

DRAFT INTERNATIONAL STANDARD

ISO/DIS 9809-4

ISO/TC 58/SC 3

Secretariat: BSI

Voting begins on:
2020-09-09

Voting terminates on:
2020-12-02

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

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

ICS: 23.020.35

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[ISO/DIS 9809-4](https://standards.iteh.ai/catalog/standards/sist/e103abd2-e4f5-405d-ab5b-88f5f9ee92c/iso-dis-9809-4)

<https://standards.iteh.ai/catalog/standards/sist/e103abd2-e4f5-405d-ab5b-88f5f9ee92c/iso-dis-9809-4>

THIS DOCUMENT IS A DRAFT CIRCULATED FOR COMMENT AND APPROVAL. IT IS THEREFORE SUBJECT TO CHANGE AND MAY NOT BE REFERRED TO AS AN INTERNATIONAL STANDARD UNTIL PUBLISHED AS SUCH.

IN ADDITION TO THEIR EVALUATION AS BEING ACCEPTABLE FOR INDUSTRIAL, TECHNOLOGICAL, COMMERCIAL AND USER PURPOSES, DRAFT INTERNATIONAL STANDARDS MAY ON OCCASION HAVE TO BE CONSIDERED IN THE LIGHT OF THEIR POTENTIAL TO BECOME STANDARDS TO WHICH REFERENCE MAY BE MADE IN NATIONAL REGULATIONS.

RECIPIENTS OF THIS DRAFT ARE INVITED TO SUBMIT, WITH THEIR COMMENTS, NOTIFICATION OF ANY RELEVANT PATENT RIGHTS OF WHICH THEY ARE AWARE AND TO PROVIDE SUPPORTING DOCUMENTATION.

This document is circulated as received from the committee secretariat.



Reference number
ISO/DIS 9809-4:2020(E)

© ISO 2020

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO/DIS 9809-4
<https://standards.iteh.ai/catalog/standards/sist/e103abd2-e4f5-405d-ab5b-88f5f9ee92c/iso-dis-9809-4>



COPYRIGHT PROTECTED DOCUMENT

© ISO 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Symbols	2
5 Inspection and testing	4
6 Materials	4
6.1 General requirements	4
6.2 Controls on chemical composition	4
6.3 Heat treatment	5
6.4 Cold working or cryoforming	5
6.5 Failure to meet test requirements	5
7 Design	6
7.1 General requirements	6
7.2 Design of cylindrical shell thickness	6
7.3 Design of convex ends (heads and bases)	6
7.4 Design of the concave base ends	8
7.5 Neck design	8
7.6 Foot rings	9
7.7 Neck rings	9
7.8 Design drawing	9
8 Construction and workmanship	9
8.1 General	9
8.2 Wall thickness	9
8.3 Surface imperfections	9
8.4 Ultrasonic examination	9
8.5 Out-of-roundness	10
8.6 Mean diameter	10
8.7 Straightness	10
8.8 Verticality and stability	10
8.9 Neck threads	11
9 Type approval procedure	11
9.1 General requirements	11
9.2 Prototype test	12
9.2.1 General requirements	12
9.2.2 Pressure cycling test	13
9.2.3 Base check	13
9.2.4 Torque test for taper thread only	14
9.2.5 Shear stress calculation for parallel threads	14
9.3 Type approval certificate	14
9.4 Specific type approval/production tests for cylinders ordered in small quantities	14
10 Batch tests	15
10.1 General requirements	15
10.2 Tensile test	17
10.3 Bend test and flattening test	18
10.3.1 Bend test	18
10.3.2 Flattening test	19
10.3.3 Ring flattening test	19
10.4 Impact test	19

10.5	Hydraulic burst test.....	21
10.5.1	Test installation.....	21
10.5.2	Test conditions.....	22
10.5.3	Interpretation of test results.....	23
10.6	Intergranular corrosion test.....	24
11	Tests/examinations on every cylinder	24
11.1	General.....	24
11.2	Hydraulic test.....	25
11.2.1	Proof pressure test.....	25
11.2.2	Volumetric expansion test.....	25
11.3	Hardness test.....	25
11.4	Leak test.....	25
11.5	Capacity check.....	26
12	Certification.....	26
13	Marking.....	26
Annex A (informative)	Description and evaluation of manufacturing imperfections and conditions for rejection of seamless steel gas cylinders at the time of final inspection by the manufacturer	27
Annex B (informative)	Ultrasonic examination	42
Annex C (informative)	Example of Type approval certificate	48
Annex D (informative)	Example of Acceptance certificate	49
Annex E (informative)	Example of shear strength calculation for parallel threads.....	52
Bibliography		54

[ISO/DIS 9809-4](https://standards.iteh.ai/catalog/standards/sist/e103abd2-e4f5-405d-ab5b-88f5f9ee92c/iso-dis-9809-4)
<https://standards.iteh.ai/catalog/standards/sist/e103abd2-e4f5-405d-ab5b-88f5f9ee92c/iso-dis-9809-4>

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.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

This second edition replaces the first edition (ISO 9809-4: 2014), which has been technically revised.

