INTERNATIONAL STANDARD

**ISO 20421-1**

First edition
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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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# 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 20421-1 was prepared by Technical Committee ISO/TC 220, *Cryogenic vessels*.

ISO 20421 consists of the following parts, under the general title *Cryogenic vessels — Large transportable vacuum-insulated vessels*:



— *Part 1: Design, fabrication, inspection and testing*

— *Part 2: Operational requirements*

# Cryogenic vessels — Large transportable vacuum-insulated vessels —

# Part 1: Design, fabrication, inspection and testing

## 1 Scope

This part of ISO 20421 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 part of ISO 20421 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 part of ISO 20421 does not include the general vehicle requirements, e.g. running gear, brakes, lighting, etc., which are in accordance with the relevant standards/regulations.

This International Standard 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.



## 2 Normative references

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

ISO 4136, *Destructive tests on welds in metallic materials — Transverse tensile test*

ISO 5173, *Destructive tests on welds in metallic materials — Bend tests*

ISO 9016, *Destructive tests on welds in metallic materials — Impact tests — Test specimen location, notch orientation and examination*

ISO 9606-1, *Approval 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 personnel*

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

ISO 14732, *Welding personnel — Approval testing of welding operators for fusion welding and of resistance weld setters for fully mechanized and automatic welding of metallic materials*

ISO 15607, *Specification and qualification of welding procedures for metallic materials — General rules*

ISO 15613, *Specification and approval 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 — Part 1: Welding procedure tests for the arc welding of steels*

ISO 15614-2, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedure tests for the arc welding of aluminium and its alloys*

ISO 15614-3, *Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for the arc welding of aluminium and its alloys*

ISO 17636, *Non-destructive examination of welds — Radiographic 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 21013-1, *Cryogenic vessels — Safety devices for protection against excessive pressure — Part 1: Reclosable pressure-relief valves*



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 23208, *Cryogenic vessels — Cleanliness for cryogenic service*

ASME VIII-2

EN 1708-1, *Welding — Basic weld joint details in steel — Part 1: Pressurized components*

EN 10028-4, *Flat products made of steels for pressure purposes — Part 4: Nickel alloy steels with specified low temperature properties*

EN 10028-7, *Flat products made of steels for pressure purposes — Part 7: Stainless Steels*

EN 12300, *Cryogenic vessels — Cleanliness for cryogenic service*

EN 13068-3, *Non-destructive testing — Radioscopic testing — Part 3: General principles of radioscopic testing of metallic materials by X- and gamma rays*

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

EN 13445-4, *Unfired pressure vessels — Part 4: Fabrication*

*UN Recommendations on the transport of dangerous goods — Model regulations (12th revised edition)*

## 3 Terms and definitions

For the purposes of this part of ISO 20421, the following terms and definitions apply.

**3.1**
**cryogenic fluid**
refrigerated liquefied gas
gas which is partially liquid because of its low temperature

NOTE 1 This includes totally evaporated liquids and supercritical fluids.

NOTE 2 In the context of this part of ISO 20421, the refrigerated but non-toxic gases and gas mixtures given in Table 1 are referred to as cryogenic fluids.

**Table 1 — Refrigerated but non-toxic gases**

| Classification code | Identification number, name and description [a] | |
|---|---|---|
| 3 °A | **Asphyxiant gases** | |
| | 1913 | Neon, refrigerated liquid |
| | 1951 | Argon, refrigerated liquid |
| | 1963 | Helium, refrigerated liquid |
| | 1970 | Krypton, refrigerated liquid |
| | 1977 | Nitrogen, refrigerated liquid |
| | 2187 | Carbon dioxide, refrigerated liquid |
| | 2591 | Xenon, refrigerated liquid |
| | 3136 | Trifluoromethane refrigerated liquid |
| | 3158 | Gas, refrigerated liquid, N.O.S. (not otherwise specified) |
| 3 °O | **Oxidizing gases** | |
| | 1003 | Air, refrigerated liquid |
| | 1073 | Oxygen, refrigerated liquid |
| | 2201 | Nitrous oxide, refrigerated liquid, oxidizing |
| | 3311 | Gas, refrigerated liquid, oxidizing, N.O.S. |
| 3 °F | **Flammable gases** | |
| | 1038 | Ethylene, refrigerated liquid |
| | 1961 | Ethane, refrigerated liquid |
| | 1966 | Hydrogen, refrigerated liquid |
| | 1972 | Methane, refrigerated liquid or natural gas, refrigerated liquid, with high methane content |
| | 3138 | Ethylene, acetylene and propylene mixture, refrigerated liquid, containing at least 71,5 % ethylene with not more than 22,5 % acetylene and not more than 6 % propylene |
| | 3312 | Gas, refrigerated liquid, flammable, N.O.S. |

[a] Classification codes, identification number, name and description according to the United Nations.

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

NOTE The large transportable cryogenic vessel comprises a complete assembly that is ready for service

**3.3**
**thermal insulation**
vacuum interspace between the inner vessel and the outer jacket

NOTE 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 vessel intended to contain the cryogenic fluid to be transported

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

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



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



**3.8**
**documentation**
technical documents delivered by the manufacturer to the owner consisting of:

— all certificates establishing the conformity with this part of ISO 20421 (e.g. material, pressure test, cleanliness, safety devices);

— a short description of the vessel (including characteristic data, etc.);

— a list of fluids and their net mass for which the cryogenic vessel is designed;

— an operating manual (for the user) which consists of:

  — a short description of the vessel (including characteristic data, etc.);

  — a statement that the vessel is in conformity with this part of ISO 20421;

  — the instructions for normal operation.

