INTERNATIONAL STANDARD

ISO 9809-2

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

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

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

Partie 2: Bouteilles en acier trempé et revenu ayant une résistance à la traction supérieure ou égale à 1 100 MPa

Reference number
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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.

Attention is drawn to the possibility that some of the elements of this part of ISO 9809 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 9809-2 was prepared by Technical Committee 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*

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

Introduction

The purpose of this part 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.

This part of ISO 9809 aims to eliminate the concern about climate, duplicate inspections and restrictions currently existing because of lack of definitive International Standards. This part of ISO 9809 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 2:
Quenched and tempered steel cylinders with tensile strength greater than or equal to 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 greater than or equal to 1 100 MPa. It does not cover cylinders with $R_m$max. > 1 300 MPa for diameters > 140 mm and guaranteed wall thicknesses (a') $\geqslant$ 12 mm, and $R_m$max. $\geqslant$ 1 400 MPa for diameters $\leqslant$ 140 mm and guaranteed wall thicknesses (a') $\geqslant$ 6 mm, because beyond these limits additional requirements may apply.

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 less than 1 100 MPa refer to ISO 9809-1. For normalized steel cylinders refer to ISO 9809-3.

NOTE 3 Grades and strength ranges of steels used for these types of cylinders may not be compatible with some gas services (see 6.1.4) and operational conditions.

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*.

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[1] To be replaced by ISO 148-1 (in preparation), ISO 148-2:1998 and ISO 148-3:1998.

[2] Replaced by ISO 6506-1:1999, ISO 6506-2:1999 and ISO 6506-3:1999.

[3] Replaced by ISO 6508-1:1999, ISO 6508-2:1999 and ISO 6508-3:1999.

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

ISO 9712:1999, *Non-destructive testing — Qualification and certification of personnel*.

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 terms and 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), $R_{p0,2}$

[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
required pressure applied during a pressure test

NOTE It is used for cylinder wall thickness calculation.

3.6
burst pressure
highest pressure reached in a cylinder during a burst test

3.7
design stress factor
F
ratio of equivalent wall stress at test pressure (p_h) to the guaranteed minimum yield stress (R_e)

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4) To be published.

4 Symbols

Table 1 lists the symbols and their designations

Table 1 — Symbols and designations

Symbol	Designation
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
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 13)
d	Depth of artificial flaw, in millimetres, in flawed cylinder burst test and flawed cylinder cycle test (see Figure 5)
D	Nominal outside diameter of the cylinder, in millimetres (see Figure 1)
D_c	External diameter, in millimetres, of cutter milling tool for flawed cylinder burst test and flawed cylinder cycle test (see Figure 5)
D_f	Diameter, in millimetres, of former (see Figure 8)
F	Design stress factor (variable) (see 3.7)
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	Length of artificial flaw, in millimetres, in flawed cylinder burst test and flawed cylinder cycle test (see Figure 5)
l	Length of cylindrical part of the cylinder, in millimetres (see Figure 3)
L_o	Original gauge length, in millimetres, as defined in ISO 6892 (see Figure 7)
p_b	Measured burst pressure, in bar [a], above atmospheric pressure
p_f	Measured failure pressure, in bar [a], above atmospheric pressure
p_h	Hydraulic test pressure, in bar [a], above atmospheric pressure
p_s [b]	Calculated design working pressure, in bar [a], above atmospheric pressure
p_y	Observed pressure when cylinder starts yielding during hydraulic bursting test, in bar [a], above atmospheric pressure
r	Inside knuckle radius, in millimetres (see Figure 1 and Figure 2)
r_c	Cutter tip radius of milling tool for artificial flaw, in millimetres, for flawed cylinder burst test and flawed cylinder cycle test (see Figure 5)
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 (see 10.2)

Table 1 (*continued*)

Symbol	Designation
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)
R_m max.	Maximum actual value of the tensile strength range, in MPa
R_m min.	Minimum actual value of the tensile strength range, in MPa
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
V	Water capacity of cylinder, in litres
w	Width, in millimetres, of the tensile test piece (see Figure 7)

