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Cryogenic vessels — Cryogenic insulation performance

Récipients cryogéniques — Performances d'isolation cryogénique

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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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).

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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*.

This second edition cancels and replaces the first edition (ISO 21014:2006), which has been technically revised.

The main changes compared to the previous edition are as follows:

- Clause 2 has been added and subsequent clauses and cross-references updated.
- For clarity, “set pressure of the pressure-limiting device” has been reworded to “set pressure of the lowest set pressure-limiting device on stream” in subclauses 3.5, 3.5.3, and 3.6.
- “(100 % for helium)” has been added to 7.2 b) 1).
- In subclause 7.2 c), the denominator in the formula for m_{ig} has been corrected from v_{el} to v_{il}.

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

Traditionally, there have been different methods of defining the insulation performance of cryogenic vessels. It is therefore necessary to harmonize such methods for different cryogenic vessels.

Figure 1 shows a logic diagram to help in the understanding of this document.

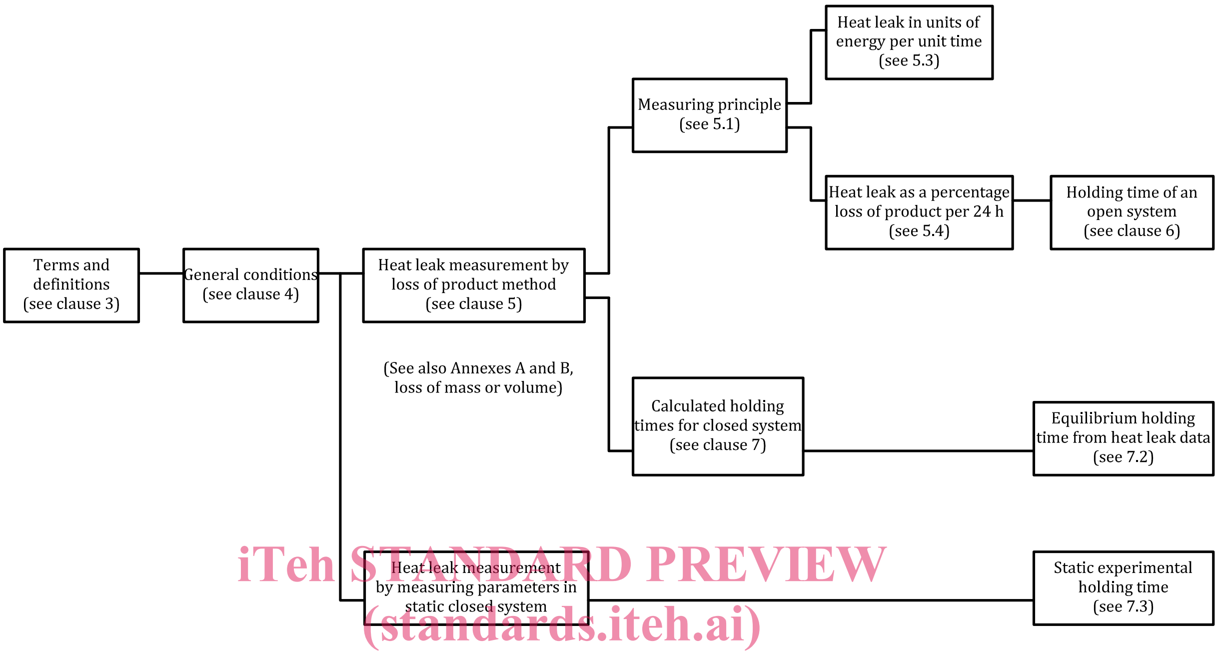

Figure 1 — Logic diagram

Cryogenic vessels — Cryogenic insulation performance

1 Scope

This document defines practical methods for determining the heat-leak performance of cryogenic vessels. The methods include measurement on both open and closed systems.

This document neither specifies the requirement levels for insulation performance nor when the defined methods are applied.

2 Normative references

There are no normative references in this document.

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:

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

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

3.1
open system
<during test> system kept at a constant pressure (e.g. atmospheric pressure) in which the gas produced by the evaporation of the test fluid is continuously released to atmosphere

3.2
closed system
<during test> system in which the mass of the contents is kept constant with no input or output of product

3.3
heat-leak rate
quantity of heat transferred per unit time from the ambient air to the contents of the inner vessel

Note 1 to entry: In an open system, the heat leak causes a loss of product; in a closed system, it causes a rise in pressure.

3.4
holding time for open system
time expected to elapse, for a specified degree of filling, from initial filling level until the vessel is empty (no more liquid) calculated from heat-leak data

3.5
holding time for closed system
time elapsed, for a specified degree of filling, from establishing the initial filling condition until the pressure has risen, due to heat leak, to the set pressure of the lowest set pressure-limiting device on stream

Note 1 to entry: For transportable vessels, this holding time is determined without the effects of stratification.

