INTERNATIONAL STANDARD

ISO 11120

Second edition
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Gas cylinders — Refillable seamless steel tubes of water capacity between 150 l and 3000 l — Design, construction and testing

Bouteilles à gaz — Tubes en acier sans soudure rechargeables d'une contenance en eau de 150 l à 3000 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.

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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 58, *Gas cylinders*, Subcommittee SC 3, *Cylinder design*.

This second edition cancels and replaces the first edition (ISO 11120:1999), which has been technically revised by the following:

— Annex A "Typical chemistry groupings for seamless steel tubes" is informative;

— nickel chromium molydbenum steel has been added in 6.1.1 and Annex A as Group V;

— reduction of maximum sulfur content in 6.2.2 from 0,020 % to 0,010 %; also the sum of sulfur and phosphorus is reduced from 0,030 % to 0,025 %;

— the modification of ultrasonic provisions for ultrasonic examination in 8.3 to include ultrasonic examination for wall thickness and for imperfections also on the supplied tubing;

— "Type Approval Procedure" has been introduced in Clause 9;

— the provisions for design of tubes for embrittling gases have been revised.

It also incorporates ISO 11120:1999/Amd 1:2013.

Introduction

This International Standard provides a specification for the design, manufacture, inspection and testing of tubes at the time of manufacture 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. It does not reflect on the suitability of the practice of any nation or region.

This International Standard 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 it is suitable for use with the conformity assessment system for UN pressure receptacles of the above-mentioned Model Regulations.

Gas cylinders — Refillable seamless steel tubes of water capacity between 150 l and 3000 l — Design, construction and testing

1 Scope

This International Standard specifies minimum requirements for the material, design, construction and workmanship, manufacturing processes, examinations and tests at manufacture of refillable quenched and tempered seamless steel tubes of water capacities exceeding 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_{ma}, of less than 1 100 MPa. These tubes can be used alone or in batteries to equip trailers or multiple element gas containers (ISO modules or skids) for the transportation and distribution of compressed gases.

This International Standard is applicable to tubes having an opening at each end.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 148-2, *Metallic materials — Charpy pendulum impact test — Part 2: Verification of testing machines*

ISO 148-3, *Metallic materials — Charpy pendulum impact test — Part 3: Preparation and characterization of Charpy V-notch test pieces for indirect verification of pendulum impact machines*

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

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

ISO 6506-2, *Metallic materials — Brinell hardness test — Part 2: Verification and calibration of testing machines*

ISO 6506-3, *Metallic materials — Brinell hardness test — Part 3: Calibration of reference blocks*

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

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 metallic materials resistant to hydrogen embrittlement*

ISO 13769, *Gas cylinders — Stamp marking*

3 Terms and definitions

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

3.1
yield strength
stress value corresponding to the upper yield strength, R_{eH}, or, for steels that 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.

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
toughening 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
seamless transportable pressure receptacle of a water capacity exceeding 150 l but not more than 3 000 l

3.5
batch
quantity of up to 30 tubes of the same nominal diameter, thickness and design made successively from the same steel cast and processed in the same heat treatment equipment (i.e. a continuous furnace process or a single furnace charge, for both austenitization and tempering) using the same heat treatment parameters

3.6
test pressure
p_h
required pressure applied during a pressure test

Note 1 to entry: It is used for tube wall thickness calculation.

3.7
design stress factor
F
ratio of the equivalent wall stress at test pressure, p_h, to guaranteed minimum yield strength, R_{eg}

3.8
laminar imperfection
any imperfection lying essentially parallel to the tube surface, within the thickness of the product

3.9
working pressure
settled pressure of a compressed gas at a uniform reference temperature of 15 °C in a full tube

4 Symbols

a Calculated minimum thickness, in millimetres, of the cylindrical shell

a' Guaranteed minimum thickness, in millimetres, of the cylindrical shell

A Percentage elongation after fracture

D Nominal outside diameter of the tube, in millimetres

f A constant in the design stress factor (see 12.3)

F Design stress factor (variable) (see 3.7)

L_0 Original gauge length, in millimetres, according to ISO 6892-1

p_h Hydraulic test pressure, in bar[1)], above atmospheric pressure

p_w Working pressure, in bars, above atmospheric pressure

R_{eg} Minimum guaranteed value of yield strength, in megapascals

R_{ea} Actual value of the yield strength, in megapascals, as determined by the tensile test (see 10.2.2)

R_{mg} Minimum guaranteed value of the tensile strength, in megapascals

R_{ma} Actual value of tensile strength, in megapascals, as determined by the tensile test (see 10.2.2)

$R_{m\ max}$ Maximum guaranteed value of the tensile strength, in megapascals

S_0 Original cross-sectional area of tensile test piece, in square millimetres, according to ISO 6892-1

1) 1 bar = 10^5 Pa = 10^5 N/m^2

5 Inspection and testing

Evaluation of conformity shall be carried out in accordance with the applicable regulations of the countries of use.

To ensure that the tubes conform to this International Standard, they shall be subject to inspection and testing in accordance with Clauses 9, 10 and 11 by an inspection body, hereafter referred to as the "Inspection Body", 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 tubes shall meet the requirements of 6.2, 6.3 and 6.4.

Steel for the fabrication of tubes shall be of nationally or internationally recognized compositions having proven reliability. Tubes shall be manufactured from carbon steel, carbon manganese steel, chromium-molybdenum steel, nickel-chromium-molybdenum steel, chromium-molybdenum-vanadium steel, or a similar alloy steel.

