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Cryogenic vessels — Large transportable vacuum-insulated vessels —

Part 1: Design, fabrication, inspection and testing

Récipients cryogéniques — Récipients transportables isolés sous vide de grande contenance —

Partie 1: Conception, fabrication, inspection et essais

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Contents

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 220, *Cryogenic vessels.*

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.

This second edition cancels and replaces the first edition (ISO 20421-1:2006), which has been technically revised. It also incorporates ISO 20421-1:2006/Cor 1:2007. The main changes compared to the previous edition are as follows:

— Subclause 12.3 has been revised;

— Annex D has been revised;

— Chinese materials have been added in Annex G.

A list of all parts in the ISO 20421 series can be found on the ISO website.

Introduction

This document has been written so that it is suitable to be referenced in the UN Model Regulations[1].

This document does not include the general vehicle requirements, e.g. running gear, brakes, lighting, etc., for which the relevant standards/regulations apply.

Cryogenic vessels — Large transportable vacuum-insulated vessels —

Part 1: Design, fabrication, inspection and testing

1 Scope

This document specifies requirements for the design, fabrication, inspection and testing of large transportable vacuum-insulated cryogenic vessels of more than 450 l volume, which are permanently (fixed tanks) or not permanently (demountable tanks and portable tanks) attached to a means of transport, for one or more modes of transport.

This document applies to large transportable vacuum-insulated cryogenic vessels for fluids specified in 3.1 and does not apply to vessels designed for toxic fluids.

This document does not include the general vehicle requirements, e.g. running gear, brakes, lighting, etc.

NOTE 1 This document does not cover specific requirements for refillable liquid-hydrogen tanks that are primarily dedicated as fuel tanks in vehicles. For fuel tanks used in land vehicles, see ISO 13985.

NOTE 2 This document does not cover specific requirements for refillable liquid hydrogen and LNG tanks that are primarily dedicated as fuel tanks in vehicles. For fuel tanks used in vehicles, see ISO 13985.

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 3834-2, *Quality requirements for fusion welding of metallic materials — Part 2: Comprehensive quality requirements*

ISO 4126-2, *Safety devices for protection against excessive pressure — Part 2: Bursting disc safety devices*

ISO 5817, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections*

ISO 9606-1, *Qualification testing of welders — Fusion welding — Part 1: Steels*

ISO 9606-2, *Qualification test of welders — Fusion welding — Part 2: Aluminium and aluminium alloys*

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

ISO 10042, *Welding — Arc-welded joints in aluminium and its alloys — Quality levels for imperfections*

ISO 10474:2013, *Steel and steel products — Inspection documents*

ISO 10675-1, *Non-destructive testing of welds — Acceptance levels for radiographic testing — Part 1: Steel, nickel, titanium and their alloys*

ISO 14732, *Welding personnel — Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials*

ISO 15613, *Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test*

ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 15614-2, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 2: Arc welding of aluminium and its alloys*

ISO 17635, *Non-destructive testing of welds — General rules for metallic materials*

ISO 17637, *Non-destructive testing of welds — Visual testing of fusion-welded joints*

ISO 20421-2, *Cryogenic vessels — Large transportable vacuum-insulated vessels — Part 2: Operational requirements*

ISO 21010, *Cryogenic vessels — Gas/material compatibility*

ISO 21011, *Cryogenic vessels — Valves for cryogenic service*

ISO 21028-1, *Cryogenic vessels — Toughness requirements for materials at cryogenic temperature — Part 1: Temperatures below -80 degrees C*

ISO 21028-2, *Cryogenic vessels — Toughness requirements for materials at cryogenic temperature — Part 2: Temperatures between -80 degrees C and -20 degrees C*

ISO 21013-3, *Cryogenic vessels — Pressure-relief accessories for cryogenic service — Part 3: Sizing and capacity determination*

ISO 23208, *Cryogenic vessels — Cleanliness for cryogenic service*

ASME VIII-2, *Rules for construction of pressure vessels, Division 2, Alternative Rules*

EN 13445-3, *Unfired pressure vessels — Part 3: Design*

3 Terms and definitions

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

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

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

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

3.1
cryogenic fluid
refrigerated liquefied gas
gas which is partially liquid because of its low temperature (see Table K.1)

Note 1 to entry: This includes totally evaporated liquids and supercritical fluids.

Note 2 to entry: In the context of this document, the refrigerated but non-toxic gases and gas mixtures given in Table K.1 are referred to as cryogenic fluids.

