BRITISH STANDARD

BS EN 13648-3:2002

Cryogenic vessels — Safety devices for protection against excessive pressure —

Part 3: Determination of required discharge — Capacity and sizing

The European Standard EN 13648-3:2002 has the status of a British Standard

ICS 23.020.40

British Standards

National foreword

This British Standard is the official English language version of EN 13648-3:2002.

The UK participation in its preparation was entrusted to Technical Committee PVE/18, Cryogenic vessels, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

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Cryogenic vessels - Safety devices for protection against excessive pressure - Part 3: Determination of required discharge - Capacity and sizing

Récipients cryogéniques - Dispositifs de protection contre les surpressions - Partie 3: Détermination du débit à évacuer - Capacité et dimensionnement

Kryo-Behälter - Sicherheitseinrichtungen gegen Drucküberschreitung - Teil 3: Ermittlung des erforderlichen Ausflusses - Ausflussmassenstrom und Auslegung

This European Standard was approved by CEN on 19 August 2002.

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Contents

Foreword

This document (EN 13648-3:2002) has been prepared by Technical Committee CEN/TC 268 "Cryogenic vessels", 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of an identical text or by endorsement, at the latest by April 2003, and conflicting national standards shall be withdrawn at the latest by April 2003.

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(s).

For relationship with EU Directive(s), see informative annex ZA, which is an integral part of this document.

EN 13648 consists of the following parts:

EN 13648-1, *Cryogenic vessels - Safety devices for protection against excessive pressure - Part 1: Safety valves for cryogenic service.*

EN 13648-2, *Cryogenic vessels - Safety devices for protection against excessive pressure - Part 2: Bursting discs safety devices for cryogenic service.*

EN 13648-3, Cryogenic vessels - Safety devices for protection against excessive pressure - Part 3: Determination of required discharge - Capacity and sizing.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

The capacity of each of the pressure relief devices is established by considering all of the probable conditions contributing to internal excess pressure. The applicable conditions are specified in the product standard of each type of cryogenic vessel.

This European Standard provides a separate calculation method for determining the contributing mass flow to be relieved for each of the specified conditions. Conformity of the pressure protection system with the requirement for each condition is assumed if the applicable method of this standard is adopted.

This European Standard is based on CGA pamphlet, S-1.2 and S-1.3 and standards prepared by CEN/TC 69.

1 Scope

This standard provides a separate calculation method for determining the contributing mass flow to be relieved resulting from 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 remaining in place but with loss of vacuum, or non vacuum insulated vessels with insulation system intact. Outer jacket at ambient temperature. Inner vessel at temperature of the contents at the relieving pressure;
- 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, and fire engulfment. Inner vessel at temperature of the contents at the relieving pressure;
- 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 contributing mass flow where an appropriate calculation method is not provided for an applicable condition.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

prEN ISO 4126-1*, Safety devices for protection against excessive pressure - Part 1: Safety valves (identical to ISO 4126-1).*

prEN ISO 4126-6:2000, *Safety devices for protection against excessive pressure - Part 6: Application, selection and installation of bursting disc safety devices (ISO/DIS 4126-6:2000).*

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 (bar abs) is the actual relieving pressure which is used for the sizing of a safety valve. This shall not be greater than 1,1 PS, where PS is the maximum allowable pressure for which the vessel is designed.

T_a (K) is the maximum ambient temperature for conditions other than fire (as specified e.g.by regulation/standard)

T_f (K) is the external environment temperature under fire conditions (in any case T_f = 922 K, i.e. 649°C or 1200 F)

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

1) for subcritical fluids, T is the saturation temperature of the liquid at pressure p;

2) for critical or supercritical fluids, T is calculated from 4.3.