[a] 1 bar = 10^5 Pa = 0,1 MPa

[b] p_s is equal to 2/3 p_h

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 in accordance with clauses 9, 10 and 11 by an authorized inspection authority (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 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 relevant conditions specified in 6.2 and 6.3 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 into 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 High strength steels used for manufacture of high strength cylinders are normally not compatible with corrosive or embrittling gases (see ISO 11114-1). They may nevertheless be used with these gases provided that their compatibility is proven by a recognized test method.

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 sulphur 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 2.

Table 2 — Chemical composition tolerances

Element	Maximum content (m/m)	Permissible range (m/m)
Carbon	< 0,30 %	0,03 %
	⩾ 0,30 %	0,04 %
Manganese	All values	0,20 %
Silicon	All values	0,15 %
Chromium	< 1,20 %	0,20 %
	⩾ 1,20 %	0,30 %
Nickel	All values	0,30 %
Molybdenum	< 0,50 %	0,10 %
	⩾ 0,50 %	0,15 %

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 its maximum content shall be representative of good steel-making practice.

6.2.2 Sulphur and phosphorus in the cast analysis of material used for the manufacture of gas cylinders shall not exceed the values shown in Table 3.

Table 3 — Maximum sulphur and phosphorus limits

Sulphur	0,010 % (m/m)
Phosphorus	0,015 % (m/m)
Sulphur + phosphorus	0,020 % (m/m)

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 Heat treatment

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

6.3.2 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.

6.3.3 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.

6.4 Testing requirements

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

6.5 Failure to meet test requirements

In the event of failure to meet 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 applied heat treatment, 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 reheat 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 reheat treatment shall consist of retempering or requenching and 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 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 applied heat treatment, 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 reinstated 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

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. The maximum range of tensile strength shall be 120 MPa (i.e R_m max. – R_m min. $\leqslant$ 120 MPa).

However, the actual value of the tensile strength as determined in 10.2 shall not exceed 1 300 MPa for cylinders with outside diameter $>$ 140 mm, and 1 400 MPa for cylinders with outside diameter $\leqslant$ 140 mm.

7.3 Calculation of cylindrical shell thickness

The guaranteed minimum thickness of the cylindrical shell (a') shall be not less than the thickness calculated using equations (1) and (2), and in addition 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 0,77.

R_e/R_g shall not exceed 0,9.

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

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

shall be satisfied by test.

NOTE 1 If the result of these requirements is a guaranteed thickness of the cylindrical shell (a') $\geqslant$ 12 mm for diameter $D >$ 140 mm, or a guaranteed thickness of the cylindrical shell a' $\geqslant$ 6 mm for diameter $D \leqslant$ 140 mm, then such a design would be outside the scope of this part of ISO 9809.

NOTE 2 It is generally assumed that p_h = 1,5 × p_s for permanent gases for cylinders designed and manufactured to 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, then

$b \geqslant 1{,}5\ a$ 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.

7.4.2 The cylinder manufacturer shall prove by the pressure cycling test detailed in 9.2.4 that the design is satisfactory.

The shapes shown in Figure 1 are typical of convex heads and base ends. Shapes A, C and D are base ends and shape B is a head.