3.2
large transportable cryogenic vessel
tank
thermally insulated vessel of more than 450 l intended for the transport of one or more *cryogenic fluids* (3.1), consisting of an *inner vessel* (3.4), an *outer jacket* (3.5), all of the valves and *service equipment* (3.9) together with the structural parts

Note 1 to entry: The large transportable cryogenic vessel comprises a complete assembly that is ready for service.

3.3
insulation
vacuum interspace between the *inner vessel* (3.4) and the *outer jacket* (3.5)

Note 1 to entry: The space may or may not be filled with material to reduce the heat transfer between the inner vessel and the outer jacket.

3.4
inner vessel
pressure (3.16) vessel intended to contain the *cryogenic fluid* (3.1) to be transported

3.5
outer jacket
gas-tight enclosure which contains the *inner vessel* (3.4) and enables the vacuum to be established

3.6
normal operation
intended operation of the vessel at a *pressure* (3.16) not greater than the maximum allowable working pressure including the *handling loads* (3.7)

3.7
handling load
load exerted on the transportable cryogenic vessel in all normal conditions of transport including loading, unloading, moving and lifting

3.8
piping system
all pipes, tubes and associated components which can come in contact with *cryogenic fluids* (3.1) including valves, fittings, pressure-relief devices and their supports

3.9
service equipment
measuring instruments and filling, discharge, venting, safety, heating, cooling and insulating devices including any equipment for storing cooling fluids

3.10
manufacturer
<large transportable cryogenic vessel> company that carries out the final assembly, including the final acceptance test, of the *large transportable cryogenic vessel* (3.2)

3.11
gross volume
<of the inner vessel> internal volume of the *inner vessel* (3.4), excluding nozzles, pipes, etc., determined at minimum design temperature and atmospheric *pressure* (3.16)

3.12
tare mass
mass of the empty *large transportable cryogenic vessel* (3.2)

3.13
net volume
volume of the *inner vessel* (3.4), below the inlet to the relief devices, excluding nozzles, pipes, etc., determined at minimum design temperature and atmospheric *pressure* (3.16)

3.14
net mass
maximum allowable mass of the *cryogenic fluid* (3.1) which may be filled

Note 1 to entry: The maximum allowable mass is equal to the mass of the cryogenic liquid occupying 98 % of the *net volume* (3.13)of the *inner vessel* (3.4) under conditions of incipient opening of the relief device with the vessel in a level attitude and the mass of the gas at the same conditions in the remaining volume of the inner vessel.

Note 2 to entry: Cryogenic liquid helium can occupy 100 % of the volume of the inner vessel at any *pressure* (3.16).

3.15
gross mass
sum of *tare mass* (3.12) plus *net mass* (3.14)

3.16
pressure
gauge pressure
pressure relative to atmospheric pressure

3.17
fixed tank
tank vehicle
large transportable vessel permanently attached to a vehicle or to units of running gear

3.18
demountable tank
large transportable vessel non-permanently attached to a vehicle

Note 1 to entry: When attached to the carrier vehicle, the demountable tank meets the requirements prescribed for a fixed tank. It is designed to be lifted only when empty.

3.19
portable tank
a thermally insulated tank having a capacity of more than 450 litres fitted with *service equipment* (3.9) and structural equipment necessary for the transport of refrigerated liquefied gases

Note 1 to entry: It can be lifted full and loaded and discharged without removal of structural element.

Note 2 to entry: The list of the refrigerated liquefied gases is available in Annex K.

3.20
maximum allowable working pressure
ps
maximum gauge *pressure* (3.16) permissible at the top of the vessel in its normal operating position

3.21
relief plate
relief plug
plate or plug retained by atmospheric *pressure* (3.16) which allows relief of excess internal pressure, generally from the vacuum jacket

3.22
bursting disc device
non-reclosing pressure-relief device ruptured by differential *pressure* (3.16)

Note 1 to entry: It is the complete assembly of installed components including the bursting disc holder, where appropriate.

3.23
pressure-strengthened vessel
pressure (3.16) vessel which has been subjected to a calculated and controlled internal pressure (strengthening pressure) after completion, the wall thickness of which is calculated on the basis of the stress at the strengthening pressure and not on the basis of the conventional design stress value of the material used

Note 1 to entry: *Pressure* (3.16) vessels made from solution heat-treated material are subject to a controlled plastic deformation during the strengthening operation as its yield point is raised. Pressure vessels made from work-hardened material are subject to little or no plastic deformation.

