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**Cryogenic vessels — Gas/material  
compatibility**

*Réipients cryogéniques — Compatibilité gaz/matériaux*

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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](http://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](http://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 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 the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 220, *Cryogenic vessels*.

This third edition cancels and replaces the second edition (ISO 21010:2014), which has been technically revised.

ISO 21010:2017

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# Cryogenic vessels — Gas/material compatibility

## 1 Scope

This document specifies gas/material compatibility requirements (such as chemical resistance) for cryogenic vessels, but it does not cover mechanical properties (e.g. for low-temperature applications).

This document provides general guidance for compatibility with gases and detailed compatibility requirements for oxygen and oxygen-enriched atmospheres. This document also defines the testing methods for establishing oxygen compatibility of materials (metallic and non-metallic) to be used for cryogenic vessels and associated equipment.

This document focuses on materials that are normally with or could be in contact with cryogenic fluids.

## 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 10297:2014, *Gas cylinders — Cylinder valves — Specification and type testing*

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

## 3 Terms and definitions

No terms and definitions are listed in this document.

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

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

## 4 Compatibility of materials with gases other than oxygen

Cryogenic vessels are used in a range of temperatures from very low temperature to ambient temperature. On excluding oxygen, compatibility problems such as corrosion normally occur at ambient temperature and become negligible at cryogenic temperatures.

In the case of gases other than oxygen, ISO 11114-1 and ISO 11114-2 can be used as a guide for cryogenic vessels.

## 5 General requirements for oxygen service

### 5.1 Evaluation of materials for oxygen service

#### 5.1.1 General

The selection of a material for use with oxygen and/or in an oxygen-enriched atmosphere is primarily a matter of understanding the circumstances that cause oxygen to react with the material. Most materials in contact with oxygen will not ignite without a source of ignition energy. When an energy input rate,

as converted to heat, is greater than the rate of heat dissipation, and the resulting heat increase is continued for sufficient time, ignition and combustion will occur. Thus, two things shall be considered:

- the material's minimum ignition temperature;
- the energy sources that will produce a sufficient increase in the temperature of the material.

These should be viewed in the context of the entire system design so that the specific factors listed below will assume proper relative significance.

The specific factors are:

- the properties of the materials, including the factors affecting ease of ignition and the conditions affecting potential resultant damage (heat of reaction);
- the operating conditions: pressure, temperature, gas velocity, oxygen concentrations, and oxygen state (gaseous or liquid) and surface contamination in accordance with ISO 23208;
- the potential sources of ignition: friction, heat of compression, heat from mass impact, heat from particle impact, static electricity, electric arc, resonance, and internal flexing etc.;
- the reaction effect (consequences on the surroundings, etc.);
- additional factors: performance requirements, prior experience, availability, and cost.

**CAUTION — This document specifies the minimum acceptance requirements for materials in oxygen and enriched air service. In the cases of severe conditions and when the operating pressure is above 40 bar, additional tests to those specified should be considered.**

### 5.1.2 Evaluation of the insulation system

Insulation systems for cryogenic vessels that can come into contact with oxygen or condensed enriched air, shall be tested in accordance with [5.4.3](#).

## 5.2 Evaluation of metallic materials

Metallic materials commonly used for the construction of cryogenic vessels do not normally present any incompatibility when in contact with oxygen. [Annex A](#) lists the metallic materials commonly used for liquid oxygen.

The cases in which ignition or violent reactions can occur are when very thin materials are used with high surface to volume ratio, and when high ignition energy is available (e.g. pump failure). Materials thinner than 0,1 mm shall be tested in accordance with [5.4.3.1](#) in conditions as close as possible to the actual operational conditions. Materials to be used in applications where the ignition energy is potentially high should be subjected to special consideration.

For cryogenic vessels intended for oxygen service, the test described in [5.4.3.1](#) shall be performed with oxygen. When materials are located in an area where contact with condensed enriched air and the presence of potential sources of ignition is a risk, the test described in [5.4.3.1](#) shall be performed with cryogenic O<sub>2</sub>/N<sub>2</sub> mixtures containing at least 50 % oxygen.

NOTE Condensed enriched air can be produced on surfaces with temperatures colder than -191,3 °C at 1 atm (101,325 Pa). The use of atm is deprecated according to ISO 80000-4:2006, Annex C.

## 5.3 Evaluation of non-metallic materials

Example of non-metallic materials includes plastics, elastomers, lubricants, ceramics, glasses and glues. Some of these materials present a high risk of ignition when in contact with oxygen and should be avoided or carefully selected and used in limited quantities.

Some fully oxidized materials, such as ceramics and glass, present no risk of ignition provided they are not contaminated.

