INTERNATIONAL STANDARD

ISO 9809-3

Third edition
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Gas cylinders — Design, construction and testing of refillable seamless steel gas cylinders and tubes —

Part 3:
Normalized steel cylinders and tubes

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

Partie 3: Bouteilles et tubes en acier normalisé

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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.

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).

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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 third edition cancels and replaces the second edition (ISO 9809-3:2010), which has been technically revised. The changes compared to the previous edition are as follows:

— water capacity extended from below 0,5 l and up to and including 450 l;

— batch size for tubes now introduced;

— bend test retained only for prototype tests;

— test requirements for check analysis (tolerances modified);

— new test requirements for threads introduced including an informative Annex F;

— original European Annexes now incorporated into the body of this document;

— Annex A "Manufacturing imperfections" now aligned with ISO/TR 16115.

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

This document provides a specification for the design, manufacture, inspection and testing of a seamless steel cylinder and tube. The objective is to balance design and economic efficiency against international acceptance and universal utility.

ISO 9809 (all parts) aims to eliminate existing concerns about climate, duplicate inspections and restrictions because of a lack of definitive International Standards.

This document is intended to be used under a variety of regulatory regimes and has been written so that it is suitable to be referenced in the UN Model Regulations[7].

Gas cylinders — Design, construction and testing of refillable seamless steel gas cylinders and tubes —

Part 3: Normalized steel cylinders and tubes

1 Scope

This document specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes, examination and testing at the time of manufacture for refillable seamless steel gas cylinders and tubes with water capacities up to and including 450 l.

It is applicable to cylinders and tubes for compressed, liquefied and dissolved gases and for normalized or normalized and tempered steel cylinders and tubes.

2 Normative references

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

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

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

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

ISO 10286, *Gas cylinders — Terminology*

ISO 9809-1, *Gas cylinders — Design, construction and testing of refillable seamless steel gas cylinders and tubes— Part 1: Quenched and tempered steel cylinders and tubes with tensile strength less than 1 100 MPa*

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

ISO 11114-4, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 4: Test methods for selecting steels resistant to hydrogen embrittlement*

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 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 for cylinders and up to 50 for tubes, plus cylinders/tubes 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

Note 1 to entry: In this document where not specifically mentioned for "cylinder/tube" only the term "cylinder" will be used.

3.2
burst pressure
p_b
highest pressure reached in a cylinder during a burst test

3.3
design stress factor
F
ratio of equivalent wall stress at test pressure, p_h, to guaranteed minimum yield strength, R_{eg}

3.4
normalizing
heat treatment in which a cylinder is heated to a uniform temperature above the upper critical point, Ac_3, of the steel and then cooled in still air

3.5
reject
cylinder that has been set aside (Level 2 or Level 3) and not allowed to enter into service

3.6
rendered unserviceable
cylinder that has been treated in such a way as to render it impossible for it to enter into service

Note 1 to entry: Examples for acceptable methods to render cylinders unserviceable can be found in ISO 18119. Any actions on cylinders rendered unserviceable are outside the scope of this document.

3.7
repair
action to return a rejected cylinder to a Level 1 condition

3.8
tempering
toughening heat treatment which follows normalizing, in which the cylinder is heated to a uniform temperature below the lower critical point, Ac_1, of the steel

3.9
test pressure
p_h
required pressure applied during a pressure test

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

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

3.11
yield strength
stress value corresponding to the lower yield strength, R_{eL} or for steels which do not exhibit a defined yield, the 0,2 % proof strength (non-proportional extension), $R_{p0,2}$

Note 1 to entry: See ISO 6892-1.

4 Symbols

A	percentage elongation after fracture
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	maximum permissible deviation of burst profile, in millimetres (see Figure 5)
D	nominal design outside diameter of the cylinder, in millimetres, (see Figure 1 and Figure 2)
D_f	diameter, in millimetres, of former (see Figure 6)
F	design stress factor (variable), see 7.2
H	outside height, in millimetres, of domed part (convex head or base end), (see Figure 1)
h	outside depth (concave base end), in millimetres (see Figure 2)
$l1$	length of cylindrical part of the cylinder, in millimetres (see Figure 3)
L_o	original gauge length, in millimetres, as defined in ISO 6892-1 (see Figure 8)
n	ratio of the diameter of the bend test former to actual thickness of test piece, t
p_b	measured burst pressure, in bars above atmospheric pressure NOTE 1 bar = 10^5 Pa = 0,1 MPa.
p_h	hydraulic test pressure, in bars, above atmospheric pressure
p_y	observed pressure when cylinder starts yielding during hydraulic bursting test, in bars
r	inside knuckle radius, in millimetres (see Figures 1 and 2)
R_{eg}	minimum guaranteed value of the yield strength (see 7.1.1), in megapascals, for the finished cylinder
R_{ea}	actual value of the yield 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
R_{ma}	actual value of the tensile strength, in megapascals, as determined by the tensile test (see 10.2)

S_o original cross-sectional area of tensile test piece, in square millimetres according to ISO 6892-1

t actual thickness of the test specimen, in millimetres

t_m average cylinder wall thickness at position of testing during the flattening test, 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 8)

5 Inspection and testing

Assessment of conformity to this international standard shall take into account the applicable regulations of the countries of use.

