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Refrigerating systems and heat pumps — Pressure relief devices and their associated piping — Methods for calculation

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National foreword

This British Standard is the UK implementation of EN 13136:2013. It supersedes BS EN 13136:2001 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RHE/18, Refrigeration safety.

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

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Kälteanlagen und Wärmepumpen - Druckentlastungseinrichtungen und zugehörige Leitungen - Berechnungsverfahren

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Page

Foreword

This document (EN 13136:2013) has been prepared by Technical Committee CEN/TC 182 “Refrigerating systems, safety and environmental requirements”, the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by April 2014, and conflicting national standards shall be withdrawn at the latest by April 2014.

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 13136:2001.

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.

Compared to EN 13136:2001, EN 13136:2013 takes into account the application of CO_2 and the amendment A1, published in 2005.

According to the CEN-CENELEC Internal Regulations, the national standards organisations 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.

Introduction

This European Standard is based on applicable parts of EN ISO 4126-1:2013, EN ISO 4126-2:2003 and EN 12284.

It is suited to the specific requirements, and includes the data, of refrigerating systems. It provides means of satisfying the pressure relief devices requirements of EN 378-2:2008+A2:2012.

1 Scope

1.1 This European Standard describes the calculation of mass flow for sizing pressure relief devices for components of refrigerating systems.

NOTE The term "refrigerating system" used in this European Standard includes heat pumps.

1.2 This European Standard describes the calculation of discharge capacities for pressure relief valves and other pressure relief devices in refrigerating systems including the necessary data for sizing these when relieving to atmosphere or to components within the system at lower pressure.

1.3 This European Standard specifies the requirements for selection of pressure relief devices to prevent excessive pressure due to internal and external heat sources, the sources of increasing pressure (e.g. compressor, heaters, etc.) and thermal expansion of trapped liquid.

1.4 This European Standard describes the calculation of the pressure loss in the upstream and downstream line of pressure relief valves and other pressure relief devices and includes the necessary data.

1.5 This European Standard refers to other relevant standards in Clause 5.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 378-1:2008+A2:2012, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 1: Basic requirements, definitions, classification and selection criteria*

EN 378-2:2008+A2:2012, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 2: Design, construction, testing, marking and documentation*

EN 764-1:2004, *Pressure equipment — Part 1: Terminology — Pressure, temperature, volume, nominal size*

EN 764-2:2012, *Pressure equipment — Part 2: Quantities, symbols and units*

EN 12284:2003, *Refrigerating systems and heat pumps — Valves — Requirements, testing and marking*

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

EN ISO 4126-2:2003, *Safety devices for protection against excessive pressure — Part 2: Bursting disc safety devices (ISO 4126-2:2003)*

ISO 817, *Refrigerants — Designation system*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 378-1:2008+A2:2012, EN 12284:2003, EN ISO 4126-1:2013, EN ISO 4126-2:2003 and EN 764-1:2004 apply.

4 Symbols

For the purposes of this document, the symbols given in EN 764-2:2012 and the following apply:

Symbol	Designation	Unit
A	Flow area of the pressure relief valve $A = \left[\frac{\pi \times d^2}{4}\right]$	mm^2
A_c	Calculated flow area	mm^2
A_{DN}	Valve cross section related to DN	mm^2
A_{in}	Inside area of inlet tube	mm^2
A_{liq}	Calculated flow area of liquid after expansion	mm^2
A_{out}	Inside area of outlet tube	mm^2
A_R	Inside area of tube	mm^2
A_{surf}	External surface area of the vessel	m^2
A_{vap}	Calculated flow area of vapour after expansion	mm^2
C	Function of the isentropic exponents (Table A.2)	–
DN	Nominal size (see EN ISO 6708:1995)	–
d	Actual most narrow flow diameter of the pressure relief valve	mm
d_c	Calculated flow diameter of the pressure relief valve	mm
d_{in}	Inside diameter of inlet tube	mm
d_{out}	Inside diameter of outlet tube	mm
D_R	Outside diameter of tube (Table A.4)	mm
d_R	Inside diameter of tube	mm
h_{vap}	Heat of vaporisation calculated at 1,1 times the set pressure of the pressure relief device (for super critical or superheated conditions see 6.1)	kJ/kg
K_b	Theoretical capacity correction factor for sub-critical flow (Table A.3)	–
K_d	Certified coefficient of discharge taking into account the backpressure ratio p_b/p_o and the possible reduced stroke of the pressure relief valve	–
K_{dr}	De-rated coefficient of discharge $\left[K_{dr} = K_d \times 0{,}9\right]$	–
K_{drl}	De-rated coefficient of discharge for liquid $\left[K_{drl} \approx K_{dr} \times 0{,}8\right]$	–
K_{vs}	Valve constant (the rate of water flow for a differential pressure Δp of 1 bar at the rated full opening)	m^3/h
K_v	Viscosity correction factor	–