The main changes compared to the previous edition are as follows:

- Update of [Clause 5](#)
- Clarification of [Figure 3](#)
- Clarification of [8.9](#)
- Modification of [9.1](#), [9.2](#), [9.2.4](#), [Annex A](#)
- New [section 9.2.5](#) for parallel threads
- New [section 9.4](#) for cylinders ordered in small quantities.

A list of all parts in the ISO 9809-series can be found on the ISO website.

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 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 (all parts) aims to eliminate the concern about climate, duplicate inspections, and restrictions currently existing because of the lack of definitive International Standards.

This document has been written so that it is suitable to be referenced in the UN Model Regulations.^[1]

iTeh STANDARD PREVIEW (standards.iteh.ai)

ISO/DIS 9809-4

<https://standards.iteh.ai/catalog/standards/sist/e103abd2-e4f5-405d-ab5b-88f5f99ee92c/iso-dis-9809-4>

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

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

1 Scope

This document specifies the minimum requirements for the material, design, construction and workmanship, manufacturing processes, examinations, and tests at manufacture for refillable seamless stainless steel gas cylinders

- with water capacities up to and including 150 l
- for compressed, liquefied, and dissolved gases
- with a maximum actual tensile strength, R_{ma} , of less than 1 100 MPa.

NOTE If so desired, cylinders of water capacity between 150 l and 450 l can be manufactured to be in full compliance with this document.

2 Normative references

ISO/DIS 9809-4

<https://standards.iteh.ai/catalog/standards/sist/e103abd2-e4f5-405d-ab5b-085b0c924102/iso-dis-9809-4>

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 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 9329-4, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 4: Austenitic stainless steels*

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

ISO 10286, *Gas cylinders - Terminology*

ISO 13769, *Gas cylinders — Stamp marking*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10286 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>

— IEC Electropedia: available at <http://www.electropedia.org/>

3.1

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

3.2

burst pressure

p_b

highest pressure reached in a cylinder during a burst test

3.3

cryoforming

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

3.4

design stress factor

F

ratio of the equivalent wall stress at test pressure, p_h , to guaranteed minimum yield strength, R_{eg}

3.5

rendered unserviceable

cylinder that has been treated in such a way as to render it impossible for use

3.6

reject

cylinder that has been set aside (Level 2 or Level 3) and not allowed to go into service

3.7

repair

action to return a rejected cylinder to a Level 1 condition

3.8

test pressure

p_h

required pressure applied during a pressure test

Note 1 to entry: Test pressure is used for the cylinder wall thickness calculation.

3.9

yield strength

R_{eg}

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

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_0

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)
b	guaranteed minimum thickness, in millimetres, at the centre of a convex base (see Figure 1)
c_1	maximum permissible deviation, in millimetres, of burst profile for quenched and tempered cylinders (see Figure 11)
c_2	maximum permissible deviation, in millimetres, of the burst profile for cryoformed or solution-annealed cylinders with less than 7,5 mm wall thickness (see Figure 12)
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 3.7)
H	outside height, in millimetres, of the domed part (convex head or base end) (see Figure 1)
h	outside depth (concave base end), in millimetres (see Figure 2)
L_0	original gauge length, in millimetres, as defined in ISO 6892 (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 test piece, t
P_b	measured burst pressure, in bar, above the atmospheric pressure
NOTE	1 bar = 10^5 Pa = 0,1 MPa.
P_h	hydraulic test pressure, in bar, above the atmospheric pressure
P_y	observed pressure when the cylinder starts yielding during the hydraulic burst test, in bar, above the atmospheric pressure
r	inside knuckle radius, in millimetres (see Figures 1 and 2)
R_{ea}	actual value of the yield strength, in megapascals, as determined by the tensile test (see 10.2)
R_{eg}	minimum guaranteed value of the yield strength (see 7.1.1), in megapascals, for the finished cylinder
R_{ma}	actual value of the tensile strength, in megapascals, as determined by the tensile test (see 10.2)
R_{mg}	minimum guaranteed value of the tensile strength, in megapascals, for the finished cylinder
S_0	original cross-sectional area of the 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 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, in millimetres, of the tensile test piece (see Figure 5)

5 Inspection and testing

Assessment of conformity to this document shall be carried out in accordance with the applicable regulations of the countries of use.