Note 2 to entry: Pressure-limiting devices include: a safety valve, a rupture disc, a back-pressure regulator, or any other device installed to limit the system pressure under normal operating conditions.

3.5.1
equilibrium holding time

holding time calculated from a specified heat leak assuming that liquid and vapour are constantly in equilibrium (without stratification)

3.5.2
longest equilibrium holding time

equilibrium holding time calculated from heat-leak data for a vessel when filled with the quantity of product giving the longest holding time

3.5.3
static experimental holding time

time it takes starting from atmospheric pressure, or from a stated pressure in the case of fluids where the starting pressure cannot be atmospheric pressure (e.g. 10 bar gauge for CO_2), to reach the set pressure of the lowest set pressure-limiting device on stream with the tank initially filled to its maximum allowable filling mass

3.6
maximum allowable filling mass

initial mass that results in the tank becoming hydraulically full (98 % for all fluids except helium and 100 % for helium) at the point that the lowest set pressure-limiting device on stream operates

Note 1 to entry: For fluids in a supercritical condition, the maximum allowable filling mass will be a function of the holding time and will be stated.

4 General conditions for all methods

4.1 The cryogenic fluid used for testing shall be agreed upon between the involved parties. Liquid nitrogen may normally be used, except in cases where the vessel to be tested is designed for a specific cryogenic fluid.

4.2 The liquid and gaseous phases shall be in equilibrium at the beginning of a test. When a test is carried out at a higher pressure than atmospheric pressure, it is important that the liquid equilibrium pressure is not lower than this test pressure.

4.3 The test environment shall be stable and constant during the test. It shall be as close as possible to the following reference conditions:

- ambient temperature, 15 °C (288,15 K);
- atmospheric pressure, 1,013 bar (101,3 MPa) (absolute).

For products other than carbon dioxide and nitrous oxide:

- vessel reference pressure, 1,013 bar (101,3 MPa) (absolute).

For carbon dioxide and nitrous oxide:

- vessel reference pressure, 15 bar (1,5 MPa) (gauge).

4.4 The vessel and its contents shall have reached a stable temperature before the beginning of the measuring period. Equilibrium conditions are obtained after a period of stabilization, the duration of which depends on the size of the vessel and the type and configuration of the insulation.

4.5 All accessories of the vessel which can influence the result of the measurement shall be clearly defined and specified in the report.

4.6 All instrumentation used shall be verified by calibration.

4.7 It is not necessary to use the method defined in this document to evaluate the insulation performance resulting from small modifications; this may be done by simple extrapolation.

5 Measuring the heat leak by the loss of product method

5.1 General

There are two methods of measuring the heat leak:

- direct measurement of loss of mass;
- indirect measurement of loss of mass by measuring the gaseous volumetric discharge rate.

The filling level shall be 50^{+10}_{0} % of the maximum filling level at the start of measurement, unless otherwise stated.

The ambient temperature, ambient barometric pressure and the operating pressure at the top of the vessel shall be recorded throughout the test so as to be used for correction purposes. The temperature sensor(s) shall be placed in the immediate proximity of the tank being tested, but sited such that they are unaffected directly by cold gas discharged from the vents.

The minimum measurement duration shall be 24 h after stable conditions have been reached.

During the test, precautions shall be taken to avoid agitation of the liquid, except for tanks designed for land transport mode.

When measuring the rate of discharge of gas escaping from the vessel by a flow meter, it is essential that the entire gas flow passes through the meter. The gas flow rate shall be determined as a mass flow rate by using either of the following:

- mass flow meter;
- volumetric flow meter (an appropriate method is shown in Annex A).

5.2 Test procedure

The test procedure shall be as follows:

a) pre-cool the vessel;

b) leave for a first stabilization period;

c) adjust the filling to the intended starting level (e.g. 50^{+10}_{0} %);

d) connect the instrumentation (e.g. gas flow meter);

e) leave for a second stabilization period;

f) take a sufficient number of readings to establish an acceptable thermal equilibrium before the start of the measuring period;

g) determine the mass of the vessel contents at the start of measuring period, if direct measurement of the mass is used;

h) record readings for a minimum of 24 h;

i) determine the loss of product in mass units (when gaseous flow is measured) in accordance with Annex A;

j) reduce to reference conditions in accordance with Annex B.

5.3 Determination of the heat leak in units of energy per unit time

The rate of product loss (kg/s) during the measurement period, corrected to the reference conditions in accordance with Annexes A and B, shall be converted to an equivalent heat leak, Q, as given in 5.4.

