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Gas cylinders — Refillable permanently mounted composite tubes for transportation

Bouteilles à gaz — Tubes composites rechargeables montés de façon permanente pour le transport

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.

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 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*.

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, and initial inspection and testing of composite tubes permanently mounted in a transport frame for worldwide usage. Current standards, such as ISO 11515 and ISO 11119, do not address the interaction between the tubes and the transport frame.

This document aims to eliminate existing concerns about duplicate inspection and restrictions because of the lack of definitive International Standards and should not be construed as reflecting on the suitability of the practice of any nation or region.

This document has been written so that it is suitable to be referenced in the UN Model Regulations[6].

This document addresses tubes of larger volume than previous standards.

This document is not applicable to on-board fuel cylinders in natural gas vehicles.

Annexes B to F are informative. Annex A is normative.

Gas cylinders — Refillable permanently mounted composite tubes for transportation

1 Scope

This document specifies the minimum requirements for the material, design construction and workmanship, manufacturing processes, examination and testing at time of manufacture of an assembly of permanently mounted composite tube(s) in a frame with associated components.

Tubes covered by the requirements of this document are:

a) of composite construction, permanently mounted in a transport frame and suitable for specified service conditions, designated as:

   1) Type 3 – a fully wrapped tube with a seamless metallic liner and composite reinforcement on both the cylindrical part and the dome ends; or

   2) Type 4 – a fully wrapped tube with a non-load sharing liner and composite reinforcement on both the cylindrical part and the dome ends.

b) with water capacities from 450 l up to and including 10 000 l;

c) containing compressed gases but excluding:

   1) liquefied gases,

   2) dissolved gases, and

   3) gases and gas mixtures which are classified for transport as toxic or oxidizing;

d) with working pressure up to 1 000 bar.

This document does not address tubes with working pressure times water capacity (p × V) more than 3 000 000 bar·l.

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 306, *Plastics — Thermoplastic materials — Determination of Vicat softening temperature (VST)*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

ISO 1496-3:1995, *Series 1 freight containers — Specification and testing — Part 3: Tank containers for liquids, gases and pressurized dry bulk*

ISO 2808, *Paints and varnishes — Determination of film thickness*

ISO 4624, *Paints and varnishes — Pull-off test for adhesion*

ISO 7866:2012, *Gas cylinders — Refillable seamless aluminium alloy gas cylinders — Design, construction and testing*

ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests*

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 9809-2, *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*

ISO 9809-3, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 3: Normalized steel cylinders*

ISO 10156, *Gas cylinders — Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets*

ISO 10286, *Gas cylinders — Terminology*

ISO 10298, *Gas cylinders — Gases and gas mixtures — Determination of toxicity for the selection of cylinder valve outlets*

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

ISO 11114-2, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 2: Non-metallic materials*

ISO 11120:2015, *Gas cylinders — Refillable seamless steel tubes of water capacity between 150 l and 3000 l — Design, construction and testing*

ISO 11439:2013, *Gas cylinders — High pressure cylinders for the on-board storage of natural gas as a fuel for automotive vehicles*

ISO 13341, *Gas cylinders — Fitting of valves to gas cylinders*

ISO 13769, *Gas cylinders — Stamp marking*

ISO 14130, *Fibre-reinforced plastic composites — Determination of apparent interlaminar shear strength by short-beam method*

ISO 14456, *Gas cylinders — Gas properties and associated classification (FTSC) codes*

ASTM D522, *Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings*

ASTM D1308, *Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes*

ASTM D2794, *Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)*

ASTM D3170, *Standard Test Method for Chipping Resistance of Coatings*

ASTM D3418, *Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry*

ASTM D4814, *Standard Specification for Automotive Spark-Ignition Engine Fuel*

ASTM G154, *Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials*

NACE/TM 0177-2016[1)], *Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H2S Environments*

INTERNATIONAL MARITIME ORGANIZATION. International Convention for Safe Containers, 1972

1) NACE standards are available from NACE International, PO Box 218340 Houston, Texas 77218-8340, U.S.A.

