INTERNATIONAL STANDARD

ISO 11120

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Gas cylinders — Refillable seamless steel tubes of water capacity between 150 l and 3 000 l — Design, construction and testing

Bouteilles à gaz — Tubes en acier sans soudure rechargeables d'une contenance en eau de 150 l à 3 000 l — Conception, construction et essais

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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.

International Standard ISO 11120 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

Annexes A and B form an integral part of this International Standard.

Annexes C, D and E are for information only.

Introduction

The purpose of this International Standard is to provide a specification for the design, manufacture, inspection and testing of tubes for worldwide usage. The objective is to balance design and economic efficiency against international acceptance and universal utility.

This International Standard aims to eliminate concern about climate, duplicate inspections and restrictions currently existing because of 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.

Gas cylinders — Refillable seamless steel tubes of water capacity between 150 l and 3 000 l — Design, construction and testing

1 Scope

This International Standard specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes and tests at manufacture of refillable quenched and tempered seamless steel tubes of water capacities from 150 l up to and including 3 000 l for compressed and liquefied gases exposed to extreme world-wide ambient temperatures (normally between −50 °C and +65 °C). This International Standard is applicable to tubes with a maximum tensile strength R_m of less than 1 100 MPa.

These tubes can be used alone or in batteries to equip trailers or skids (ISO modules) for the transportation and distribution of compressed gases.

This International Standard does not include consideration of any additional stresses that may occur during service or transport, e.g. bending stresses, etc.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard 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[1)], *Steel — Charpy impact test (V-notch).*

ISO 6506[2)], *Metallic materials — Hardness test — Brinell test.*

ISO 6892, *Metallic materials — Tensile testing at ambient temperature.*

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

ISO 11484, *Steel tubes for pressure purposes — Qualification and certification of non-destructive testing (NDT) personnel.*

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1) To be replaced by ISO 148-1, ISO 148-2 and ISO 148-3.

2) To be replaced by ISO 6506-1, ISO 6506-2 and ISO 6506-3.

3 Definitions

For the purposes of this International Standard the following definitions apply.

3.1
yield stress
value corresponding to the 0,2 % proof stress, $R_{p\,0,2}$

3.2
quenching
hardening heat treatment in which a tube, 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 tube is heated to a uniform temperature below the lower critical point Ac_1 of the steel

3.4
tube
a double ended pressure gas cylinder manufactured from seamless tubing

3.5
batch
a quantity of up to 200 tubes of the same nominal diameter, thickness and design made from the same steel cast and subjected to the same heat treatment for the same duration of time

3.6
test pressure
required pressure (p_h) applied during a pressure test

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

4 Symbols

Symbol	Definition
a	calculated minimum thickness, in millimetres, of the cylindrical shell
a'	guaranteed minimum thickness, in millimetres, of the cylindrical shell
A	percentage elongation
D	nominal outside diameter of the tube, in millimetres
f	a constant in the design stress factor (see 11.3)
F	design stress factor (see 3.7)
L_0	original gauge length, in millimetres, according to ISO 6892
p_h	hydraulic test pressure, in bar[a] above atmospheric pressure
R_e	guaranteed minimum value of yield stress, in megapascals[a]
R_{ea}	value of the actual yield stress, in megapascals, determined by the tensile test
R_g	guaranteed minimum value of the tensile strength, in megapascals
R_m	actual value of tensile strength, in megapascals, determined by the tensile test
S_0	original cross-sectional area of tensile test piece, in square millimetres, according to ISO 6892
a 1 bar = 100 kPa; 1 MPa = 10 bar.	

5 Inspection and testing

Evaluation of conformity is required to be performed in accordance with the relevant regulations of the country(ies) where the tubes are to be used.

In order to ensure that tubes are in compliance with this International Standard they shall be subject to inspection in accordance with clauses 9 and 10 by an authorized inspection body (hereafter referred to as “the inspector”) recognized in the countries of use. The inspector shall be competent for inspection of tubes.

6 Materials

6.1 General requirements

6.1.1 Materials for the manufacture of tubes shall meet the requirements of 6.2, 6.3 and 6.4.

Steels for the fabrication of tubes shall be of nationally or internationally recognized compositions having proven reliability. These steels shall fall within one of the chemical groups as shown in annex A.

New steel compositions, and steels for which limited experience exists in tube/cylinder service, shall be fully tested and approved by a national authority and have been manufactured from not less than five casts of steel.

