

BS EN ISO 21013-3:2016



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Cryogenic vessels — Pressure-relief accessories for cryogenic service

Part 3: Sizing and capacity determination
(ISO 21013-3:2016)

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National foreword

This British Standard is the UK implementation of EN ISO 21013-3:2016. It supersedes BS EN 13648-3:2002 and BS ISO 21013-3:2006 which are withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PVE/18, Cryogenic vessels.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

**Cryogenic vessels - Pressure-relief accessories for
cryogenic service - Part 3: Sizing and capacity
determination (ISO 21013-3:2016)**

Réceptacles cryogéniques - Dispositifs de sécurité pour
le service cryogénique - Partie 3: Détermination de la
taille et du volume (ISO 21013-3:2016)

Kryo-Behälter - Druckentlastungseinrichtungen für
den Kryo-Betrieb - Teil 3: Bestimmung von Größe und
Durchfluss (ISO 21013-3:2016)

This European Standard was approved by CEN on 15 April 2016.

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European foreword

This document (EN ISO 21013-3:2016) has been prepared by Technical Committee ISO/TC 220 “Cryogenic vessels” in collaboration with Technical Committee CEN/TC 268 “Cryogenic vessels and specific hydrogen technologies applications” the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2016, and conflicting national standards shall be withdrawn at the latest by December 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 13648-3:2002.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive.

For relationship with EU Directive, see informative Annex ZA, which is an integral part of this document.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Endorsement notice

The text of ISO 21013-3:2016 has been approved by CEN as EN ISO 21013-3:2016 without any modification.

Annex ZA (informative)

Relationship between this European Standard and the Essential Requirements of EU Directive (2014/68/UE — Pressure Equipment Directive)

This European Standard has been prepared under a mandate given to CEN by the European Commission to provide a means of conforming to Essential Requirements of the New Approach Directive (2014/68/UE – Pressure Equipment Directive)

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Directive (2014/68/UE – Pressure Equipment Directive)

Clause(s)/subclause(s) of this EN	Essential Requirements (ERs) of Directive ...	Qualifying remarks/Notes
4, 5	Protection against exceeding the allowable limits of pressure equipment	Annex I, 2.10
6, 7	Safety accessories	Annex I, 2.11
4.3	External fire	Annex I, 2.12

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

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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).

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).

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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](#)

The committee responsible for this document is ISO/TC 220, *Cryogenic vessels*.

This second edition cancels and replaces the first edition (ISO 21013-3:2006), which has 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 specified 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 specified 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 specified 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 specified 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 or nitrogen 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 or nitrogen 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 needs to be adopted to determine the required mass flow where an appropriate calculation method is not provided for an applicable condition.

Recommendations for pressure relief devices for cryostats are given in [Annex A](#).

2 Normative references

There are no normative references in this document.

3 Symbols

A	arithmetic mean of inner and outer surface areas of vessel insulating material	m^2
A_B	actual flow area of a pipe element	m^2
A_e	total outer surface area of pipe network between the outer jacket and location	xm^2
A_F	minimum flow area (reference area) in a pipe network	m^2
A_{Fd}	minimum flow area (reference area) in the pipe network, downstream of relief valve	m^2
A_{Fu}	minimum flow area (reference area) in the pipe network, upstream of relief valve	m^2
A_i	total outside surface area of inner vessel	m^2
A_j	total outer surface area of pipe network between the inner and outer jackets (interspace)	m^2
A_L	larger flow area of a pipe element containing two different flow area sizes	m^2
A_n	cross-sectional area, support, or pipe material	m^2
A_R	area ratio, A_S/A_L	—
A_S	smaller flow area of a pipe element containing two different flow area sizes	m^2
A_V	actual flow (orifice) area of a pressure relief valve	mm^2
A_{Va}	actual flow (orifice) area of pressure relief valve selected for final analysis	mm^2
A_{V1}	minimum required relief valve flow (orifice) area	mm^2
A_2	external heat transfer surface area of ambient air vaporizer	m^2
c_p	constant pressure specific heat capacity at the average of T_n and T_e	$\text{kJ}/(\text{kg}\cdot\text{K})$
C_V	experimentally determined flow rate through a pipe element or device	$\text{gal}/\text{min}/\text{psi}$
e_1	nominal insulating material thickness, normal vacuum, non-fire condition	m
e_3	minimum insulating material thickness, considering loss of vacuum, non-fire condition	m
e_5	insulating material thickness remaining in place during fire conditions	m
f_T	pipe flow friction coefficient	—
h	enthalpy of fluid at conditions of v	kJ/kg
h_r	specific enthalpy at relief valve inlet and outlet	kJ/kg
K_A	flow resistance coefficient of a pipe element in terms of A_F	—
K_B	flow resistance coefficient of a pipe element in terms of A_B	—
K_b	subcritical flow coefficient	—
K_{dr}	derated coefficient of discharge	—

