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ISO/DIS 21013-3

ISO/TC **220** Secretariat: **AFNOR**

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Cryogenic vessels — Pressure-relief accessories for cryogenic service —

Part 3:
Sizing and capacity determination

Récipients cryogéniques — Dispositifs de sécurité pour le service cryogénique —

Partie 3: Détermination de la taille et du volume

ICS: 23.020.40

ISO/CEN PARALLEL PROCESSING

This draft has been developed within the International Organization for Standardization (ISO), and processed under the **ISO lead** mode of collaboration as defined in the Vienna Agreement.

This draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel five month enquiry.

Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month approval vote in ISO and formal vote in CEN.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

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Foreword

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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. www.iso.org/directives

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword - Supplementary information

ISO 21013-3 was prepared by Technical Committee ISO/TC 220, *Cryogenic vessels*, and by Technical Committee CEN/TC 268, *Cryogenic vessels* in collaboration.

This second edition cancels and replaces the first edition (EN 13648-3:2002 and ISO 21013-3:2006), which have been technically revised.

ISO 21013 consists of the following parts, under the general title *Cryogenic vessels — Pressure relief accessories for cryogenic service*:

— *Part 1: Reclosable pressure-relief valves*

— *Part 2:Non-reclosable pressure-relief devices*

— *Part 3: Sizing and capacity determination*

— *Part 4:Pressure-relief accessories for cryogenic service*

Cryogenic vessels — Pressure relief accessories for cryogenic service — Part 3: Sizing and capacity determination

1 Scope

This part of ISO 21013 provides separate calculation methods for determining the required mass flow to be relieved for each of the following specified conditions.

— Vacuum-insulated vessels with insulation system (outer jacket + insulating material) intact under normal vacuum; outer jacket at ambient temperature; inner vessel at temperature of the contents at the relieving pressure.

— Vacuum-insulated vessels with insulation system (outer jacket + insulating material) intact under normal vacuum; outer jacket at ambient temperature; inner vessel at temperature of the contents at the relieving pressure; pressure regulator of the pressure build-up system functioning at full potential.

— Vacuum or non-vacuum-insulated vessels with insulation system remaining in place, but with loss of vacuum in the case of vacuum-insulated vessels, outer jacket at ambient temperature, inner vessel at temperature of the contents at the relieving pressure. OR: Vacuum or non-vacuum-insulated vessels with insulation system remaining fully or partially in place, but with loss of vacuum in the case of vacuum-insulated vessels, fire engulfment; inner vessel at temperature of the contents at the relieving pressure.

— Vacuum-insulated vessels containing fluids with saturation temperature below 75 K at 1 bar with insulation system remaining in place, but with loss of vacuum with air in the vacuum space.

— Vacuum insulated vessels containing fluids with saturation temperature below 75 K at 1 bar with insulation system remaining in place, but with loss of vacuum with air in the vacuum space with fire engulfment.

— Vessels with insulation system totally lost and fire engulfment.

Good engineering practice based on well-established theoretical physical science shall be adopted to determine the required mass flow where an appropriate calculation method is not provided for an applicable condition.

Cryostats can be considered pressure vessels for application of this standard. Additional upset conditions (quenching, etc.) and resulting heat transfer shall be considered in the calculations.

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 4126-1, *Safety devices for protection against excessive pressure — Part 1: Safety valves*

ISO 4126-6:2014, *Safety devices for protection against excessive pressure — Part 6: Application, selection and installation of bursting disc safety devices*

3 Calculation of the total quantity of heat transferred per unit time from the hot wall (outer jacket) to the cold wall (inner vessel)

3.1 General

P (in bar abs) is the actual relieving pressure inside the vessel, which is used for calculating the required mass flow through pressure-relief devices.

T_a (in K) is the maximum ambient temperature for conditions other than fire (as specified, for example, by a regulation or standard).

T_f (in K) is the external environment temperature under fire conditions, which is taken to be 922 K in this part of ISO 21013.

T (in K) is the relieving temperature in the vessel to be taken into account:

a) For sub-critical fluids, T is the saturation temperature of the liquid at pressure P;

b) For critical or supercritical fluids, T is calculated from 4.3.