The manufacturer of the finished tube shall provide a detailed specification with tolerances for the supplied tubing including:

— chemical composition;

— dimensions;

— surface quality.

6.1.2 The steel used for the fabrication of tubes shall be fully killed.

6.1.3 The manufacturer of the tubing shall supply certificates of a reference heat treatment representative of the final heat treatment.

NOTE Additional requirements related to tubes for use with embrittling gases are given in clause 11.

6.2 Controls on chemical composition

6.2.1 A steel is defined by the steel-making process and by its chemical composition.

Steel-making shall be defined by reference to a given process (oxygen converter, electric arc furnace or equivalent) and to the killing method.

The chemical composition of the steel shall be defined at least by:

— the carbon, manganese and silicon contents in all cases;

— the chromium, nickel, molybdenum, vanadium or niobium contents when these are 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, molybdenum, vanadium or niobium contents shall be given, with tolerances, such that the differences between the maximum and minimum values of the cast do not exceed the ranges shown in Table 1.

Table 1 — Chemical composition tolerances

Element	Content	Permissible range
Carbon	< 0,30 %	0,06 %
	⩾ 0,30 %	0,07 %
Manganese	all contents	0,30 %
Silicon	all contents	0,30 %
Chromium	< 1,50 %	0,30 %
	⩾ 1,50 %	0,50 %
Nickel	all contents	0,40 %
Molybdenum	all contents	0,15 %
Vanadium	all contents	0,10 %
Niobium	all contents	0,10 %

Elements not included in the declared chemical composition shall not be deliberately added. The content of such elements shall be limited to ensure that they have no detrimental effect on the properties of the finished product.

6.2.2 The maximum sulphur and phosphorus contents in the cast analysis shall not exceed 0,020 % each and their sum shall not exceed 0,030 %. Check analyses of the supplied tubing shall not exceed 0,025 % and 0,035 % respectively.

6.2.3 The manufacturer of the finished tube shall obtain and produce certificates of cast (heat) analyses of steels supplied for the construction of tubes.

6.3 Heat treatment

6.3.1 Each tube shall be heat treated, and for each stage of treatment, i.e. quenching and tempering, the heat treatment procedure shall include a record of:

— the temperature;

— the temperature holding time;

— the cooling medium.

6.3.2 Heat treatment shall be carried out in such a way that it does not induce excessive stresses which may initiate irreversible failures in the tube.

6.3.3 The austenization temperature prior to quenching shall be defined within ± 30 °C of the temperature retained for the steel type under consideration, but it shall never be less than the upper critical point (Ac_3) of the steel concerned.

6.3.4 Quenching in media other than oil or air is permissible provided that the method produce tubes free of cracks as verified by non destructive testing.

6.3.5 The tempering temperature shall be defined within ± 30 °C of the temperature for guaranteeing specified mechanical properties but shall not be less than 540 °C.

6.4 Mechanical properties

The material of the finished tube shall satisfy the requirements of 9.2 and 10.4.

6.5 Failure to meet test requirements

6.5.1 In the event of failure to meet 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 tubes of the batch to a further heat treatment.

2) If the failure is not due to the heat treatment applied, all the identified defective tubes shall be rejected or repaired by an approved method. The non-rejected and repaired tubes are then considered as a new batch.

In both cases the new batch shall be tested by the inspector. All the relevant 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 tubes of the batch shall be rejected.

6.5.2 Where reheat-treatment is required, the tubes shall be retempered or requenched and tempered.

A maximum of two reaustenitizing treatments is permitted.

Whenever tubes are reheat-treated the wall thickness can be affected by scale formation, therefore the minimum design wall thickness shall be checked in the finished tube.

7 Design

7.1 Calculation of cylindrical shell thickness

The guaranteed minimum thickness of the cylindrical shell (a') shall be not less than the thickness calculated using the Lamé-von Mises formula, as follows:

$$a = \frac{D}{2}\left[1 - \sqrt{\frac{10\,FR_e - \sqrt{3}p_h}{10\,FR_e}}\right]$$

where the value of F is the lesser of $\dfrac{0{,}65}{R_e/R_g}$ or 0,85

R_e/R_g shall not exceed 0,90.

Additional requirements related to tubes for use with embrittling gases are given in clause 11.

NOTE Regional international agreements may limit the magnitude of the F factor used for design.

