SLOVENSKI STANDARD
oSIST prEN 17527:2020

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Kriostati za helij - Zaščita pred prekoračitvijo tlaka

Helium cryostats - Protection against excessive pressure

Helium Kryostate - Schutz gegen Drucküberschreitung

Cryostats pour hélium - Protections contre les surpressions

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13.240	Varstvo pred previsokim tlakom	Protection against excessive pressure
23.020.40	Proti mrazu odporne posode (kriogenske posode)	Cryogenic vessels

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Helium cryostats - Protection against excessive pressure

Cryostats pour hélium - Protections contre les surpressions

Helium Kryostate - Schutz gegen Drucküberschreitung

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (prEN 17527:2020) has been prepared by Technical Committee CEN/TC 268 “Cryogenic vessels and specific hydrogen technologies applications”, the secretariat of which is held by AFNOR.

This document is currently submitted to the CEN Enquiry.

Introduction

Helium cryostats, other than cryogenic vessels used for storage of cryogenic liquids covered by EN ISO 21009-2 and EN 13458, include additional specific components such as superconducting magnets and cavities, electrical heaters, heat exchangers, bellows, circulation pumps and internal control valves. These components imply additional risks such as sudden excessive pressure, which strongly influence the design of pressure relief systems and are not covered by existing standards. Helium cryostats are characterized by a variety of complex and individual design solutions, often exploiting small design margins for cutting — edge performance. Therefore, a common and specific technical solution for the protection against excessive pressure cannot be standardized. Rather, the approach on how to obtain the state of the art protection can be standardized and therefore is covered by this document, specifying the procedure and minimum requirements for the various aspects in the main part of the document. Additional information, example solutions and exemplary measures are provided in the extensive Annex, which mirrors the structure of the main part.

This document covers the typical sources that may lead to excessive pressure in helium cryostats and the conditions, which are relevant for the protection against excessive pressure during system failures, in order to harmonize risk assessments and design best practices. The document uses common SI-based units.

The user of this document may refer to CEN/CENELEC Internal Regulations Part 3, which deals with the use of verbal forms for the formulation of provisions.

1 Scope

This document specifies the minimum requirements for the protection of helium cryostats against excessive pressure, including the specific risks associated with cryostats for superconducting magnets and cryostats for superconducting radio-frequency cavities, coldboxes of helium refrigerators and liquefiers as well as helium distribution systems including valve boxes. It includes risk assessment, protection concepts, dimensioning of pressure relief devices, types of pressure relief devices, substance release and operation of helium cryostats.

In order to fulfil the aim of this document, the characteristics of pressure relief devices are taken into account.

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.

EN 13445-2, *Unfired pressure vessels — Part 2: Materials*

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

EN ISO 4126-1:2013, *Safety devices for protection against excessive pressure — Part 1: Safety valves (ISO 4126-1:2013)*

EN ISO 4126-3:2006, *Safety devices for protection against excessive pressure — Part 3: Safety valves and bursting disc safety devices in combination (ISO 4126-3:2006)*

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

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

ISO 4126-9, *Safety devices for protection against excessive pressure — Part 9: Application and installation of safety devices excluding stand-alone bursting disc safety devices*

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:

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

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

3.1
relevant national third party
inspection body authorized by national regulations

3.2
back pressure

p_b

pressure existing at the outlet of a pressure relief device as a result of the pressure in the downstream system

[SOURCE: EN ISO 4126-1:2013, 3.11, modified]

3.3
bath cooling

cooling method in which the object to be cooled is submerged in a vessel filled with a liquid cooling medium

Note 1 to entry: The enthalpy of evaporation is used for cooling, with the phase change providing a nearly constant cooling temperature.

3.4
blowdown

Δp_{reseat}

difference between set and reseating pressure

[SOURCE: EN ISO 4126-1:2013, 3.15]

3.5
build up back pressure

Δp_{bb}

pressure existing at the outlet of a pressure relief device caused by flow through the device and the downstream system

[SOURCE: EN ISO 4126-1:2013, 3.13]

3.6
bursting pressure

p_{burst}

value of the differential pressure between the upstream side and the downstream side of the bursting disc when it bursts

[SOURCE: EN ISO 4126-2:2019, 3.10]

3.7
chattering

unstable discharge of a pressure relief valve characterised by high frequency opening and closing

3.8
coincident temperature

temperature of the bursting disc associated with a bursting pressure

[SOURCE: EN ISO 4126-2:2019, 3.14, modified]

3.9
cryogenic fluid
fluid with a normal boiling point below 120 K respectively −153 °C

3.10
cryogenics
study of technologies, procedures and equipment at temperatures below 120 K respectively −153 °C

3.11
cryostat
vacuum-insulated device for the operation of components at cryogenic temperatures using cryogenic fluids

Note 1 to entry: A cryostat is considered as an assembly.