3.2 Under conditions other than fire

3.2.1 For vacuum-insulated vessels under normal vacuum, the quantity of heat transferred per unit time (in watts) by heat leak through the insulation system is

$$W_1 = (T_a - T)U_1 A$$

where

U_1 is the overall heat transfer coefficient of the insulating material under normal vacuum, in W/(m²·K),

$$U_1 = \frac{k_1}{e_1}$$

where

k_1 Is the mean thermal conductivity of the insulating material under normal vacuum, between T and T_a, in W/(m·K);

e_1 Is the nominal insulating material thickness, in m;

A Is the arithmetic mean of the inner and outer surface areas of the vessel insulating material, in m².

3.2.2 Quantity of heat transferred per unit time (in watts) by the pressure build-up device circuit with the regulator fully open:

W_2 determined from the type (ambient air, water or steam, electrical, etc.) and the design of the pressure build-up device circuit. For example, in the case of an ambient air vaporizer;

$$W_2 = U_2 A_2 \cdot (Ta - T)$$

where

U_2 is the overall convective heat transfer coefficient of the ambient air vaporizer, in W/(m²·K);

A_2 is the external heat transfer surface area of the vaporizer, in m^2.

As a first approximation, the following may be used:

$$U_2(T_a - T) = 19000 \text{ W/m}^2 \text{ for } T \leq 75 \text{ K}$$

$$U_2(Ta - T) = 2850 \text{ W/m}^2 \text{ for } T > 75 \text{ K}$$

W_1 shall be included in W_2.

3.2.3 For vacuum-insulated vessels in case of loss of vacuum or non-vacuum-insulated vessels, quantity of heat transferred per unit time (in watts) by heat leak through the insulating material:

$$W_3 = (T_a - T) U_3 A$$

where

U_3 Is the overall heat transfer coefficient of the insulating material when saturated with gaseous lading or air at atmospheric pressure, whichever is greater, in W/(m^2·K);

If the insulation is fully effective for conduction, convection and radiation heat transfer at 328 K, then U_3 may be calculated as

$$U_3 = \frac{k_3}{e_3}$$

Vacuum space, gas space, or space occupied by the deteriorated insulation shall not be included in the thickness of the insulation. The effectiveness of these spaces or deteriorated insulation in reducing conduction, convection, or radiation heat transfer may be evaluated separately and included in the overall heat transfer coefficient, U_3, using methods found in published heat transfer literature. Deterioration of the insulation can be caused by the following:

— moisture condensation;

— air condensation;

— increase in density of the insulation due to sudden loss of vacuum

k_3 Is the mean thermal conductivity of the insulating material saturated with gaseous lading or air at atmospheric pressure, whichever provides the greater coefficient, between T and T_a, in W/(m·K); Values of k_3 for gases are listed in Table 1.

Table 1 — Thermal conductivity for refrigerated (cryogenic) fluids at the mean temperature between saturation and 328 K (k_3) and 922 K (k_5) at 1 bar

Fluid	k_3 [W/(m·K)]	k_5 [W/(m·K)]
Air	0,019	0,043
Argon	0,013	0,027
Carbon dioxide	0,017	0,039
Carbon monoxide	0,020	0,039
Helium	0,104	0,211

Fluid	k_3 [W/(m·K)]	k_5 [W/(m·K)]
Hydrogen	0,116	0,217
Methane	0,024	0,074
Neon	0,034	0,067
Nitrogen	0,019	0,040
Oxygen	0,019	0,043

e3 Is the minimum insulating material thickness taking into account the manufacturing tolerances or effects of sudden loss of vacuum, in m.

NOTE This formula cannot be applicable at temperatures below 75 K with a small thickness of insulating material, as the maximum heat transfer coefficient would be given by air condensation.

3.2.4 Quantity of heat transferred per unit time (in watts) by supports and piping located in the interspace:

$$W_4 = (T_a - T) \cdot (w_1 + w_2 + \ldots + w_n + \ldots)$$

where

w_n Is the heat leak per degree K contributed by one of the supports or the pipes, in W/K,

$$w_n = k_n \frac{A_n}{l_n}$$

where

k_n Is the mean thermal conductivity of the support or pipe material between T and T_a, in W/(m·K);

A_n Is the support or pipe section area, in m^2;

l_n Is the support or pipe length in the vacuum interspace, in m.

3.3 Under fire conditions

3.3.1 Quantity of heat transferred per unit time (in watts) by heat leak through the vessel walls

3.3.1.1 Insulation system remains fully or partially in place during fire conditions:

$$W_5 = 2{,}6 \cdot (922 - T) \cdot U_5 A^{0{,}82}$$

where

U_5 Is the overall heat transfer coefficient of the container-insulating material when saturated with gaseous lading or air at atmospheric pressure, whichever is greater, in W/(m²·K).