3.2 For conditions other than fire

3.2.1 Vacuum insulated vessels under normal vacuum : quantity of heat transferred per unit time (Watt) by heat leak through the insulation system:

$$W_1 = (T_a - T)\ U_1 \Sigma$$

where

U_1 is the overall heat transfer coefficient of the insulating material under normal vacuum, in $Wm^{-2}K^{-1}$

$$U_1 = \frac{\lambda_1}{e_1}$$

λ_1 is the thermal conductivity coefficient of the insulating material under normal vacuum, between T and T_a, in $W.m^{-1}K^{-1}$;

e_1 is the nominal insulating material thickness, in m;

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

3.2.2 Vacuum insulated vessels in case of loss of vacuum or non vacuum insulated vessels; quantity of heat transferred per unit time (Watt) by heat leak through the insulating material:

$$W_2 = (T_a - T)\ U_2 \Sigma$$

where

U_2 is the overall heat transfer coefficient of the insulating material at atmospheric pressure, in $Wm^{-2}K^{-1}$

$$U_2 = \frac{\lambda_2}{e_2}$$

λ_2 is the thermal conductivity coefficient of the insulating material saturated with gaseous lading or air at atmospheric pressure, whichever provides the greater coefficient, between T and T_a, in $Wm^{-1}K^{-1}$.

e_2 is the minimum insulating material thickness taking into account the manufacturing tolerancies or effects of sudden loss of vacuum, in m.

NOTE This formula cannot apply to application at very low temperatures with small thickness of insulating material, as the maximum heat transfer coefficient would be given by air condensation. This phenomena has been studied for helium in W. Lehmann, Sicherheitstechnische Aspekte bei Auslegung and Betrieb von Lhe-badgekühlten-SL-Badkyokasten."

3.2.3 Quantity of heat transferred per unit time (Watt) by supports and piping located in the interspace

$$W_3 = (T_a - T)(w_1 + w_2 + ... + w_n + ...)$$

where

w_n is the heat leak per degree K contributed by one of the supports or the pipes, in WK^{-1}

$$w_n = \lambda_n \frac{S_n}{l_n}$$

λ_n is the thermal conductivity coefficient of the support or pipe material between T and T_a, in $Wm^{-1}K^{-1}$;

S_n is the support or pipe section area, in m²;

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

3.2.4 Quantity of heat transferred per unit time (Watt) by the pressure built up device circuit with the regulator fully open :

W_4 determined from the type (ambient air, water or steam, electrical …) and the design of the pressure built up device circuit. For example, in the case of ambient air vaporiser:

$$W_4 = U_4 A \left(T_a - T\right)$$

where

U_4 is the overall convective heat transfer coefficient of the ambient air vaporiser, in $Wm^{-2}K^{-1}$;

A is the external heat transfer surface area of the vaporiser, in m².

3.3 Under fire conditions

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

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

$$W_5 = 2{,}6 \left(922 - T\right) U_5 \Sigma^{0{,}82}$$

where

$U_5 = \frac{\lambda_5}{e}$, in $Wm^{-2} K^{-1}$;

λ_5 is the thermal conductivity coefficient of the insulating material saturated with gaseous lading or air at atmosphere pressure whichever provides the greater coefficient between T and 922 K, in $Wm^{-1}K^{-1}$;

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

Σ is the mean surface area of the insulating material remaining in place during fire conditions, in m².

If outer jacket remains in place during fire conditions, but if 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 outer jacket and inner vessel, whichever provides the greater coefficient between T and 922 K. Σ is equal to the mean surface area of the interspace.

3.3.1.2 Insulation system does not remain in place during fire conditions

$$W_6 = 7{,}1 \cdot 10^4 \sigma^{0{,}82}$$

where

σ is the total outside surface area of the inner vessel, in m².

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

3.3.3 Total quantity W (Watt) of heat transferred per unit time from the hot wall to the cold wall

Total W is obtained by summing the relevant Ws in accordance with requirements of the relevant cryogenic vessel standards.

4 Calculation of the mass flow Q_m (kg h^{-1}) to be relieved by the safety devices

4.1 The relieving pressure p is less than 40 % of the critical pressure:

$$Q_m = 3{,}6\frac{W}{L}$$

where

L is the latent vaporization heat of the cryogenic liquid in relieving conditions, in kJkg^{-1}.

4.2 The relieving pressure p is below the critical pressure, but equal to or greater than 40 % of these pressure:

$$Q_m = 3{,}6\left(\frac{v_g - v_l}{v_g}\right)\frac{W}{L}$$

where

v_g is the specific volume of saturated gas at the relieving pressure p, in m^{3}kg^{-1};

v_l is the specific volume of saturated liquid at the relieving pressure p, in m^{3}kg^{-1}.