NOTE Steels of the types shown in Annex A have been proven to be acceptable by experience.

The steel shall be at least 95 % iron. New steel compositions, and steels for which limited experience exists in tube/cylinder service, shall be fully tested and approved by an authorized body 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, and

— surface quality.

6.1.2 The material used for the manufacture of tubes shall be steel, other than rimming quality, fully killed with aluminium and/or silicon.

The material shall have non-ageing properties, having a sufficient amount of nitrogen binding elements (e.g. Al ≥ 0,015 %).

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 shall be part of the order.

6.1.3 In order to prove the heat treatability of a certain tube type, it is recommended that the manufacturer of the tubing supply a certificate of mechanical properties, as a guidance to the tube manufacturer to achieve the properties required by this International Standard. This certificate is obtained carrying out a reference heat treatment, representative of the final heat treatment, on a sample of tubing.

6.1.4 The tube manufacturer shall establish means to identify the tubes with the cast of steel from which they are made.

6.1.5 Grades of steel used for tube manufacture shall be compatible with the intended gas service, e.g. corrosive gases and embrittling gases (see ISO 11114-1).

NOTE Additional requirements related to tubes for use with embrittling gases are given in Clause 12.

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, and

— the maximum sulfur 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	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
Chromium	<1,50	0,30
	≥1,50	0,50
Nickel	All values	0,40
Molybdenum	All values	0,15

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.

The combined content of the elements vanadium, niobium, titanium, boron and zirconium, shall not exceed 0,15 %. This requirement shall not apply to Group IV steels as per Annex A.

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 The maximum sulfur and phosphorus contents in the cast and check analyses shall not exceed 0,010 % and 0,020 %, respectively, and their sum shall not exceed 0,025 %.

6.2.3 The manufacturer of the finished tube shall obtain and make available the certificate of cast (heat) analyses of the steel supplied for the construction of the tube.

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, and

— the cooling medium.

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

6.3.3 The austenitization temperature prior to quenching shall be within ±30 °C of the temperature retained for the steel type concerned, 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 produces tubes free of cracks as verified by non-destructive examination.

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

6.4 Mechanical properties

The mechanical properties of the finished tube or the test ring shall be verified according to 10.2 and 11.3 and the results shall be in compliance with the design drawing.

6.5 Failure to meet test requirements

6.5.1 In this clause, test requirements cover only the tests required in Clauses 9, 10 and 11.

6.5.2 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 tubes do not meet the required mechanical properties due to the heat treatment applied, the manufacturer may subject all the tubes of the batch to one further heat treatment or reject the corresponding tubes. If one or more tests prove even partially unsatisfactory results, all the tubes of the batch shall be rejected.

2) If the failure is due to a cause other than the heat treatment applied, all tubes with imperfections shall be either rejected or repaired such that the repaired tubes pass the test(s) required for the repair. They shall then be re-instated as part of the original batch.

6.5.3 Where reheat-treatment is required, the tubes shall be re-tempered or re-quenched and tempered. A maximum of two austenitizing treatments is permitted. Whenever tubes are reheat-treated, the wall thickness can be affected by scale formation, therefore the guaranteed minimum 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:

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

where the value of F is the lesser of $0{,}65/(R_{eg}/R_{mg})$ or 0,85.

R_{eg}/R_{mg} shall not exceed 0,90.

Additional requirements related to tubes for use with embrittling gases are given in Clause 12.

NOTE 1 It is generally assumed that $p_h = 1{,}5p_w$ for compressed gases for tubes designed and manufactured to conform with this International Standard.

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 F, torsional stresses, dynamic loadings etc.) 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 can be necessary to consider potential bending stresses. For general guidance, see Annex F.

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 $D/12$. However, internal diameters of neck openings may be smaller provided appropriate tools are used to perform the visual inspection, i.e. bore scope, mirrors, high intensity lighting, etc.

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.

NOTE Stress analysis should be carried out to ensure that design limits are not exceeded.

7.3 Design drawing

A fully dimensioned drawing shall be prepared which includes the specification of the material such as heat treatment details, guaranteed mechanical properties and mass of the tube.

8 Construction and workmanship

8.1 General

The tube shall be manufactured from seamless steel tubing, typically hot rolled, extended/extruded 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.

Defects shall not be repaired by welding.

8.2 Surface imperfections

The internal and external surfaces of the finished tube shall be free from imperfections which could adversely affect the safe working of the tube.

NOTE See Annex C for examples of imperfections and guidance on their evaluation.

The machined surfaces of the neck shall be inspected with a non-destructive examination method acceptable to the Inspection Body, such as magnetic particle inspection (see ISO 10893-5), dye penetrant methods (see ISO 10893-4), eddy current (see ISO 10893-2), etc., to ensure that they are free from imperfections.

8.3 Ultrasonic examination

After completion of the final heat treatment and any operation resulting in loss of wall thickness (e.g. grinding or machining), each tube shall be ultrasonically examined for internal and external defects and laminar imperfections and to determine wall thickness in accordance with Annex B.

An ultrasonic examination for imperfections and wall thickness, in accordance with Annex B, shall also be carried out on the supplied tubing.

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

8.4 End closure (fitting)

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

8.5 Dimensional tolerances

8.5.1 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.

8.5.2 Outside diameter

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