To ensure that the cylinders conform to this document, they shall be subject to inspection and testing in accordance with [Clauses 9, 10 and 11](#).

Tests and examinations performed to demonstrate compliance with this document shall be conducted using instruments calibrated before being put into service and thereafter according to an established programme.

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](#).

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 Grades of 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).

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 document.

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, 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 9329-4.

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.

6.5 Failure to meet test requirements

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 may subject all the cylinders implicated by the failure to only one 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.

This reheat treatment shall consist of either partial or complete reheat treatment.

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

7.1.2 Cylinders shall 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 Design 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 \(2\)](#).

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

with an absolute minimum of $a = 1,5$ mm. <https://standards.iteh.ai/catalog/standards/sist/e103abd2-e4f5-405d-ab5b-88f5f99ee02c/iso-dis-9809-4>

The burst ratio shall be satisfied by test as given in [Formula \(3\)](#).

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

NOTE It is generally assumed that $p_h = 1,5$ times working pressure for compressed gases for cylinders designed and manufactured to conform with this document.

7.3 Design of convex ends (heads and bases)

7.3.1 When convex base ends (see [Figure 1](#)) are used, 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 when 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 dimension H in [Figure 1](#).

Shape b) shall not be excluded from this requirement.

7.3.2 The cylinder manufacturer shall prove by the pressure cycling test detailed in 9.2.2 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.