$K_{dr,a}$	derated coefficient of discharge of next largest available valve orifice area greater than A_{V1}	—
$K_{dr,1}$	derated coefficient of discharge of initially analyzed valve	—
k_n	mean thermal conductivity of an individual support or pipe, between T and T_a	W/(m·K)
K_R	flow resistance coefficient of complete pipe network in terms of reference area, A_F	—
K_{RC}	flow resistance coefficient at the transition between critical and subcritical flow	—
K_{Rd}	overall flow resistance coefficient of pipe network, downstream of pressure relief valve	—
K_{Ru}	overall flow resistance coefficient of pipe network, upstream of pressure relief valve	—
K_{SUM}	total flow resistance coefficient of a series or parallel pipe network	—
K_V	experimentally determined flow rate through a pipe element or device	m ³ /h/bar
k_1	mean thermal conductivity of insulating material, normal vacuum, non-fire condition	W/(m·K)
k_3	mean thermal conductivity of insulating material with air or gaseous lading, non-fire condition	W/(m·K)
L	latent heat of vaporization of cryogenic liquid at relieving conditions	kJ/kg
l	length, pipe element	m
L_a	latent heat of vaporization of cryogenic liquid at a pressure of 1,013 bar	kJ/kg
l_n	length of support or pipe in vacuum interspace	m
L'	enthalpy-to-volume expansion ratio for critical or all-gas fluid flow conditions	kJ/kg
M	molar mass	kg/mol
m_{max}	maximum mass capacity of vessel	kg
N	normal evaporation rate (NER)	%/day
P	relieving pressure, inner vessel	bar
P_b	pressure, safety relief valve outlet	bar
P_{b10}	pressure at relief valve outlet for a downstream built-up backpressure of 10 %	bar
P_{exit}	pressure at pipe network exit	bar
P_i	pressure, safety relief valve inlet	bar
P_S	pressure relief valve set pressure	bar
Q_m	mass flow rate	kg/h
Q_{ma}	mass flow rate of a relief valve within a given pipe network	kg/h
Q_{mNER}	mass flow rate due to the normal evaporation rate	kg/h

R	universal gas constant	J/(mol·K)
r	pipe elbow transition radius	m
T	relieving temperature, inner vessel	K
T_a	maximum external ambient temperature, non-fire condition	K
$T_{b,Pb}$	temperature at relief valve outlet	K
T_{b10}	temperature at relief valve outlet for a downstream built-up backpressure of 10 %	K
T_e	external temperature for a given condition	K
$T_{exit,Pb}$	temperature at pipe network exit	K
T_f	external temperature, fire condition	K
T_i	temperature, safety relief valve inlet	K
T_n	temperature of fluid at a given flow start location along the pipe network	K
T_{sat}	saturation temperature of fluid at a pressure of 1 bar	K
T_x	temperature of fluid at a given location x along the pipe network	K
U_p	overall heat transfer coefficient of a pipe network for given temperature conditions	W/ (m ² ·K)
U_1	heat transfer coefficient of insulating material, normal vacuum, non-fire condition	W/ (m ² ·K)
U_2	overall convective heat transfer coefficient of ambient air vaporizer	W/ (m ² ·K)
U_3	heat transfer coefficient of insulating material with air or gaseous lading, non-fire condition	W/ (m ² ·K)
U_{3a}	heat transfer coefficient, air or nitrogen condensation, loss of vacuum, non-fire condition	W/m ²
U_5	heat transfer coefficient of insulating material with air or gaseous lading, fire condition	W/ (m ² ·K)
U_{5a}	heat transfer coefficient, air or nitrogen condensation, loss of vacuum, fire condition	W/m ²
w_n	heat leak from an individual support or pipe	W/K
W_T	total heat transfer rate for specified conditions	Watt [W]
W_{T1}	total heat transfer rate under normal operation	Watt [W]
W_{T1NER}	total NER heat transfer rate under normal operation	Watt [W]
W_{T2}	total heat transfer rate under normal operation, including pressure build-up device	Watt [W]
W_{T2NER}	total NER heat transfer rate under normal operation, including pressure build-up device	Watt [W]

W_{T3}	total heat transfer rate, loss of vacuum, insulation in place, non-fire condition, $T_{\text{sat}} > 75 \text{ K}$	Watt [W]
W_{T3a}	total heat transfer rate, loss of vacuum, insulation in place, non-fire condition, $T_{\text{sat}} \leq 75 \text{ K}$	Watt [W]
W_{T5}	total heat transfer rate, loss of vacuum, insulation in place, fire condition, $T_{\text{sat}} > 75 \text{ K}$	Watt [W]
W_{T5a}	total heat transfer rate, loss of vacuum, insulation in place, fire condition, $T_{\text{sat}} \leq 75 \text{ K}$	Watt [W]
W_{T6}	total heat transfer rate, loss of vacuum, insulation not in place, fire condition	Watt [W]
W_1	heat transfer rate through insulation system, normal vacuum, non-fire condition	Watt [W]
W_2	heat transfer rate through pressure build-up device, fully open regulator	Watt [W]
W_3	heat transfer rate through insulation system, loss of vacuum, non-fire condition	Watt [W]
W_{3a}	heat transfer rate through air or nitrogen condensation, loss of vacuum, non-fire condition	Watt [W]
W_4	heat transfer rate through interspace supports and piping	Watt [W]
W_5	heat transfer rate through vessel walls, insulation in place, fire condition	Watt [W]
W_{5a}	heat transfer rate through air or nitrogen condensation, loss of vacuum, fire condition	Watt [W]
W_6	heat transfer rate through vessel walls, insulation not in place, fire condition	Watt [W]
x	lengthwise location along a pipe network	m
X	number of insulation layers	—
Y	heat transfer rate U_{3a} or U_{5a}	—
Z_i	compressibility factor at pressure, P_i , and temperature, T_i	—
φ	pressure ratio P_{exit}/P	—
κ	isentropic exponent	—
λ_1	subcritical flow coefficient	—
λ_2	subcritical flow coefficient	—
ν	specific volume of critical or all-gas fluid at a given temperature at pressure, P	m^3/kg
ν_{b10}	specific volume at relief valve outlet for a downstream built-up backpressure of 10 %	m^3/kg
$\nu_{b,Pb}$	specific volume at pressure relief valve outlet, evaluated at h_r and a trial value of P_b	m^3/kg
$\nu_{d\text{max}}$	maximum average downstream specific volume, as per desired backpressure limit	m^3/kg
ν_{d10}	average downstream specific volume, for a downstream built-up backpressure of 10 %	m^3/kg