3.24
residual elongation
original elongation of the steel minus the elongation created by the cold-forming deformation

3.25
leakproofness test
test using gas subjecting the shell and its *service equipment* (3.9), to an effective internal *pressure* (3.16) not less than 90 % of the MAWP but not greater than the design pressure

4 Symbols

Symbol	Definition	Unit
b	width of pad, ring or shell reinforcement	mm
c	allowance for corrosion	mm
d_i	diameter of opening	mm
d_a	outside diameter of tube or nozzle	mm
f	narrow side of rectangular or elliptical plate	mm
h	thickness of pad reinforcement	mm
l_c	cone length between effective stiffenings (see Figure 5)	mm
l	ligament (web) between two nozzles	mm
l_b, l'_b	buckling length	mm
l_s	length of nozzle reinforcement outstanding	mm
n	number of lobes	—
p	design pressure as defined in 10.3.2.2	—
p_c	calculation pressure as defined in 10.2.3.1 a)	bar (or MPa)
p_e	allowable external pressure limited by elastic buckling	bar (or MPa)
p_k	strengthening pressure	bar (or MPa)
p_L	liquid pressure	bar (or MPa)
p_p	allowable external pressure limited by plastic deformation	bar (or MPa)
p_s	maximum allowable gauge pressure	bar (or MPa)
p_T	test pressure (see 6.2)	bar (or MPa)
r	radius, e.g. inside knuckle radius of dished end and cones	mm
s	minimum thickness	mm
s_A	required wall thickness at opening edge	mm
s_e	actual wall thickness	mm
s_g	required wall thickness outside corner area	mm

s_n	length of nozzle reinforcement in stand	mm
s_S	wall thickness of nozzle	mm
s_1	required wall thickness within corner area	mm
t	in this context, centre-to-centre distance between two nozzles	mm
x	(decay-length zone) distance over which governing stress is assumed to act	mm
x_i	characteristic lengths (i = 1,2,3) to define corner area [Figure 7 a) and Figure 7 b) and 10.3.6.5.4]	mm
η	factor indicative of the utilization of the permissible design stress in joints or factor allowing for weakenings	—
A	cross-sectional area of reinforcing element	mm^2
C, β	design factors	—
D	shell diameter	mm
D_a	outside diameter, e.g. of a cylindrical shell	mm
D_{a1}	outside diameter of connected cylinder (see Figure 7)	mm
D_{a2}	outside diameter at effective stiffening (see Figure 9)	mm
D_i	internal diameter, e.g. of a cylindrical shell	mm
D_k	design diameter (see Figure 7)	mm
D_s	shell diameter at nozzle (see Figure 8)	mm
E	Young's modulus	N/mm^2
I	moment of inertia of reinforcing element	mm^4
R_e	minimum guaranteed yield stress or 0,2 % proof stress at 20 °C (1 % proof stress for austenitic steel)	N/mm^2
R_m	minimum guaranteed tensile strength at 20 °C	N/mm^2
K	material property used for design (see 10.3.2.3)	N/mm^2
K_T	material property at temperature T in °C (e.g. K_{20} for material property at 20 °C (see 10.3.2.3.2)	N/mm^2
R	radius of curvature, e.g. inside crown radius of dished end	mm
S	safety factor at design pressure, in relation with R_e	—
S_k	safety factor against elastic buckling at design pressure	—
S_p	safety factor against plastic deformation	—
Z	auxiliary value	—

v	Poisson's ratio	—
u	out of roundness (see 11.5.5.2)	—
φ	cone angle	°

5 General requirements

5.1 The large transportable cryogenic vessel shall safely withstand the mechanical and thermal loads and the chemical effects encountered during pressure test and normal operation. These requirements are deemed to be satisfied if Clauses 6 to 12 are fulfilled. The vessel shall be marked in accordance with Clause 13, tested in accordance with Clause 14 and operated in accordance with ISO 20421-2.

5.2 Large transportable cryogenic vessels shall be equipped with valves, pressure-relief devices, etc., configured and installed in such a way that the vessel can be operated safely. The number of openings in the inner vessel for this equipment shall be kept to a minimum.

5.3 The large transportable cryogenic vessel shall be clean for the intended service in accordance with ISO 23208.

5.4 The manufacturer shall retain the documents referred to in Clause 16, and all supporting documentation (including that from his subcontractors, if any), for a required period (e.g. product liability). In addition, the manufacturer shall retain all supporting and background documentation (including that from his subcontractors, if any) which establishes that the vessel conforms to this document.

6 Mechanical loads

6.1 General

The large transportable cryogenic vessel shall resist the mechanical loads mentioned in 10.2.3 without such deformation which can affect safety and which can lead to leakage. This requirement can be validated by:

— the calculation;

— the calculation and pressure-strengthening method, if allowed;

— the calculation and experimental method.