4.3 The relieving pressure p is equal to or greater than the critical pressure:

$$Q_m = 3{,}6\frac{W}{L'}$$

where

L' is the specific heat input: $v\left[\frac{\partial h}{\partial v}\right]_p$ at the relieving pressure p and at the temperature T (K), in kJkg^{-1} where

$$\frac{\sqrt{v}}{v\left[\frac{\partial h}{\partial v}\right]_p}$$ is a maximum;

v is the specific volume of critical or supercritical fluid at the relieving pressure p and any temperature within the operating range, in m^{3}kg^{-1};

h is the enthalpy of the fluid in the same conditions as above, in kJkg^{-1}.

EXAMPLE Calculate the value of L' and T to be used for liquid hydrogen relieving at pressure p = 13,8 bar abs as given in Table 1.

Table 1

Temperature (K)	ν (m^3kg^{-1})	$v\left[\frac{\partial h}{\partial v}\right]_p$ ($kJkg^{-1}$)	$\frac{\sqrt{v}}{v\left[\frac{\partial h}{\partial v}\right]_p}$
33,3	0,0271567	214,09	0,0007697
34,7	0,0582961	236,56	0,0010206
34,8	0,0588450	237,49	0,0010214 max
34,9	0,0593488	238,65	0,0010208
38,9	0,0855371	304,53	0,0009603
44,4	0,1109707	384,77	0,0008657

At p = 13,8 bar abs, the maximum value of $\frac{\sqrt{v}}{v\left[\frac{\partial h}{\partial v}\right]_p}$ occurs at T = 34,8 K for hydrogen

In these conditions: L' = 237,49 $kJkg^{-1}$

5 Rule for the safety devices installation

The pipe between outer jacket and safety device should not be longer than 0,6 m otherwise, heat transfer to the released flow shall be taken into account. This heat transfer reduces the product density and consequently reduces the effective discharge rate of the relief system (see calculation methods in the bibliography).

The maximum pressure drop of the pipework to the pressure relieving valve at the maximum flow capacity of the safety valve shall be 2% (of the set pressure of the pressure relief valve) less than the specified minimum blowdown of that pressure relief valve.

Where the blowdown is not known, the pressure drop shall be no greater than 3% of the safety valve set pressure at the rated flow.

6 Sizing of safety devices

6.1 Safety valves

According to prEN ISO 4126-1.

6.2 Bursting disc

According to prEN ISO 4126-6:2000 annex B.

6.3 Sizing of safety valves and bursting discs

For all safety devices which have to evacuate together the mass flow Q_m at the same relieving pressure p, Q_m shall be less than or equal to the sum of the relieving capacity of all the individual relieving devices.

Without a separate justification, the following rules are valid. Under fire conditions and in case of transportable vessels for nitrogen, oxygen or argon having water capacity exceeding 450 liters, the minimum required mass flow of the pressure relief devices, shall not be less than 0,018 kg h^{-1} of air per liter of water capacity, at T = 288 K and p = 2,7 bar abs.

Annex ZA
(informative)

Clauses of this European Standard addressing essential requirements or other provisions of EU Directives

This European Standard 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 Directives: Pressure Equipment Directive 97/23/CE dated 29-05-1997.

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

The clauses of this European Standard given in Table ZA.1 are likely to support requirements of Directives.

Table ZA.1 — Comparison between the PED and this European Standard

Harmonised clauses of EN 13648-3	Content	PED
3, 4	Protection against exceeding the allowable limits of pressure equipment	Annex I, 2.10
5,6	Safety accessories	Annex I, 2.11
3.3	External fire	Annex I, 2.12

Compliance with the clauses of this standard provides one means of conforming to the specific essential requirements of the directive concerned and associated EFTA regulations.

Bibliography

[1] CGA S-1.2 – 1995, *Pressure Relief Device Standards – Part 2: Cargo and Portable Tanks for Compressed Gases.*

[2] CGA S-1.3 – 1995, *Pressure Relief Device Standards – Part 3: Stationery Storage Containers for Compressed Gases.*

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