K	Isentropic exponent of the refrigerant; for calculation, the value of K shall be as measured at 25 °C and 1,013 bar	–
L	Length of tube	mm
L_{in}	Length of inlet tube	mm
L_{out}	Length of outlet tube	mm
n	Rotational frequency	min^{-1}
p_{atm}	Atmospheric pressure (1 bar)	bar
p_b	Back pressure at outlet of pressure relief device, absolute	bar
p_c	Critical absolute pressure	bar
p_o	Actual relieving pressure $p_o = 1{,}1\ p_{set} + p_{atm}$	bar
p_s	Maximum allowable pressure of a component, gauge[a]	bar
p_{set}	Set pressure, gauge (the pre-determined pressure at which a pressure relief valve under operation starts to open)	bar
P_1	Pressure at the inlet to downstream line absolute (in practice = p_b)	bar
P_2	Pressure at the outlet of downstream line absolute	bar
Δp	Differential pressure	bar
Δp_{in}	Pressure loss in the upstream line of pressure relief valve	bar
Δp_{out}	Pressure loss in the downstream line of pressure relief valve	bar
Q_h	Rate of heat production, internal heat source	kW
Q_{liq}	Flow of liquid after expansion	kg/h
Q_m	Calculated refrigerant mass flow rate of the pressure relief device	kg/h
q_m	Theoretical discharge capacity	$kg/h \cdot mm^2$
q'_m	Actual discharge capacity determined by tests	$kg/h \cdot mm^2$
Q_{md}	Minimum required discharge capacity, of refrigerant, of the pressure relief device	kg/h
$Q_{md'}$	Adjusted discharge capacity of refrigerant, of the pressure relief device, used for pressure drop calculation	kg/h
Q_{vap}	Flow of vapour after expansion	kg/h
R	Bending radius of tube (Table A.4)	mm
Re	Reynolds number	–
s	Thickness of insulation	m
V	Theoretical displacement	m^3
v_o	Specific volume of vapour or liquid	m^3/kg
w_0	Actual flow speed of liquid in the smallest section of pressure relief valve	m/s
w_1	Speed at the inlet into the downstream line	m/s
x	Vapour fraction of refrigerant at p_C	–

α	Flush connection angle (Table A.4)	°
ζ	Pressure loss coefficient $\zeta = \sum_{n=1}^{n} \zeta_n$	–
ζ_{DN}	Pressure loss coefficient related to DN	–
ζ_n	Pressure loss coefficient of a single component	–
η_v	Volumetric efficiency estimated at suction pressure and discharge pressure equivalent to the pressure relief device setting	–
λ	Friction loss coefficient of tube (plain steel tube $\lambda \approx 0{,}02$)	–
ν	Kinematic viscosity	m^2/s
ρ	Density of vapour or liquid ($\rho = {}^1/v_o$)	kg/m^3
ρ_{10}	Vapour density at refrigerant saturation pressure/dew point at 10 °C	kg/m^3
φ	Density of heat flow rate	kW/m^2
φ_{red}	Reduced density of heat flow rate	kW/m^2
[a] The Pressure Equipment Directive 97/23/EC identifies the maximum allowable pressure by the symbol "PS".		