Any combustible non-metallic materials, used in steady or incidental contact with liquid oxygen, where the presence of a potential source of ignition is a risk, shall be tested in accordance with [5.4.2](#) and [5.4.3.1](#). Consideration shall be given to testing materials used in those parts of the system where liquid oxygen accumulation might incidentally occur.

For cryogenic vessels intended for oxygen service, the test described in [5.4.3](#) shall be performed with oxygen. When materials are located in an area where contact with condensed enriched air and the presence of potential sources of ignition is a risk, the test described in [5.4.3](#) shall be performed with cryogenic O<sub>2</sub>/N<sub>2</sub> mixtures containing at least 50 % oxygen.

NOTE Condensed enriched air can be produced on surfaces with temperature colder than -191,3 °C at 1 atm (101,325 Pa). The use of atm is deprecated according to ISO 80000-4:2006, Annex C.

Any combustible non-metallic materials, used in steady or incidental contact with gaseous oxygen where the presence of potential sources of ignition is a risk, shall be tested in accordance with [5.4.2](#). Consideration shall be given to testing materials used in those parts of the system where gaseous oxygen accumulation might incidentally occur.

## 5.4 Test methods and acceptance criteria

### 5.4.1 General

Each material to be tested shall be clearly identified, usually by the commercial name and the manufacturer's name.

### 5.4.2 Ignition tests

#### 5.4.2.1 Pass criteria

Two alternative test methods are described in [5.4.2.2](#) and [5.4.2.3](#). Materials not satisfying the requirements of [5.4.2.2](#) or [5.4.2.3](#) can still be used providing they successfully pass, in their actual operating configuration, the “oxygen pressure surge test” described in ISO 10297:2014, 5.9 (e.g. for a valve-sealing material, the entire valve or a representative assembly shall be tested).

#### 5.4.2.2 Spontaneous ignition test (bomb test)

##### 5.4.2.2.1 Test procedure

The test procedure is given in [Annex B](#).

##### 5.4.2.2.2 Acceptance criteria

The spontaneous ignition temperature determined in accordance with [5.4.2.2.1](#) shall be no less than the values given in [Table 1](#).

**Table 1 — Minimum spontaneous ignition temperature**

Maximum permissible pressure bar	Minimum spontaneous ignition temperature (SIT) °C	Remarks
3	200	
10	230	
20	250	
40	300	
100	350	
150	375	Complementary test may be advisable (see <a href="#">5.1</a> )
207	400	
207 < pressure ≤ 345	400	
NOTE Intermediate values can be determined by linear interpolation.		

### 5.4.2.3 Pressure surge test

#### 5.4.2.3.1 Test procedure

The test procedure is given in [Annex C](#).

#### 5.4.2.3.2 Acceptance criteria

No reaction shall be observed after two sets of five consecutive pressure surge impacts at the intended maximum working pressure.

### 5.4.3 Insulation test

In order to test insulation, either one of the two tests shall be performed.

#### 5.4.3.1 Mechanical impact test in liquid oxygen (LOX)

##### a) Test procedure

The mechanical impact test shall be performed at atmospheric pressure in liquid oxygen generally as described in Reference [4] to [8]. This is an example of preferred test equipment, but the details are not mandatory. The test shall be conducted

- on material with the surface condition that is intended for use,
- on material in a physical form delivered for use (i.e. solid, powder etc.), and
- at an impact energy per unit area of at least 79 J/cm<sup>2</sup>.

##### b) Acceptance criteria

No reaction shall be detected within a series of 20 tests.

#### 5.4.3.2 Hot wire test

Representative samples of the insulation system, when touched with a glowing platinum (or other) wire in a 100 % oxygen atmosphere at 1 bar pressure, shall not sustain combustion.

NOTE Representative samples of the insulation system are intended to be installed in the vessel; the full thickness of the insulation can be tested.



## 5.5 Alternative method for acceptance

The use of materials in cryogenic vessels based on documented evidence of previous long-term satisfactory service or favourable risk assessment is acceptable.

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## Annex A (informative)

### Metallic materials commonly used for liquid oxygen service

**Table A.1 — Metallic materials commonly used for liquid oxygen service**

Cryogenic vessels and associated equipment		Metallic materials commonly used				
		Low alloy steels	Nickel steels	Austenitic stainless steels	Copper and copper alloys	Aluminium and aluminium alloys
Large transportable vessels	Inner vessel		×	×		
	Outer jacket	×		×		
Small transportable vessels	Inner vessel		×	×		
	Outer jacket	×		×		
Static vessels	Inner vessel		×	×		
	Outer jacket	×				
Valves and protective devices				×	×	
Flexible hoses				×		
Vaporizers				×		×
Insulation systems						×

Compatibility of all materials should be evaluated before use.

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