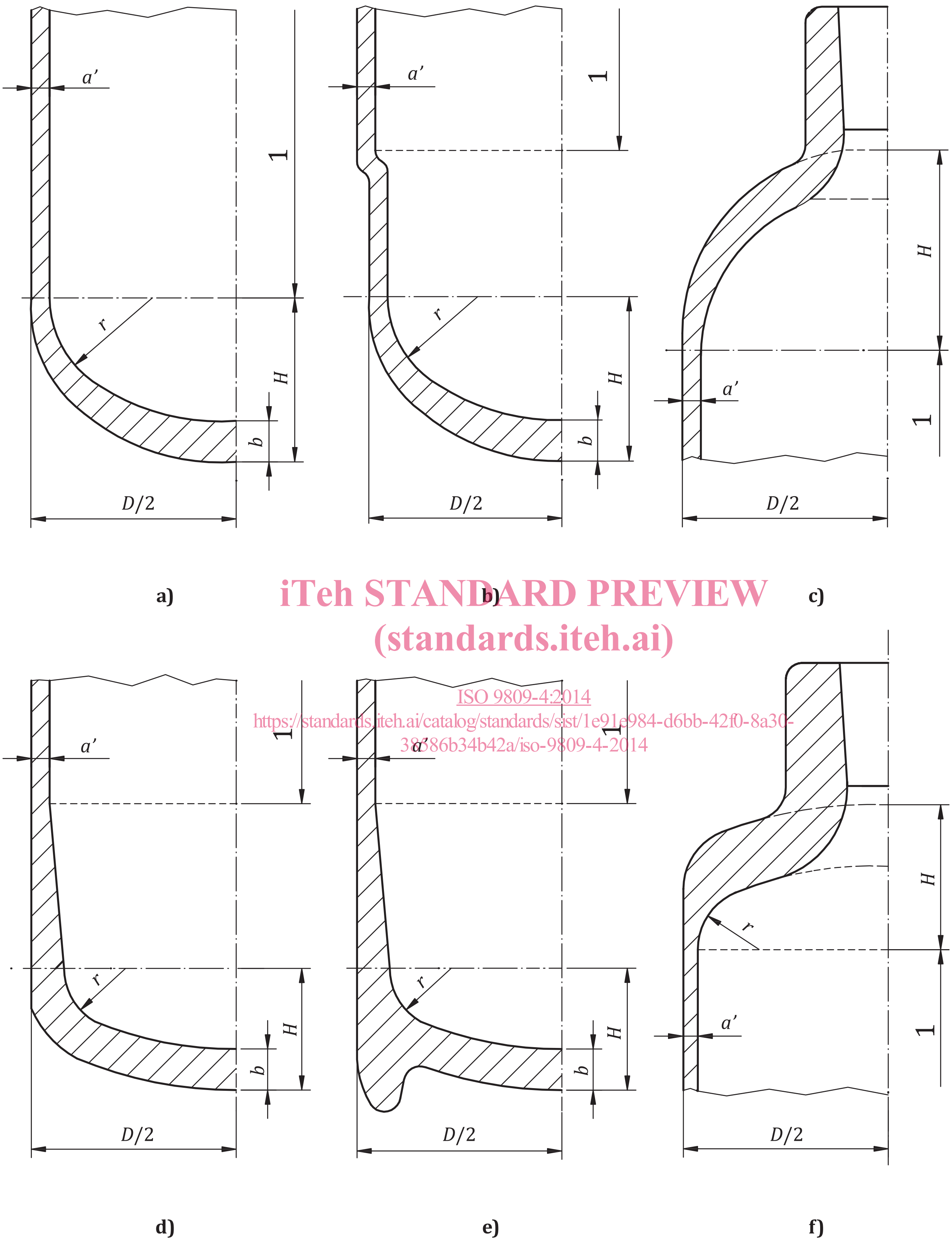

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ISO 9809-4:2014
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Key

1 cylindrical part

Figure 1 — Typical convex ends

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7.4 Calculation of the concave base ends

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

— $a_1 \geq 2\ a$;

— $a_2 \geq 2\ a$;

— $h \geq 0{,}12\ D$;

— $r \geq 0{,}075\ D$.

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

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 design shall be verified and considered satisfactory by the application of the pressure cycling test given in 9.2.2.

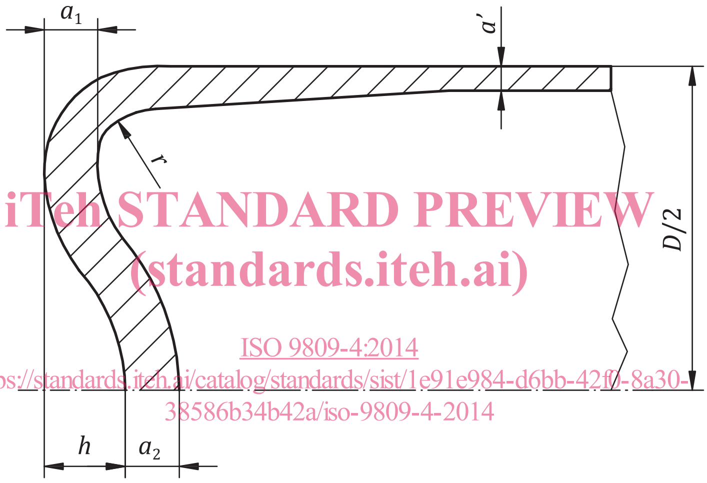

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Figure 2 — Concave base ends

7.5 Neck design

7.5.1 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 can vary according to the diameter of the thread, the form of the thread, and the sealant used in the fitting of the valve.

NOTE For guidance on torques, see ISO 13341.

7.5.2 In establishing the minimum thickness, consideration should be given to obtaining a thickness of the wall in the cylinder neck which will prevent the permanent expansion of the neck during the initial and subsequent fittings of the valve into the cylinder without the support of an attachment. The external diameter and thickness of the formed neck end of the cylinder shall not be damaged (no permanent expansion or crack) by the application of the maximum torque required to fit the valve to the cylinder (see ISO 13341) and the stresses when the cylinder is subjected to its test pressure. In specific cases (e.g. very thin-walled cylinders) where these stresses cannot be supported by the neck itself, the neck can 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.

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