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 10286 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
autofrettage
pressure application procedure which strains the metal liner past its yield strength sufficient to cause permanent plastic deformation, and results in the liner having compressive stresses and the fibres having tensile stresses when at zero internal gauge pressure

3.2
autofrettage pressure
pressure within the over-wrapped tube at which the required distribution of stresses between the liner and the over-wrap is established

3.3
composite tube
tube made of resin-impregnated continuous filament wound over liner

3.4
finished tubes

completed tubes which are ready for use, typical of normal production, complete with identification marks and external coating including integral insulation specified by the manufacturer, but free from non-integral insulation or protection

3.5
liner
inner portion of a composite tube, comprising a metallic (seamless) or non-metallic (seamless or welded) vessel, whose purpose is both to contain the gas and transmit the gas pressure to the composite overwrap

3.6
overwrap
reinforcement system of filament and resin applied over the liner

3.7
test pressure
required pressure applied during a pressure test

3.8
working pressure
settled pressure at uniform temperature of 15 °C

3.9
oxidizing gas
gas containing more than the equivalent of 30 bar partial pressure of oxygen

Note 1 to entry: See ISO 14456.

3.10
non-load sharing liner
non-metallic liner that has a burst pressure less than 5 % of the nominal burst pressure of the finished composite tube

3.11
load sharing liner
liner that has a burst pressure greater than or equal to 5 % of the nominal burst pressure of the finished composite tube

3.12
permanently mounted composite tubes
tubes mounted in an ISO frame or tube trailer for transportation as a unit, such that tools are required to remove them, and not intended to be transported or used outside of the ISO frame or tube trailer

3.13
settled pressure
pressure of the contents of a pressure receptacle in thermal and diffusive equilibrium

3.14
polymer
large, chain-like molecule made up of monomers, which are small molecules, and can be naturally occurring or synthetic

Note 1 to entry: For use in this document, includes polymer mixtures, additives, plastics, and other non-metallic materials suitable for use as a non-load sharing liner.

4 Basis for the design requirements

4.1 General

WARNING — The combination of pressure and volume up to 3 000 000 bar·l represents a substantial amount of energy that has to be taken into consideration with regard to the intended service (e.g. safety distances to be established in case of an incident).

The requirements specified in this clause are provided as the basis for the design, manufacture, inspection, testing and approval of tubes that are to be permanently mounted in a frame and used to transport gases at ambient temperatures. The requirements do not include vacuum service.

4.2 Design life

Design life shall be specified by the manufacturer and demonstrated by design prototype testing. The minimum design life shall be 15 years and the maximum design life shall be 30 years, except that the maximum design life for Type 3 tubes with carbon steel liners shall be 20 years.

4.3 Design number of filling cycles

Tubes shall be designed to be filled 750 times per year of design life.

4.4 Temperature range

4.4.1 Gas temperature

Tubes shall be designed to have a settled gas temperature of not less than −40 °C and not more than +65 °C.

NOTE Developed gas temperatures in the tubes during filling and discharge can vary beyond these limits.

4.4.2 Tube material temperature

Tubes shall be designed to be suitable for external exposure to temperatures from −40 °C to 82 °C.

Temperatures over +65 °C shall be sufficiently local, or of short duration, such that the bulk temperature of gas in the tube does not exceed +65 °C.

4.5 Gas compatibility

Compatibility of the liner shall be demonstrated for the intended content for all pressure and temperature ranges (e.g. by reference to ISO 11114-1, ISO 11114-2, reference to current use, or verification of key properties following exposure).

Type 3 tubes with steel liners shall not carry CNG for which the chemical composition is not in accordance with ISO 11439:2013, 4.5.

NOTE See ISO 11120:2015, Clause 12 for additional guidance on requirements for embrittling gases.

4.6 Prohibited gases

The tubes shall not be filled with oxidizing gas, with toxic gases, or with dissolved or liquified gases as specified in ISO 10156, ISO 10298 and ISO 14456.

4.7 External environment

General compatibility with environmental fluids shall be demonstrated by conducting testing as specified in A.8.

5 Conformity

5.1 General

To ensure that the tubes conform to the requirements of this document, they shall be subject to inspection and testing in accordance with Clauses 5, 6, and 7.

Equipment used for measurement, testing and examination during production shall be maintained and calibrated.