To ensure that 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 normalized or normalized and tempered gas cylinders shall be those generically classified as carbon-steels or carbon-manganese steels. The maximum actual tensile strength, R_{ma}, for cylinders made from those steels shall not exceed 800 MPa.

Other steels specified in ISO 9809-1 or ISO 9809-2 for quenched and tempered cylinders may be used and subjected to normalizing and tempering as specified in 6.3 provided that they additionally pass the impact test requirements given in ISO 9809-1, and the maximum actual tensile strength, R_{ma}, does not exceed 950 MPa.

The steel used 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.

6.1.2 The material used for the manufacture of gas cylinders shall be steel, other than rimming quality, with non-ageing properties and shall be fully killed with aluminium and/or silicon. If only aluminium is used for killing, the metallic aluminium content shall be at least 0,015 %.

Where examination of this non-ageing property is required by the customer, the criteria by which it is to be specified should 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 and ISO 11114-4).

6.1.5 Wherever continuously cast billet material is used, the manufacturer shall ensure that there are no deleterious imperfections (porosity) in the material to be used for making cylinders (see 9.2.4).

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 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.

Table 1 — Chemical composition tolerances

Element	Maximum content (mass fraction) %	Permissible range (mass fraction) %	Check analysis Deviation from the limits specified for the cast analyses (mass fraction) %
Carbon	<0,30 %	0,06	±0,02
	≥0,30 %	0,07	±0,02
Manganese	All values	0,30	≤1,00 ± 0,04 >1,00 ≤ 1,70 ± 0,05
Silicon	All values	0,30	±0,03

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

6.2.2 Except for steels conforming to ISO 9809-1 or ISO 9809-2, the limits on carbon, manganese and other alloying elements, given in Table 2, shall not be exceeded in the cast analysis of material used.

Table 2 — Limits on carbon, manganese and other alloying elements (mass fraction)

Element	Cast analysis (mass fraction) %	Check analysis Deviation from the limits specified for the cast analyses (mass fraction) %
Carbon	0,45	See Table 1
Manganese	1,70	See Table 1
Chromium	0,20	+0,05
Molybdenum	0,20	+0,03
Nickel	0,20	+0,05
Copper	0,20	+0,05

Table 2 *(continued)*

Element	Cast analysis (mass fraction) %	Check analysis Deviation from the limits specified for the cast analyses (mass fraction) %
Combined value of micro alloying elements: i.e. V, Nb, Ti, B, Zr, Sn	0,15	

6.2.3 The limits on sulfur and phosphorus, given in Table 3, shall not be exceeded in the cast analysis of material used.

Table 3 — Maximum sulfur and phosphorus limits (mass fraction)

Sulfur	0,015 %
Phosphorus	0,020 %
Sulfur and phosphorus	0,030 %

6.2.4 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 specimens taken during 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 Tables 1 and 2.

6.3 Heat treatment

The heat treatment process applied to the finished cylinder shall be either normalizing or normalizing and tempering. The cylinder manufacturer shall certify the heat treatment process applied.

The heat treatment 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.

6.4 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.

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 representing the nature of 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 heat treatment shall consist of re-normalizing or re-normalizing and tempering or re-tempering.

      Whenever 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 batch shall be performed again. If one or more of these retests 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 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 For calculation purposes, the value of R_{eg} shall not exceed 0,75 R_{mg}.

7.1.4 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 that calculated using Formulae (1) and (2). Additionally, Formula (3) shall be satisfied:

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

where $F \leq 0{,}85$.

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.

The burst ratio shall be satisfied by test as given in Formula (3):

$$p_b / p_h \geq 1{,}22 / (R_{eg} / R_{mg}) \quad (3)$$

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

NOTE 2 For some applications such as tubes assembled in batteries to equip trailers or skids (ISO modules) or MEGCs for the transportation and distribution of gases, it is important that stresses associated with mounting the tube (e.g. bending stresses, see Annex E, torsional stresses, dynamic loadings) are considered by the assembly manufacturer and the tube manufacturer.