**3.9**
**piping system**
all pipes, tubes and associated components which can come in contact with cryogenic fluids including valves, fittings, pressure-relief devices and their supports

**3.10**
**service equipment**
measuring instruments and filling, discharge, venting, safety, heating, cooling and insulating devices

**3.11**
**manufacturer of the large transportable cryogenic vessel**
company that carries out the final assembly, including the final acceptance test, of the large transportable cryogenic vessel

**3.12**
**gross volume of the inner vessel**
internal volume of the inner vessel, excluding nozzles, pipes, etc., determined at minimum design temperature and atmospheric pressure

**3.13**
**tare mass**
mass of the empty large transportable cryogenic vessel

**3.14**
**net volume of the inner vessel**
volume of the inner vessel, below the inlet to the relief devices, excluding nozzles, pipes, etc., determined at minimum design temperature and atmospheric pressure

**3.15**
**net mass**
maximum allowable mass of the cryogenic fluid which may be filled



NOTE 1 The maximum allowable mass is equal to the mass of the cryogenic liquid occupying 98 % of the net volume of the inner vessel 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 Cryogenic liquid helium can occupy 100 % of the volume of the inner vessel at any pressure.

**3.16**
**gross mass**
sum of tare mass plus net mass

**3.17**
**pressure**
pressure relative to atmospheric pressure, i.e. gauge pressure

**3.18**
**fixed tank**
tank vehicle
large transportable vessel permanently attached to a vehicle or to units of running gear

**3.19**
**demountable tank**
large transportable vessel non-permanently attached to a vehicle

NOTE 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.

**3.20**
**portable tank**
large transportable vessel designed primarily to be loaded onto a transport vehicle or ship

NOTE It can be lifted full and loaded and discharged without removal of structural element.

**3.21**
**maximum allowable pressure**
$p_s$
maximum pressure permissible at the top of the vessel in its normal operating position

**3.22**
**relief plate/plug**
plate or plug retained by atmospheric pressure which allows relief of excess internal pressure, generally from the vacuum jacket

**3.23**
**bursting disc device**
a non-reclosing pressure-relief device ruptured by differential pressure

NOTE It is the complete assembly of installed components including where appropriate the bursting disc holder.

**3.24**
**pressure-strengthened vessel**
pressure 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 Pressure vessels made from solution heat-treated material will be subject to a controlled plastic deformation during the strengthening operation as its yield point is raised. Pressure vessels made from work-hardened material will be subject to little or no plastic deformation.



## 4 Symbols

For the purposes of this part of ISO 20421, the following symbols apply (units of measurement are in the column at right):



| | | |
|---|---|---|
| $c$ | 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 |
| $l_b$, $l'_b$ | buckling length | mm |
| $n$ | number of lobes | — |
| $p$ | design pressure as defined in 10.3.2.2 | bar |
| $p$ | calculation pressure | bar |
| $p_e$ | allowable external pressure limited by elastic buckling | bar |
| $p_k$ | strengthening pressure | bar |
| $p_p$ | allowable external pressure limited by plastic deformation | bar |
| $p_s$ | maximum allowable pressure | bar |
| $p_T$ | pressure test (see 6.2) | bar |

| | | |
|---|---|---|
| $r$ | radius, e.g. inside knuckle radius of dished end and cones | mm |
| $s$ | minimum thickness | mm |
| $s_e$ | actual wall thickness | mm |
| $v$ | factor indicative of the utilization of the permissible design stress in joints or factor allowing for weakenings | — |
| $x$ | (decay-length zone) distance over which governing stress is assumed to act | mm |
| $A$ | cross-sectional area of reinforcing element | $mm^2$ |
| $C$, $\beta$ | design factors | — |
| $D$ | shell diameter | mm |
| $D_a$ | outside diameter, e.g. of a cylindrical shell | mm |
| $D_i$ | internal diameter, e.g. of a cylindrical shell | 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 11.5.4.2) | — |

## 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 3.8, and all supporting documentation (including that from his subcontractors, if any), for a period required by regulation(s) (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 part of ISO 20421.

## 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 could affect safety and which could 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:

$$p_T \geqslant 1{,}3(p_s + 1)$$

where

$p_T$ = test pressure (in bar);

$p_s$ = maximum allowable pressure (in bar);

+ 1 = allowance for external vacuum (in bar).

## 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 the previous paragraph):

— a minimum working temperature of −20 °C;

— a maximum working temperature of 50 °C.

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

## 9 Materials

For the materials used to manufacture the transportable cryogenic vessels, the requirements defined in 9.1 to 9.3 shall be met.



### 9.1 Selection of materials



**9.1.1** Materials which are or might 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 the main body of this part of ISO 20421, are suitable for and may be employed in the manufacture of the cryogenic vessels, in conformance with ISO 20421-1.

### 9.2 Inspection certificates

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

**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 3.1b in accordance with ISO 10474.

**9.2.3** The delivery of material which is not manufactured to a recognized International Standard shall be guaranteed by an inspection certificate 3.1a in accordance with ISO 10474 confirming that the material fulfils 9.1 of this part of ISO 20421-1. 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.