5 General

Requirements for protection against excessive pressure in refrigeration systems and heat pumps are given in EN 378-2.

For design and manufacturing of bodies, bonnets and bolts for pressure relief devices — safety valves and bursting discs — specification of strength pressure test, EN 12284 applies.

For other aspects, the requirements of EN ISO 4126-1:2013 Safety Valves, Clause 3, Terms and definitions, Clause 5, Design, Clause 7, Type tests and Clause 10, Marking and sealing and EN ISO 4126-2:2003 Bursting Disc Safety Devices, Clause 17 Marking, 17.2 Bursting discs/bursting disc assemblies and 17.3 Bursting disc holders apply.

NOTE Calculations for flow areas for non-evaporating and evaporating liquids are given in Annex B. Calculations for a pressure relief device with the corresponding pipes are given in Annex C.

6 Pressure relief devices for protection of system components

6.1 General

Calculations shall be based on known or assumed processes which result in increases in pressure. All foreseeable processes shall be considered including those covered in 6.2, 6.3 and 6.4.

For the general purposes of this European Standard, h_{vap} is calculated at 1,1 times the set pressure of the pressure relief device.

If the set pressure of the pressure relief valve times 1,1, is higher than the saturated pressure of the refrigerant at (critical temperature minus 5 [K]) then h_{vap} and v_o shall be taken at critical temperature minus 5 [K].

If the temperature, at 1,1 times the set pressure of the pressure relief device, is higher than the saturated temperature (superheated gas), then h_{vap} shall be taken at saturated condition.

In case of relieving CO_2 to a pressure below the triple point (e.g. atmospheric pressure), there is a possibility to create solid CO_2. Necessary precautions shall be taken to ensure a safe operation.

Vessels operating normally in the gas phase may however contain liquid refrigerant, which may evaporate under an external heat impact.

NOTE Vessels only containing refrigerant in the gas phase do not produce a continuous mass flow under an external heat impact.

In case of supercritical pressure, the valve shall be suitable for both gas and liquid.

6.2 Excessive pressure caused by heat sources

6.2.1 External heat sources

Where necessary the minimum required discharge capacity of the pressure relief device for pressure vessels shall be determined by the following:

$$Q_{\text{md}} = \frac{3600 \times \varphi \times A_{\text{surf}}}{h_{\text{vap}}} \quad \text{[kg/h]} \tag{1}$$

For those pressure vessels in this European Standard, the density of heat flow rate is assumed to be

$$\varphi = 10\ \text{kW/m}^2 \tag{2}$$

but a higher value shall be used if necessary.

Where the thickness(s) of the insulation of the pressure vessel is bigger than 0,04 [m] and the insulation is tested according to reaction of fire as described in EN 13501-1 and classified better than class C, a reduced density of heat flow rate can be used and determined as follows:

$$\varphi_{\text{red}} = \varphi \times \frac{0{,}04}{s}\ [\text{kW/m}^2] \tag{3}$$

The sizing of the pressure relief device and calculating of pressure loss are carried out in accordance with Clause 7.

For pressure vessels the total external surface area of the vessel shall be taken as $A_{\text{surf.}}$

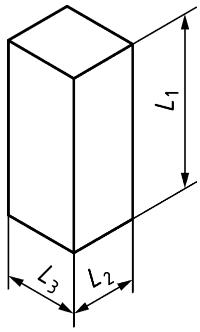


Figure 1 — Plate Heat Exchanger (PHE)

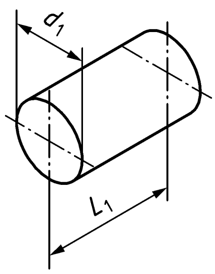


Figure 2 — Plate and Shell Heat Exchanger (PSHE)

A_{surf} of Plate Heat Exchanger will be calculated as follows:

$$A_{surf} = 2 \times (L_1 \times L_2 + L_2 \times L_3 + L_1 \times L_3) \text{ [m}^2\text{]} \quad (4)$$