7.5 Calculation of concave base ends

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

$a_1 \geqslant 2a$

$a_2 \geqslant 2\ a$

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

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

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

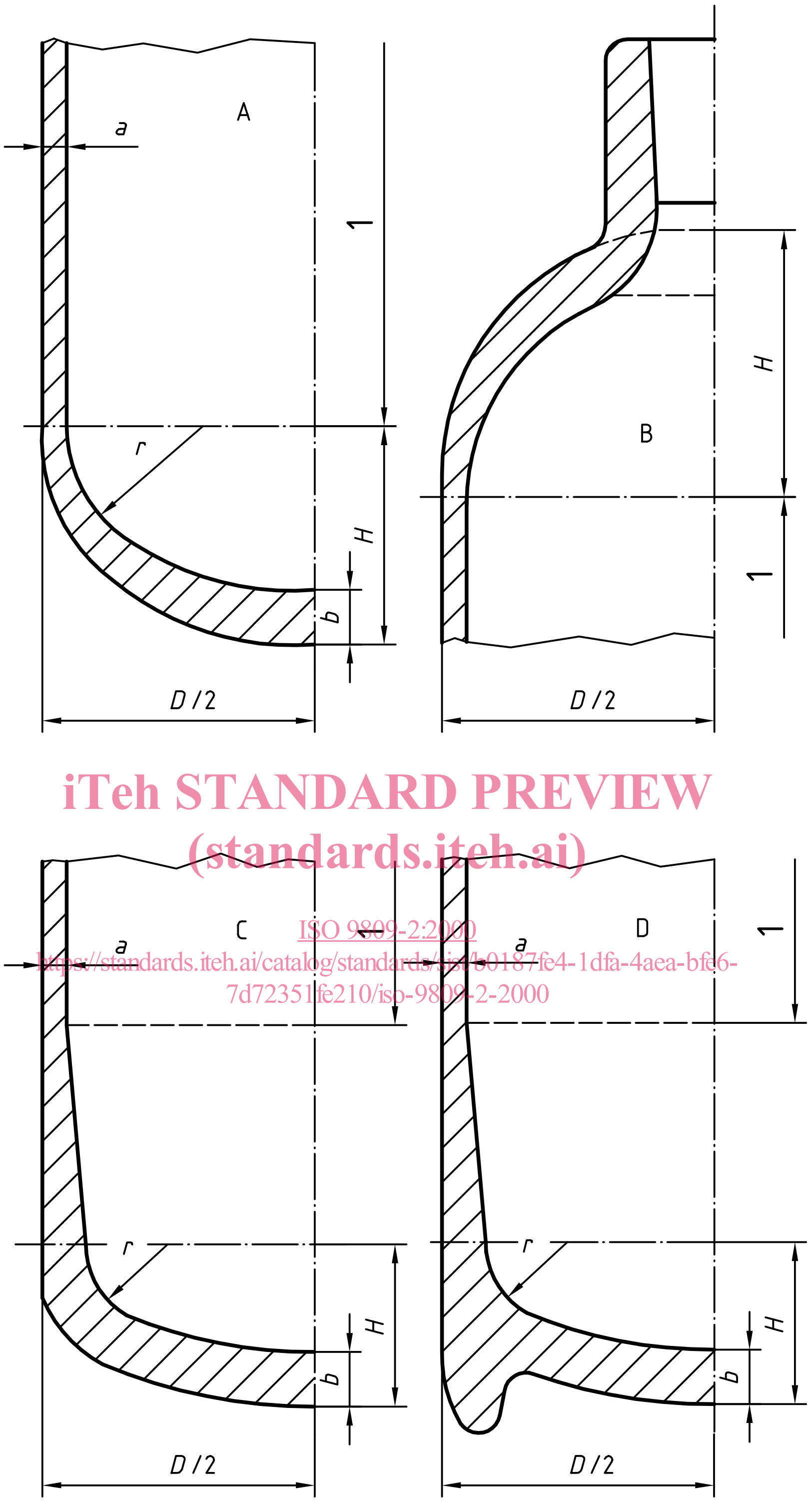
In order that a satisfactory stress distribution be obtainable, the thickness of the cylinder shall increase progressively in the transition region between the cylindrical part and the base.

The cylinder manufacturer shall in any case prove by the pressure cycling test detailed in 9.2.4 that the design is satisfactory.

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. (Guidance on torques is given in ISO 13341.)

7.6.2 In establishing the minimum thickness, consideration shall be given to obtaining a wall thickness 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.



Key

1 Cylindrical part

Figure 1 — Typical convex ends