6.2 Load during the pressure test

The load exerted during the pressure test shall be calculated with Formula (1):

$$p_T \geq 1{,}3(p_S + 1)\,\text{bar} \;\text{ or }\; \left[p_T \geq 1{,}3(p_S + 0{,}1)\ \text{MPa}\right] \quad (1)$$

where

p_T is the test pressure (in bar);

p_S is the maximum allowable pressure (in bar);

+1 is the allowance for external vacuum (in bar).

+0,1 is the allowance for external vacuum (in MPa).

7 Chemical effects

Due to operating temperatures and the materials of construction, the possibility of chemical action on the inner surfaces in contact with the cryogenic fluids can be neglected.

Due to the fact that the inner vessel is inside an evacuated outer jacket, neither external corrosion of the inner vessel, nor corrosion on the inner surfaces of the outer jacket will occur. Therefore, inspection openings are not required in the inner vessel or the outer jacket.

Corrosion allowance is also not required on surfaces in contact with the operating fluid or exposed to the vacuum interspace between the inner vessel and the outer jacket.

The material and the protection for the surfaces exposed to the atmosphere shall be suitable for intended use (e.g. resistant to industrial and marine atmospheres).

8 Thermal conditions

The following thermal conditions shall be taken into account:

For the inner vessel and its associated equipment the full range of temperature expected.

For the outer jacket and equipment thereof (other than equipment covered in Clause 7):

— a minimum working temperature of −20 °C;

— a maximum working temperature of 50 °C.

NOTE 1 Some locations require lower minimum working temperature e.g. −40 °C and/or higher maximum working temperature, e.g. +65 °C.

NOTE 2 This does not apply if the jacket is designed for a lower temperature to be marked on the nameplate.

9 Materials

9.1 Selection of materials

9.1.1 Materials which are, or can be, in contact with cryogenic fluids shall be in accordance with ISO 21010.

9.1.2 Materials used at low temperatures shall follow the requirements of the relevant parts of ISO 21028-1 and ISO 21028-2; for non-metallic materials, low-temperature suitability shall be validated by an experimental method, taking into account operating temperatures.

9.1.3 The base materials, listed in Annex G, subject to meeting the extra requirements given in Clauses 5 to 16, are suitable for and may be employed in the manufacture of the cryogenic vessels, in conformance with this document.

9.2 Inspection documentation

9.2.1 The material according to ISO 21028-1 and ISO 21028-2 shall be declared by an inspection certificate 3.1 in accordance with ISO 10474:2013, 5.1.

9.2.2 The material manufactured to a recognized International Standard shall meet the testing requirements of ISO 21028-1 and ISO 21028-2 and shall be declared by an inspection certificate 3.1 in accordance with ISO 10474:2013, 5.1.

9.2.3 The delivery of material which is not manufactured to a recognized International Standard shall be guaranteed by an inspection certificate 3.2 in accordance with ISO 10474:2013, 5.2 confirming that the material fulfils the requirements in 9.1. The material manufacturer shall follow a recognized International Standard for processing and establishing the guaranteed material properties.

9.2.4 The outer jacket and the equipment not subjected to low temperature shall be manufactured from material suitable for the intended service.

10 Design

10.1 Design options

10.1.1 General

The design shall be carried out in accordance with one of the options given in 10.1.2, 10.1.3 or 10.1.4.

Metallic materials used at cryogenic temperatures shall meet the requirements of the relevant clauses of ISO 21028-1 and ISO 21028-2.

In the case of 9 % Ni steel, the additional requirements in Annex C shall be satisfied.

10.1.2 Design by calculation

Calculation of all pressure- and load-bearing components shall be carried out. The pressure part thicknesses of the inner vessel and outer jacket shall not be less than required by 10.3. Additional calculations may be required to ensure the design is satisfactory for the operating conditions including an allowance for dynamic loads.

10.1.3 Design by calculation and pressure strengthening

The pressure-retaining capability of inner vessels manufactured from austenitic stainless steel, strengthened by pressure, shall be calculated in accordance with Annex D.

10.1.4 Design of components by calculation supplemented with experimental methods

Where it is not possible to design non-inner vessel components by calculation alone, planned and controlled experimental means may be used provided that the results confirm the safety factors required in 10.3. An example is the application of strain gauges to assess stress levels.

10.2 Common design requirements

10.2.1 General

The requirements of 10.2.2 to 10.2.7 are applicable to all vessels irrespective of the design option used.

In the event of an increase in at least one of the following parameters, the initial design process shall be repeated to take account of these modifications:

— maximum allowable pressure;

— specific mass (density) of the densest gas for which the vessel is designed;

— maximum tare weight of the inner vessel;

— nominal length and/or diameter of the inner shell.