3.12
current lead
electrical connection between the power supply unit and the superconducting magnet for charging, operating or discharging the magnet

Note 1 to entry: In larger systems, current leads are actively cooled due to the high thermal conduction and the large temperature gradient. The current lead consists of e.g. a copper part as electrical conductor and a heat exchanger for cooling.

3.13
dewar
vacuum-insulated storage and transport container for storing cryogenic fluids

3.14
driven mode
<superconducting magnet> operation of a magnet by a power supply unit, where the magnet is always connected to the power supply unit or, in the event of quench, to an external protective circuit or a discharge resistor

3.1.5
full-lift Pressure Relief Valve
PRV
PRV that opens instantaneously within 5 % of the pressure increase up to the design limited lift. The proportion of the lift up to the instantaneous opening (proportional range) may not exceed 20 % of the total lift

3.16
leak rate
pV throughput of a specific fluid which flows through a leak under specific conditions

Note 1 to entry: For vacuum and/or cryogenic technologies, the leak rate is often expressed in the unit mbar l/s.

[SOURCE: EN ISO 20484:2017, 4.3.5]

3.17
maximum allowable pressure
p_s
maximum gauge pressure for which the equipment is designed, as specified by the manufacturer

[SOURCE: EN ISO 4126-1:2013, 3.6, modified]

3.18
maximum credible incident
worst incident within the realm of possibility that has a propensity to cause significant damage

Note 1 to entry: The MCI is the design bases for the dimensioning of the primary PRD.

3.19
multi-layer insulation
very effective thermal insulation method used in cryogenics, which significantly reduces the heat transport caused by thermal radiation

Note 1 to entry: Multi-layer insulation (MLI) consists of multiple layers of highly reflective films enclosing the cryogenic components. MLI is used along with vacuum insulation.

3.20
nominal operating pressure
$p_{operate}$
pressure expected during normal operation

3.21
overpressure
Δp_{over}
pressure increase over the set pressure

[SOURCE: EN ISO 4126-1:2013, 3.7]

3.22
performance tolerance
Δp_{burst}
range of pressure between the specified minimum bursting pressure and the specified maximum bursting pressure, or the range of pressure in positive and negative percentages or quantities which is related to the specified bursting pressure

[SOURCE: EN ISO 4126-2:2019, 3.15]

3.23
persistent mode
<superconducting magnet> magnet operation without connection to the power supply unit, where the power supply unit is disconnected after charging the magnet and the superconducting magnet operates in short-circuit mode

3.24
pV throughput
rate at which a volume of gas at specified pressure passes a given cross-section of the system

Note 1 to entry: The pV throughput is expressed in mbar l/s.

[SOURCE: EN ISO 20484:2017, 4.2.3, modified – Note 1 to entry has been changed]

3.25
quench
<superconducting magnet> spontaneous transition of a superconductor or a superconducting component from the superconducting state to the normal conducting state

3.26
relieving pressure
p_0
pressure used for the sizing of pressure relief devices; for a pressure relief valve the relieving pressure is greater than or equal to the set pressure plus overpressure

[SOURCE: EN ISO 4126-1:2013, 3.10, modified]

3.27
reseating pressure
p_{reseat}
inlet static pressure at which the disc re-establishes contact with the seat or until zero lift

Exact wording is: value of the inlet static pressure at which the disc re-establishes contact with the seat or at which the lift becomes zero

[SOURCE: EN ISO 4126-1:2013, 3.8, modified]

3.28
set pressure
p_{set}

predetermined gauge pressure at which the pressure relief valve commences to open

Note 1 to entry: It is the gauge pressure measured at the valve inlet at which the pressure forces tending to open the valve for the specific service conditions are in equilibrium with the forces retaining the valve disc on its seat.

[SOURCE: EN ISO 4126-1:2013, 3.5, modified]

3.29
specified bursting pressure
$p_{sp,burst}$
bursting pressure quoted with a coincident temperature when defining the bursting disc requirements (used in conjunction with a performance tolerance)

[SOURCE: EN ISO 4126-2:2019, 3.11, modified]

3.30
specified maximum bursting pressure
$p_{burst,max}$
maximum pressure quoted with a coincident temperature when defining the bursting disc requirements (used in conjunction with minimum bursting pressure)

[SOURCE: EN ISO 4126-2:2019, 3.12, modified]

3.31
specified minimum bursting pressure

$p_{burst,min}$

minimum pressure quoted with a coincident temperature when defining the bursting disc requirements (used in conjunction with maximum bursting pressure)

[SOURCE: EN ISO 4126-2:2019, 3.13, modified]

3.32
superconducting magnet

magnet whose coils are cooled, usually with helium, to a temperature at which the conductor becomes superconducting, effectively removing all electrical resistance

Note 1 to entry: At sufficiently low temperatures and within certain operating parameters, superconducting materials do not have an ohmic resistance, which allows an electrical current to flow without energy loss.

