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

**Part 3:
Normalized steel cylinders**

*Bouteilles à gaz — Bouteilles à gaz rechargeables en acier sans
soudure — Conception, construction et essais —
Partie 3: Bouteilles 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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 9809-3 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

This second edition cancels and replaces the first edition (ISO 9809-3:2000), which has been technically revised by the following:

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- a) the reduction of maximum sulfur content in 6.2.3 from 0,020 % to 0,015 %, which is now applicable to all strength levels;
<https://standards.iteh.ai/catalog/standards/sist/c469cdc-166b-4fab-afa9-47af6407ec33/iso-9809-3-2010>
- b) the note in 7.3 regarding limitation of the *F* factor was deleted (as required by the United Nations *Recommandations on the Transport of Dangerous Goods: Model Regulations*);
- c) the modification of provisions for ultrasonic examination in 8.4 to include ultrasonic examination on the cylindrical area to be closed, prior to the forming process;
- d) the addition of the requirement of a base check according to 9.2.4 for all cylinder types during prototype testing;
- e) the addition of the requirement of a base check according to 9.2.4 for cylinders made from continuously cast billet material during batch testing.

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*

Stainless steel cylinders with tensile strength of less than 1 100 MPa will form the subject of a part 4.

This corrected version of ISO 9809-3:2010 incorporates the following corrections.

Clause 4, Symbols: the following row was deleted:

d_2	Maximum permissible deviation of burst profile, in millimetres (see Figure 5b), c) and d)
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6.1.5: "(see 9.2.6)" was changed to "(see 9.2.4)".

9.2.2.3.1: "the bursting pressure p_h " was corrected to "the bursting pressure, p_b " to match the symbol defined in Article 4.

10.2.1: "the formula in 9.2.1 a)" was corrected to read "the formula in 10.2.1 a)".

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Introduction

This part of ISO 9809 provides 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 (all parts) aims to eliminate existing concerns about climate, duplicate inspections and restrictions because of a 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.

This part of ISO 9809 addresses the general requirements on design, construction and initial inspection and testing of pressure receptacles of the United Nations *Recommendations on the Transport of Dangerous Goods: Model Regulations*.

It is intended to be used under a variety of regulatory regimes, but is suitable for use with the conformity assessment system in 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 3: Normalized steel cylinders

1 Scope

This part of ISO 9809 specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes, examination and testing at manufacture of refillable normalized or normalized 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.

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

NOTE 2 For quenched and tempered steel cylinders with maximum tensile strength less than 1 100 MPa, see ISO 9809-1. For quenched and tempered cylinders with maximum tensile strength \geq 1 100 MPa, see ISO 9809-2.

2 Normative references

ISO 9809-3:2010

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The following referenced documents are indispensable for the application 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 (scales A, B, C, D, E, F, G, H, K, N, T)*

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

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 personnel*

ISO 9809-1, *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*

ISO 13769, *Gas cylinders — Stamp marking*

3 Terms and definitions

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

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 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 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

3.6 test pressure
 p_h
required pressure applied during a pressure test

NOTE It is used for cylinder wall thickness calculation.

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

3.8 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), $R_{p0,2}$

See ISO 6892-1.

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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 after fracture
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 8)
F	Design stress factor (variable), see 7.2
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	Length of cylindrical part of the cylinder, in millimetres (see Figure 3)
L_0	Original gauge length, in millimetres, as defined in ISO 6892-1 (see Figure 7)
n	Ratio of the diameter of the bend test former to actual thickness of test piece, t
p_b	Measured burst pressure, in bars ¹⁾ above atmospheric pressure
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_0	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 7)

1) 1 bar = 10⁵ Pa = 10⁵ N/m².

5 Inspection and testing

NOTE Evaluation of conformity can be carried out according to the regulations recognized by the country(ies) in which the cylinders are intended to be used.

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 (hereinafter referred to as “the inspector”) authorized to do so.

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

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; [ISO 9809-3:2010](https://standards.iteh.ai/catalog/standards/sist/c469cdc-166b-4fab-afa9-d7ad02cc59/iso-9809-3-2010)
- c) new cylinder steels resulting from technical progress. <https://standards.iteh.ai/catalog/standards/sist/c469cdc-166b-4fab-afa9-d7ad02cc59/iso-9809-3-2010>

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) %
Carbon	< 0,30 %	0,06
	≥ 0,30 %	0,07
Manganese	All values	0,30
Silicon	All values	0,30

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)

Carbon	0,45 %
Manganese	1,70 %
Chromium	0,20 %
Molybdenum	0,20 %
Nickel	0,20 %
Copper	0,20 %
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 ISO 9329-1.

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 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.

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 may 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 Calculation of cylindrical shell thickness

The guaranteed minimum thickness of the cylindrical shell, a' , shall not be less than that calculated using Equations (1) and (2). Additionally, condition (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 Equation (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 Equation (3):

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

NOTE It is generally assumed that $p_h = 1,5$ times working pressure for compressed gases for 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:

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

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

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

Shape b) shall not be excluded from this requirement.