5.2 Design documentation

5.2.1 General

Type approval consists of:

a) Tube design approval, comprising submissions of information by the manufacturer to the inspector, as detailed in 5.2.2.

b) Prototype testing of the tube, comprising testing carried out under the supervision of the inspector. The tube material, design, manufacture and examination shall be shown to be satisfactory for the intended service by meeting the requirements of 6.5.

c) Frame design approval, comprising submissions of information by the manufacturer to the inspector, as detailed in 5.2.3.3.

d) Prototype testing for the mounting frame. The mounting frame material, design, manufacture and examination shall be proved to be adequate for its intended service by meeting the requirements of Clause 9.

The test data shall also document the dimensions and weights of each of the test tubes.

5.2.2 Tube design verification

Design verification shall include a review of the:

a) statement of service, in accordance with the requirements of 5.2.3.1;

b) design data, in accordance with the requirements of 5.2.3.2, 5.2.3.3, 5.2.3.4, and 5.2.3.5;

c) fire protection, in accordance with the requirements of 5.2.4

provided by the manufacturer who can then request the inspector to provide a design conformance report.

The title, reference number, revision number and dates of original issue and version issues of each document shall be given.

5.2.3 Statement of design intent

NOTE The purpose of this design statement is to provide guidance to the installers of tubes and users.

5.2.3.1 Statement of service

The statement of service shall include:

a) a statement that the tube design is suitable for use in the service conditions defined in Clause 4 for the service life of the tube;

b) a statement of the design life;

c) a specification for fire protection, such as the pressure relief devices, and insulation if provided;

d) a specification for the support methods (i.e. boss or strap mount) and protective coatings if applicable;

e) a description of the tube design;

f) a description of the filling/emptying interfaces (e.g. threaded interfaces), with specifications as required;

g) a reference to operational controls required for filling and emptying;

h) a statement of the impact resistance level.

5.2.3.2 Tube drawings

Drawings and supporting documents shall include at least:

a) a title, reference number, date of issue, and revision numbers with dates of issue if applicable;

b) a reference to this document (ISO 17519: 2019);

c) all dimensions and tolerances, including key subcomponents (e.g. liners and bosses);

d) mass, complete with tolerance of finished tubes;

e) all material specifications, including fibres, resins, and key subcomponents (e.g. bosses, liner), complete with minimum mechanical or tolerance ranges, and heat treatment;

f) method of manufacture for subcomponents and overwrap, including key process specifications, the number and type of strands used in the winding band, number of layers, and layer orientation;

g) test pressure and working pressure of the tube, and minimum burst pressure of the liner for Type 3 tubes;

h) autofrettage pressure and approximate duration (if applicable);

i) maximum developed pressure at 65 °C for specific gas to be transported (if applicable);

j) details of the fire protection system and of any exterior protective coating;

k) the design life in years (minimum 15 years and maximum 30 years);

l) manufacturer's recommended time in the fire if a thermally activated pressure relief device (PRD) is not used (based on time to burst during qualification testing, see A.9.6 for acceptable results and minimum time);

m) port details including thread form, sealing method, seal specification (0-ring specification if used), and installation instructions;

n) water volume of finished tube with a stated acceptance tolerance;

o) list of intended contents if intended for dedicated gas service;

p) other data required for safe operational use.

5.2.3.3 Frame drawings

Drawings shall include at least:

a) a title, reference number, date of issue, and revision numbers with dates of issue if applicable;

b) a reference to this document (ISO 17519: 2019);

c) all dimensions and tolerances;

d) mass, complete with tolerance of finished frames;

e) material specifications, complete with minimum mechanical properties or tolerance ranges;

f) other data required for safe operational use.

5.2.3.4 Stress analysis report

A stress analysis shall be carried out so as to demonstrate that the tube meets the requirements of 6.3.3.

A stress analysis shall be carried out so as to demonstrate that the frame can withstand the forces developed from the loading prescribed in 9.5, and shall show a safety factor as appropriate:

— for steels having a clearly defined yield point, a safety factor of 1,5 in relation to minimum yield strength;

— for steels with no clearly defined yield point, a safety factor of 1,5 in relation to the minimum 0,2 % offset yield strength;

— for austenitic steels, a safety factor of 1,5 in relation to the 1 % offset yield strength;

— for materials other than steel, design practices shall ensure a level of safety equivalent to those established for steel.

A table summarizing the calculated stresses shall be provided.

5.2.3.5 Material property data

A detailed description of the materials and material properties (with tolerances) used in the preparation of the stress analysis report, including any modification of material properties caused by the tube fabrication processes (e.g. heat treatment specification if applicable), including the hardness of the metallic liner, shall be provided.