[SOURCE: IEC 60050-815]

3.33
superimposed back pressure

p_{bs}

pressure existing at the outlet of a pressure relief device at the time the device is required to operate

[SOURCE: EN ISO 4126-1:2013, 3.13, modified]

3.34
test pressure

p_{test}

pressure to which the equipment is subjected for test purposes

Note 1 to entry: In helium cryostats, hydrostatic tests are generally impractical and even disadvantageous, so that only pneumatic tests are permissible.

Note 2 to entry: National regulations referring to risks associated with the use of compressible media during proof tests shall be observed.

[SOURCE: EN 764-1:2004]

3.35
thermal acoustic oscillation

resonant gas oscillation built-up spontaneously within a connecting tube between high and low temperature levels

3.36
vacuum jacket

evacuated outer shell of a cryostat surrounding the cryogenic components. The insulating vacuum inhibits the heat conduction by residual gas

Note 1 to entry: The vacuum jacket itself normally remains at ambient temperature.

3.37
valve box
assembly for distributing coolant to several cryostats and for controlling the flow in supply and return lines

Note 1 to entry: A valve box consists of a vacuum vessel with an arrangement of cryogenic valves and pipework.

4 Symbols

A_c	Affected cryogenic surface area	cm²
a_i	Initial filling level	–
A_{leak}	Cross section of leak	m²
A_{scd}	Affected surface area of the superconducting device	cm²
A_{th}	Minimum discharge area of the PRD	m²
C	Discharge function	–
c	Specific heat capacity of the vessel/pipework material	J/(kgK)
c_p	Specific heat capacity at constant pressure	J/(kgK)
c_{th}	Velocity at the throat of PRD	m/s
E_{mag}	Electromagnetic energy stored in the magnet	J
E_{max}	Maximum thermal energy of the electrical arc	J
E_{wall}	Thermal energy transferred directly into the vessel/pipework wall in case of dielectric breakdown	J
h	Specific enthalpy	J/kg
h'	Specific enthalpy of saturated liquid	J/kg
h''	Specific enthalpy of saturated vapour	J/kg
Δh	Specific heat input	J/kg
$h_{0,x}$	adjusted specific enthalpy	J/kg
Δh_{air}	Enthalpy difference of air	J/kg
h_{th}	Specific enthalpy at the throat	J/kg
I	Current	A
$\bar{k}$	Average heat transfer coefficient to the helium flow	W/(m²K)
K_d	Discharge coefficient	–

K_{dr}	Certified discharge coefficient	–
l	Length of the pipe section	m
L	Inductance	H
L_c	Characteristic length of heat transfer problem	m
L_{fusion}	Latent heat of fusion of vessel/pipework material	J/kg
$\dot{M}$	Relieving mass flow rate	kg/s
M_c	Total mass of the cryogenic fluid in the system	kg
M_{He}	Helium mass stored in the cryostat	kg
$\dot{M}_{LBV}$	Mass flow rate to vacuum space in case of LBV (loss of beamline vacuum)	kg/s
$\dot{M}_{lcf}$	Mass flow rate to vacuum space in case of leak of cryogenic fluid	kg/s
$\dot{m}_{th}$	Mass flux at the throat of PRD	kg/(m²s)
P	Perimeter of the pipe section	m
Δp	Pressure drop	bar(a)
p_0	Relieving pressure	bar(a)
p_0^*	Relieving pressure from which on critical (sonic) flow occurs in the throat area A_{th}	bar(a)
$p_{0,x}$	Adjusted relieving pressure	bar(a)
p_{amb}	Ambient pressure	bar(a)
p_b	Back pressure	bar(a)
Δp_{bb}	Built-up back pressure along the downstream pipework	bar(a)
p_{bs}	Superimposed back pressure	bar(a)
p_{burst}	Bursting pressure	bar(g)
$p_{burst,max}$	Maximum bursting pressure	bar(g)
$p_{burst,min}$	Minimum bursting pressure	bar(g)
p_c	Initial pressure inside the cryogenic circuit	bar(a)
p_{crit}	Thermodynamic critical pressure	bar(a)