NOTE 3 In addition, during hydraulic pressure testing, tubes could be supported or lifted by their necks; therefore, it should be necessary to consider potential bending stresses. For general guidance, see Annex E.

7.3 Design of convex ends (heads and bases)

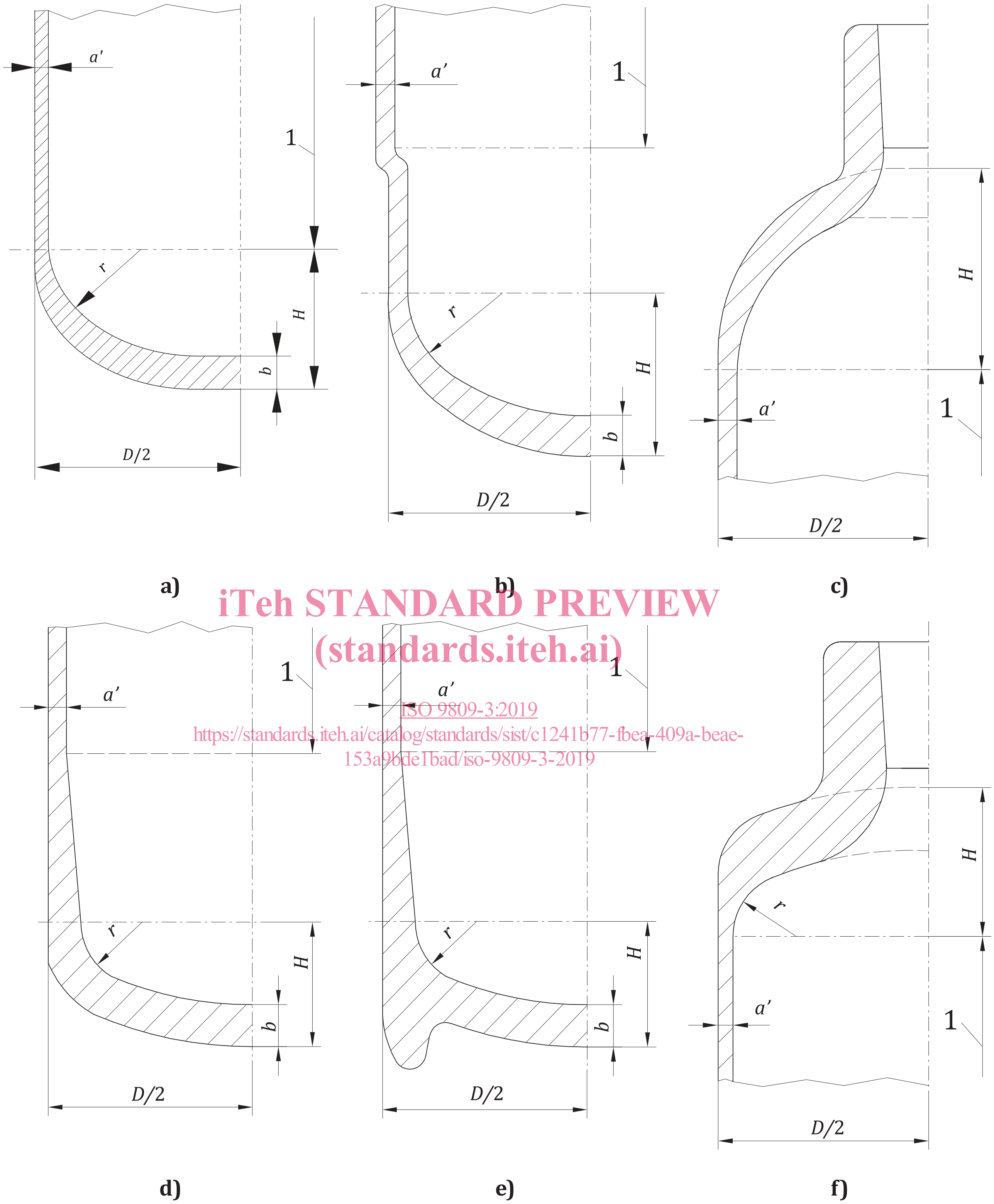
7.3.1 When convex base ends (see Figure 1) are used the thickness, b, at the centre of a convex end shall be not less than that required by the following criteria: where the inside knuckle radius, r, is not less than 0,075 D, then:

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

$b \geq a$ 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) in Figure 1 shall not be excluded from this requirement.



Key

1 cylindrical part

Figure 1 — Typical convex ends