To calculate the heat leak with a product other than the test product, compensation using linear extrapolation in accordance with Annex C shall be applied, but only if the difference between the boiling temperature of these products at the reference conditions does not exceed 20 K.

5.4 Determination of the heat leak as a percentage loss of product per 24 h

Based on the result obtained in accordance with 5.3, the heat leak as a percentage loss of product per 24 h is calculated as follows.

a) Correct the measured heat leak to the reference condition for the test product by linear extrapolation, as specified in 5.3.

b) Calculate the equivalent loss of the test product per day in accordance with the following formula:

$$L = \frac{86\,400\left(v_\mathrm{g} - v_\mathrm{l}\right)Q}{v_\mathrm{g} h_\mathrm{fg} F} \times 100\,\%$$

where

F	is the maximum allowable filling mass of the test product (kg);
L	is the equivalent loss of product as a percentage of F per day;
Q	is the heat leak (W);
h_fg	is the latent heat of vaporization (J/kg) at the vessel reference pressure (see 4.3);
v_g	is the specific volume of vapour (m^3/kg) at the vessel reference pressure (see 4.3);
v_l	is the specific volume of saturated liquid (m^3/kg) at the vessel reference pressure (see 4.3);
86 400	is the number of seconds per day.

All product-related data shall be taken at correct reference conditions for the specified product. Annex C shall be used to determine the equivalent loss of product as a percentage of full tank content per day, for a product other than the test product.

6 Determination of the holding time for open systems from heat-leak data

The holding time, in days, for open systems is equal to $\frac{100}{L}$ for the specified product.

7 Holding times for closed systems

7.1 Determination of the equilibrium holding time from heat-leak data

The system is in thermal equilibrium, i.e. the liquid and gas phases are saturated and at a temperature corresponding to the saturation pressure at all times. The calculation process shall incorporate correctly the temperature and pressure dependence of the thermodynamic properties. The data source used for calculations shall be identified and the actual value shall be shown in the calculation. Thermodynamic data from bibliography items [1], [2] or [3] may be used. The influence of phase change in the system has to be accounted for in a proper manner.

The thermal mass of the vessel shall be neglected in the calculation, which results in shorter holding times.

For a degree of filling less than that used for the longest holding time, the holding time shall be defined as the time elapsed between when the initial filling condition is established and when the pressure-limiting device opens.

Heat-leak data corrected in accordance with Annex C shall be used when different products are concerned.

7.2 Determination of the optimum equilibrium holding time from heat-leak data

The equilibrium holding time for a specific product shall be calculated from heat-leak data as follows.

a) Correct the heat leak, *Q*, measured in accordance with Clause 5, to the reference conditions for the specified product by linear extrapolation (see Annex C).

b) Determine the reference quantity of the specified product as follows.

  1) When the critical pressure is greater than the pressure of the pressure-limiting device, the reference quantity is the quantity of product which fills, at operating temperature, 98 % (100 % for helium) of the volume of the tank below the inlet of the pressure-limiting device under conditions of the pressure-limiting device's incipient opening.

  2) When the critical pressure is less than the pressure of the pressure-limiting device, the reference quantity of the product depends directly on the holding time required.

c) The equilibrium holding time, *H*, in hours shall be calculated from the first law of thermodynamics for a constant volume system.

$$H = \frac{\left(m_{\mathrm{eg}}\, u_{\mathrm{eg}} + m_{\mathrm{el}}\, u_{\mathrm{el}}\right) - \left(m_{\mathrm{ig}}\, u_{\mathrm{ig}} + m_{\mathrm{il}}\, u_{\mathrm{il}}\right)}{3\,600Q}$$

and

$$m_{\mathrm{eg}} = \frac{V - \left(M \times v_{\mathrm{el}}\right)}{\left(v_{\mathrm{eg}} - v_{\mathrm{el}}\right)}$$

$$m_{\mathrm{el}} = \frac{V - \left(M \times v_{\mathrm{eg}}\right)}{\left(v_{\mathrm{el}} - v_{\mathrm{eg}}\right)}$$

$$m_{ig} = \frac{V - \left(M \times v_{il}\right)}{\left(v_{ig} - v_{il}\right)}$$

$$m_{\mathrm{il}} = \frac{V - \left(M \times v_{\mathrm{ig}}\right)}{\left(v_{\mathrm{il}} - v_{\mathrm{ig}}\right)}$$

where

M is the mass of contents (kg), as defined in 7.2 b);

Q is the heat leak (W) determined in 5.3;

V is the container gross volume (m^3);

m_{eg} is the mass of vapour at end condition (kg);

m_{el} is the mass of liquid at end condition (kg);

m_{ig} is the mass of vapour at initial condition (kg);