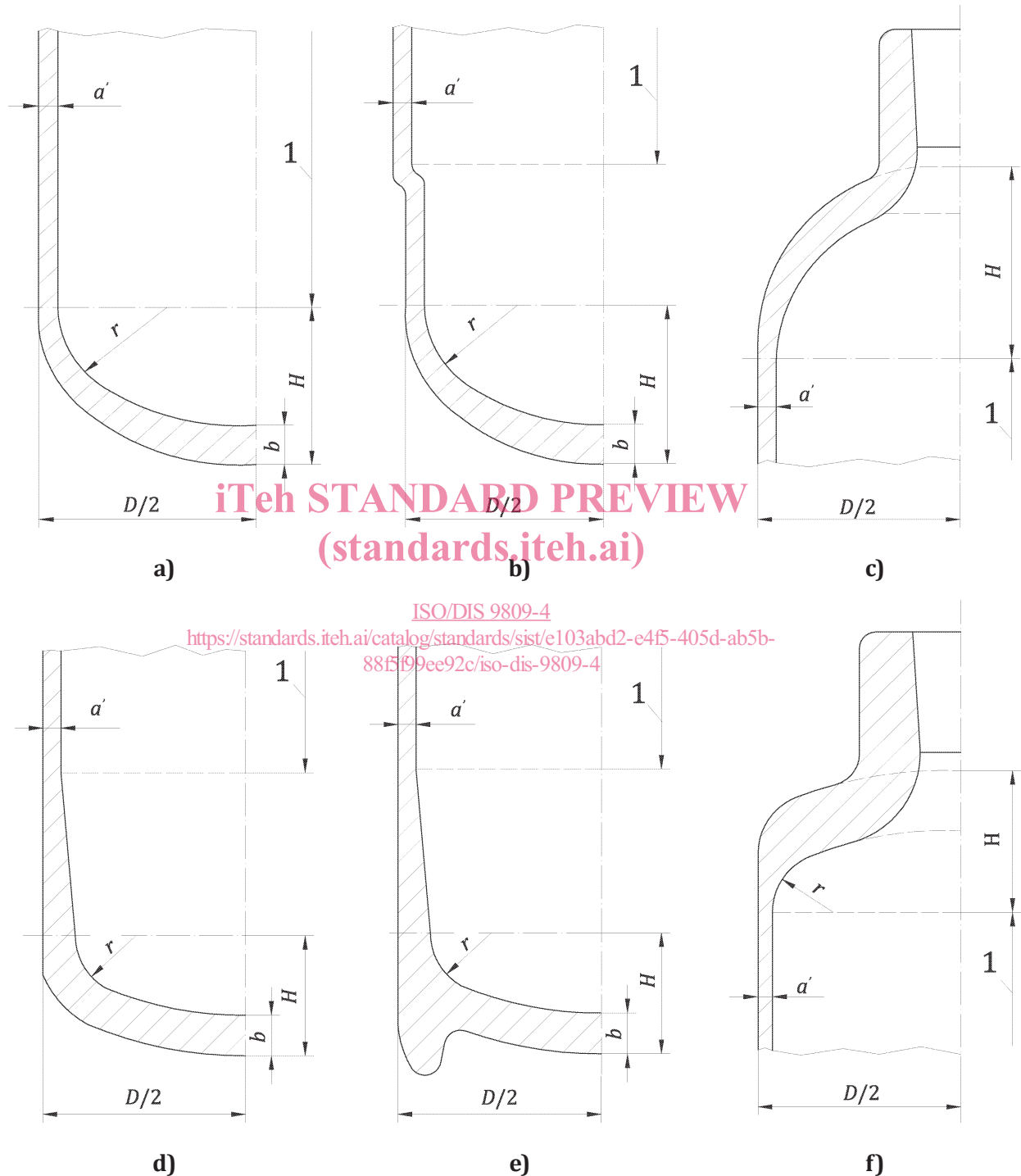


Figure 1 — Typical convex ends

7.4 Design of the concave base ends

7.4.1 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 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.

7.4.2 The cylinder manufacturer shall in any case prove by the application of the pressure cycling test detailed in 9.2.2 that the design is satisfactory.

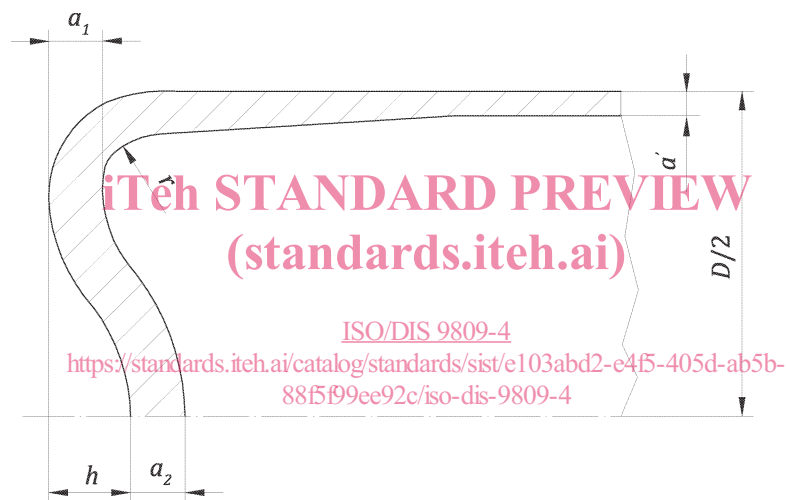


Figure 2 — Concave base ends

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 valve type, diameter of the thread, the form of the thread, and the sealant used in the fitting of the valve.

NOTE For information on torques, see ISO 13341.

7.5.2 In establishing the minimum thickness, the thickness of the wall in the cylinder neck shall prevent permanent expansion of the neck during the initial and subsequent fittings of the valve into the cylinder without 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 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 (see 9.2.4 and 9.2.5).

7.6 Foot rings

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

7.7 Neck rings

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

The axial load to remove the neck ring shall be greater than 10 times the weight of the empty cylinder but not less than 1 000 N, and that the torque to turn the neck ring is greater than 100 Nm.

7.8 Design drawing

A fully dimensioned drawing shall be prepared which includes the specification of the material and details relevant to the design of the permanent fittings. Dimensions of non-safety related fittings can be agreed between the customer and manufacturer and need not be shown on the design drawing.

8 Construction and workmanship

8.1 General

The cylinder shall be produced by

- a) forging or drop forging from a solid ingot or billet,
- b) manufacturing from seamless tube,
- c) pressing from a flat plate, or
- d) cold working or cryoforming preform.

Metal shall not be added in the process of closure of the end. Manufacturing defects shall not be corrected by plugging of bases (e.g. addition of metal by welding).

8.2 Wall thickness

During production, each cylinder or semi-finished shell shall be examined for thickness. The wall thickness at any point shall be not less than the minimum thickness specified.

8.3 Surface imperfections

The internal and external surfaces of the finished cylinder shall be visually inspected to determine that they are free from imperfections which could adversely affect the safe working of the cylinder. For examples of imperfections and assistance on their evaluation, see [Annex A](#).

8.4 Ultrasonic examination

8.4.1 After completion of the final heat treatment and cold working and after the final cylindrical wall thickness has been achieved, each cylinder shall be ultrasonically examined for internal, external, and sub-surface imperfections in accordance with [Annex B](#).

8.4.2 In addition to the ultrasonic examination as specified in [8.4.1](#), the cylindrical area to be closed (which creates the shoulder and in case of cylinders made from tube, also the base) shall be ultrasonically