If the insulation is fully effective for conduction, convection, and radiation heat transfer for an external temperature of 922 K, U_5 may be calculated as:

$U_5 = \frac{k_5}{e}$, in W/(m^2·K)

Vacuum space, gas space, or space occupied by the deteriorated insulation shall not be included in the thickness of the insulation. The effectiveness of these spaces or deteriorated insulation in reducing conduction, convection, or radiation heat transfer may be evaluated separately and included in the overall heat transfer coefficient, U_5, using methods found in published heat transfer literature. Deterioration of the insulation can be caused by the following:

— Moisture condensation;

— Air condensation;

— Increase in density of the insulation due to sudden loss of vacuum;

— Degradation due to heat.

k_5 Is the mean thermal conductivity of the insulating material saturated with gaseous lading or air at atmospheric pressure, whichever provides the greater coefficient, between T and 922 K, in W/(m·K); Values of k_5 for gases are given in Table 1.

e Is the thickness of the insulating material remaining in place during fire conditions, in m;

A Is the mean surface area of the insulating material remaining in place during fire conditions, in m^2.

If the outer jacket remains in place during fire conditions, but if the insulating material is entirely destroyed, U_5 is equal to the overall heat transfer coefficient with gaseous lading or air at atmospheric pressure in the space between the outer jacket and the inner vessel, whichever provides the greater coefficient, between T and 922 K. A is equal to the mean surface area of the interspace.

3.3.1.2 Insulation system does not remain in place during fire conditions:

$$W_5 = 7{,}1 \times 10^4 A_i^{0{,}82}$$

where

A_i Is the total outside surface area of the inner vessel, in m^2.

W_5 is the quantity of heat transferred per unit time, in watts

3.3.2 Quantity of heat transferred by supports and piping located in the interspace can be neglected in this case

3.4 Air or Nitrogen condensation

3.4.1 General

Air or nitrogen condensation case for loss of vacuum condition shall be considered for fluids with saturation temperature below 75 K at 1 bar absolute pressure.

Air condensation, for the case of loss of vacuum to the atmosphere on a vacuum insulated container is highly dependent on the type of insulation and how the insulation is designed. Since air condensation occurs primarily below 75 K, and fluids with saturation temperature below 75 K are generally stored and transported in containers insulated with multi-layer insulation, this standard covers air condensation on multi-layer insulated containers only. In the absence of pertinent reliable data on perlite insulated vessels, data for the high air access case may be used as a minimum.

Condensation of air on a multi-layer insulated surface below 75 K will depend on the rate of air access to the insulated surface. On a multi-layer insulated container, air condensation rate can vary depending on the number of layers and air access allowed by the design of the insulation.

Figures 1 and 2 provide heat transfer rates from air condensation to the stored fluid as a function of the number of layers of insulation, for low air access insulation design and high air access insulation design, respectively. Examples of high air access insulation include multilayer insulation of vessel heads and multilayer insulation using strips of materials. The fire engulfment curves are extrapolated values for 922K ambient temperature. Unless heat transfer rates under loss of vacuum condition from air condensation can be determined for the same type and design of multi-layer insulation from prototype tests or actual incidents, heat transfer rates from Figures 1 and 2 as applicable shall be used.

3.4.2 Loss of vacuum with air and nitrogen

For vacuum-insulated vessels in the case of a loss of vacuum, heat transfer from air or nitrogen condensation is given by:

$$W_{3a} = U_{3a} \cdot A_i$$

where

W_{3a} is the heat transfer through air or nitrogen condensation, in watts.

U_{3a} is the heat transfer through air or nitrogen condensation, in watts per square meter of the inner vessel outer surface area, from Figures 1 and 2.

3.4.3 Fire with loss of vacuum with air or nitrogen

For vacuum-insulated vessels in the case of fire and with loss of vacuum with air or nitrogen, heat transfer from air or nitrogen condensation is given by:

$$W_{5a} = 1{,}95 \cdot U_{5a} \cdot (A_i)^{0.82}$$

or

$$W_6 = 7{,}1 \cdot (10)^4 (A_i)^{0.82}$$

where

W_{5a} is the heat transfer through air or nitrogen condensation during fire conditions, in watts.

U_{5a} is the heat transfer through air or nitrogen condensation during fire conditions, in watts per square meter of the inner vessel surface area, from Figures 1 and 2.

W_6 is the heat transfer during fire conditions, in watts.