7.2 Design of tube ends

Tube ends shall be approximately hemispherical with thickness not less than the calculated minimum wall thickness, a.

The dimensions of the tube end profiles shall be specified for each design taking into consideration the stress distribution and the manufacturing process.

To permit internal visual inspection of the tube, an adequate opening shall be provided at the neck ends. The nominal diameter of the opening shall be greater than D/12.

NOTE Stress analysis should be carried out to ensure that design limits are not exceeded, in particular where this opening is large.

When the tube ends are threaded, the thickness at the thread root shall be sufficient to take into account the developed stress in this part.

8 Construction and workmanship

8.1 General

The tube shall be manufactured from seamless steel tubing, typically hot rolled, extended or forged.

The ends shall be hot formed using either forging or spinning methods.

Metal shall not be added in the process of closure of the end.

Repair of defects by welding is prohibited.

8.2 Wall thickness

Each length of supplied tubing shall be examined to determine thickness.

The wall thickness at any point shall be not less than the minimum thickness specified.

Checking for wall thickness shall be by the ultrasonic method in accordance with annex B.

8.3 Surface defects

The internal and external surfaces of the finished tube shall be free from defects which would adversely affect the safe working of the tube. See annex C for examples of defects and guidance on their evaluation.

8.4 Ultrasonic examination

Each tube shall be ultrasonically examined for defects in accordance with annex B.

Examination of tubes to be used for embrittling gases (e.g. hydrogen) shall be carried out both on the supplied tubing and at completion of tube manufacture. For tubes containing other gases examination may be carried out either during or at the completion of manufacture.

8.5 End closure (fitting)

Closure of the finished tube shall be accomplished by a method other than welding, brazing or brazewelding, and shall be capable of preventing leakage.

8.6 Dimensional tolerances

8.6.1 Out-of-roundness

The out-of-roundness of the cylindrical shell, i.e. the difference between the maximum and minimum outside diameters at the same cross-section, shall not exceed 2 % of the mean value of these diameters measured at least at the quarter and mid-length locations on the tube.

8.6.2 Outside diameter

The mean external diameter shall not deviate by more than ± 1 % from the nominal design diameter; this shall be verified at the quarter and mid-length locations on the tube.

8.6.3 Straightness

The maximum deviation of the cylindrical part of the shell from a straight line shall not exceed 3 mm per metre length.

8.6.4 Eccentricity

The values of the minimum and maximum thicknesses shall differ by no more than 12,5 % from the mean value of these two thicknesses; this shall be verified at least at the quarter and mid-length locations on the tubes.

8.6.5 Length

The tolerance on the design overall length of the tube only, excluding fittings, shall not exceed the lesser of ± 1,5 % or ± 50 mm.

8.6.6 Water capacity

The tolerance on the design water capacity shall be within the range $^{+10}_{0}$ %.

8.6.7 Mass

The tolerance on design mass of any individual tube shall not exceed ± 10 %.

If tubes are intended to constitute a battery, the tolerance on the shipment average tube mass shall be within the range $^{+5}_{-10}$ % of the unit design mass.

9 Batch tests

9.1 General requirements

The following tests and inspections shall be carried out under the responsibility of the inspector (see clause 5).

NOTE The type approval procedures normally used for cylinders of nominal water capacity less than 150 l are not applicable to the production runs for tubes.

9.2 Mechanical tests

9.2.1 General

From each production batch, test pieces shall be selected for mechanical testing from a ring of material of minimum length 200 mm taken from supplied tubing which is representative of the final condition of the tube(s), including any heat treatment.

The sample as defined above shall be placed so it is subjected at the same time as the tube(s) to the same heat treatment conditions, including with respect to single- or double-sided quenching.

9.2.2 Tensile test

The test shall be carried out in accordance with ISO 6892 on a cylindrical proportional test piece taken longitudinally (along the axis of the ring) in the ring wall and machined. The gauge length of the test piece L_0 shall be equal to $5{,}65\sqrt{S_0}$

The results of the tensile test shall be at least equal to the minimum guaranteed values of the properties, and in all cases:

— R_m shall not exceed 1 100 MPa;

— the elongation after fracture shall be not less than 14 %;

— the ratio R_{ea}/R_m shall be not more than 0,95.

NOTE Additional requirements related to tubes for use with embrittling gases are given in clause 11.