A_{surf} for Plate and Shell Heat Exchanger will be calculated as follows:

$$A_{surf} = 2 \times (\pi / 4 \times d_1^{\,2}) + (\pi \times \mathrm{d}_1 \times L_1) \text{ [m}^2\text{]} \quad (5)$$

Heat exchangers are generally considered to be vessels. Due to its unique design, some fin and tube heat exchangers in refrigeration systems may be classified according to Article 1 paragraph 2.1.2 last sentence. For further details, see guideline 2/4 of PED 97/23/EC.

Higher values for density of heat flow rate than 10 kW/m^2 may be necessary where in case of fire full engulfment for the pressure vessel is to be expected and/or in the case the pressure vessel is insulated with a flammable insulation. Other calculation methods could be necessary in case of heat radiation with a higher heat flow directed to one side of the vessel.

Where pressure vessels of a refrigerating system are protected against excessive pressure according to EN 378-2:2008+A2:2012, 6.2 and monitored according to EN 378-3:2008+A1:2012, Clause 7 and installed in special machinery rooms as specified in EN 378-3:2008+A1:2012, Clause 5, no external heat sources for sizing the pressure relief devices used for those vessels themselves may be considered. But, nevertheless, for the sizing of those pressure relief devices on the low pressure side of the refrigerating system all connected pressure vessels, compressors and pumps should be taken into account (EN 378-2:2008+A2:2012, 6.2.6.3).

Combustion heat potential of insulations in case of fire is not part of the calculations in this European Standard. Care should be taken at welding activities near insulated vessels and pipes. Electric equipment inside of the flammable insulation should be carried out according to EN 60204-1.

6.2.2 Internal heat sources

The minimum required discharge capacity of the pressure relief device for conditions which arise due to an internal source of excessive heat shall be determined by the following:

$$Q_{md} = \frac{3600 \times Q_h}{h_{vap}} \text{ [kg/h]} \quad (6)$$

The sizing of the pressure relief device and calculating of pressure loss are carried out in accordance with Clause 7.

6.3 Excessive pressure caused by compressors

The minimum required discharge capacity of the pressure relief device for excessive pressure caused by compressors shall be determined by the following:

$$Q_{\text{md}} = 60 \times V \times n \times \rho_{10} \times \eta_{\text{v}} \quad \text{[kg/h]} \qquad (7)$$

For low temperature operations, where it can be established that the compressor motor cannot run with the suction pressure corresponding to 10 °C saturated conditions, then the value at the highest suction pressure shall be used in the calculation.

NOTE 1 In cases where discharge shut-off valves are not fitted, a high pressure relief device will suffice, providing there are no intermediate shut-off valves.

NOTE 2 Non-positive displacement compressors need not have a pressure relief device providing it is not possible to exceed the maximum allowable pressure.

NOTE 3 Relieving to the low pressure side may cause compressor overheating and / or uncontrolled internal pressure in compressors (e.g. in screw compressors).

EN 12693 covers compressors which can run against a closed discharge valve. EN 12693 should, therefore, be considered, especially the requirement covering conditions under which the allowable evaporating temperature exceeds the value of 10 °C by more than 5 K.

The sizing of the pressure relief device and the calculation of the pressure loss shall be carried out in accordance with Clause 7.

6.4 Excessive pressure caused by liquid expansion

The effective area $\left[A \times K_{\text{dr}}\right]$ of the pressure relief device to protect against excessive pressure caused by the expansion of trapped liquid shall be at least 0,02 mm^2 per litre of trapped volume, except that the minimum diameter shall not be less than 1 mm.

For refrigerants where the temperature difference between relieving temperature and critical temperature is less than 20 [K], then the expansion of trapped liquid shall be at least 0,04 mm^2 per litre of trapped volume.

NOTE Liquids having a temperature close to the critical temperature expand considerably.

It is advisable to take into account the backpressure ratio p_b/p_o and the possibly reduced stroke of the pressure relief valve.