Test data from samples manufactured by filament winding (or an equivalent process, to be described) shall be provided and shall at least include:

a) glass transition temperature in case of thermoset resin (ASTM D3418);

b) interlaminar shear strength of the cured composite material (ISO 14130); and

c) the suitability of the materials for service under the conditions specified in Clause 4.

5.2.4 Fire protection

The arrangement of the pressure relief and fire detection systems, and/or insulation if provided, that protects the tube from sudden rupture when it is exposed to the tests described in A.9, shall be specified. To pass the test, the tube shall meet the requirements of A.9.6.

5.2.5 Tube specification sheet

A summary of the documents providing the information required in 5.2.2 shall be listed on a specification sheet for each tube design.

5.3 Type approval

An example of a type approval document is given in the Annex B.

5.4 Assembly documentation

The assembler permanently mounting the tube in the frame, the frame manufacturer and the tube manufacturer can be separate companies. When more than one company is involved, responsibility for the final product shall be agreed between the parties involved.

Where tubes are transported to the frame manufacturer or assembler, precautions shall be taken to avoid any external impact on the tube. If it is suspected or known that the tube has had an external impact, it shall be inspected prior to assembly so as to ensure that its in-service use has not been compromised.

6 Tube requirements

6.1 Failure modes

The tube shall be designed to meet the requirements described in A.1 and A.7, thereby demonstrating either a “leakage-before-break” failure mode or the ability to cycle to test pressure a total of 3 times the expected number of pressure cycles to be seen during the lifetime of the tube.

6.2 Materials

Materials used shall meet the service conditions specified in Clause 4. The design shall ensure that incompatible materials do not come in contact with each other.

6.2.1 Liner materials

6.2.1.1 Metal liners

Seamless steel liners shall conform to the chemical composition, heat treatment, tensile test, and impact test requirements of ISO 9809-1, ISO 9809-2, ISO 9809-3 or ISO 11120, as appropriate for the steel used, and shall meet the requirements of A.20, and A.21.

Seamless aluminium alloy liners shall conform to the requirements of ISO 7866 for chemical composition, thermal treatment, tensile test, corrosion resistance (ISO 7866:2012, Annex A), and sustained load cracking resistance (ISO 7866:2012, Annex B).

Liner burst pressure shall not be more than 30 % of the minimum design burst pressure of the finished tube.

6.2.1.2 Polymer liners

The polymeric material shall be compatible with the service conditions specified in Clause 4 and the relevant requirements of ISO 11114-2.

6.2.2 Composite materials

6.2.2.1 Resins

Thermosetting or thermoplastic resins may be used. Examples of suitable matrix materials are epoxy, modified epoxy, polyester and vinyl-ester, polyurethane thermosetting resin and polyethylene, polypropylene and polyamide thermoplastic.

The glass transition temperature of a thermosetting resin material used shall be determined in accordance with the requirements of ASTM D3418 and checked against the test requirements in 6.5.2.9. The Vicat softening point of a thermoplastic resin material used shall be determined in accordance with the requirements of ISO 306.

6.2.2.2 Fibres

The structural reinforcing filament materials to be used shall be glass fibre, aramid fibre or carbon fibre or a combination of these fibres. If carbon fibre reinforcement is used, the design shall address the prevention of galvanic corrosion when it is in contact with metallic components of the tube.

The tube manufacturer shall retain:

a) specifications for composite materials;

b) the material manufacturer's recommendations for storage, conditions and shelf life; and

c) the fibre manufacturer's written confirmation that each shipment conforms to the specification requirements.

6.2.3 Metal end bosses

The metal end bosses connected to the liner shall be of a material compatible with the service conditions specified in Clause 4 and meet the relevant requirements of ISO 11114-1.

6.3 Design requirements

6.3.1 Test pressure

Test pressure shall be 1,5 times working pressure.

6.3.2 Burst pressure and fibre stress ratios

The composite over-wrap shall be designed for high reliability under sustained loading and cyclic loading and these requirements shall be achieved by meeting or exceeding the composite reinforcement stress ratio values given in Table 1.

Stress ratio is defined as the stress in the fibre at the specified minimum burst pressure divided by the stress in the fibre at working pressure.

The burst ratio is defined as the minimum design burst pressure of the tube divided by the working pressure.