The possibility of contamination by dirt should be considered.

Where practicable, the pressure relief device shall relieve to the low pressure side of the system and the pressure relief device shall meet the following requirements even at maximum back pressure:

$$p_{\text{o}} \leq 1{,}1 \times p_{\text{set}} + p_{\text{atm}} \quad \text{[bar]} \qquad (8)$$

7 Discharge capacities of pressure relief devices

7.1 General

When the operational characteristics have been satisfactorily established, it is acceptable to use steam, air or other gas of known characteristics as the fluid for flow characteristics tests except for valves designed for liquid service (see Annex B). When discharged quantities are being assessed, the valve disc shall be held at the minimum lift as determined by the operating characteristics test.

7.2 Determination of pressure relief valve performance

7.2.1 Determination of coefficient of discharge

The coefficient of discharge is calculated from:

$$K_{\mathrm{d}} = \frac{q'_{\mathrm{m}}}{q_{\mathrm{m}}} \quad [\text{-}] \tag{9}$$

The de-rated coefficient of discharge is calculated from:

$$K_{\mathrm{dr}} = 0{,}9 \times K_{\mathrm{d}} \quad [\text{-}] \tag{10}$$

7.2.2 Critical and sub-critical flow

The flow of a gas or vapour through an orifice, such as the flow areas of a pressure relief valve, increases as the outlet pressure is decreased until critical flow is achieved. Further decrease in outlet pressure will not result in any further increase in flow.

Critical flow occurs when

$$\frac{p_{\mathrm{b}}}{p_{\mathrm{o}}} \leq \left[\frac{2}{\kappa+1}\right]^{\kappa/(\kappa-1)} \quad [–] \tag{11}$$

and sub-critical flow occurs when

$$\frac{p_{\mathrm{b}}}{p_{\mathrm{o}}} > \left[\frac{2}{\kappa+1}\right]^{\kappa/(\kappa-1)} \quad [–] \tag{12}$$

assuming the validity of Rankine's law. If the flow is critical K_{b} = 1, and if the flow is sub-critical, the correction factor shall be calculated according to Formula (14) in 7.2.4 or taken from Table A.3.

7.2.3 Function of the isentropic exponent *(C)*

The function (C) of the isentropic exponent is calculated from:

$$C = 3{,}948 \times \sqrt{\kappa \times \left[\frac{2}{\kappa+1}\right]^{(\kappa+1)/(\kappa-1)}} \quad [–] \tag{13}$$

For this calculation, the value of K shall be as measured at 25 °C and 1,013 bar. Values of K and calculated values of C for some refrigerants are given in Table A.1, and values of C as a function of K are given in Table A.2.

7.2.4 Correction factor for sub-critical flow

The correction factor for sub-critical flow is calculated from:

$$K_b = \sqrt{\frac{\frac{2\cdot\kappa}{\kappa-1}\times\left[\left(\frac{p_b}{p_0}\right)^{2/\kappa}-\left(\frac{p_b}{p_0}\right)^{(\kappa+1)/\kappa}\right]}{\kappa\times\left(\frac{2}{\kappa+1}\right)^{(\kappa+1)/(\kappa-1)}}} \quad [–] \tag{14}$$

For this calculation the value of κ shall be as measured at 25 °C and 1,013 bar. Values of K_b as a function of p_b/p_o are given in Table A.3 for various values of κ.

7.2.5 Discharge capacity of pressure relief valves

7.2.5.1 General

For the most common use of pressure relief valves in refrigerating systems, the back pressure is lower than approximately 0,5 x relieving pressure ($p_b \leq 0,5\,p_o$) and $K_b = 1$, which indicates that the flow through the pressure relief valve is "critical flow".

For valves where the lift is a function of back pressure, the manufacturer shall state the maximum permissible back pressure ratio p_b/p_o and the relating certified coefficient of discharge taking into account the possibly reduced stroke of the pressure relief valve.

7.2.5.2 Calculation of the mass flow

The mass flow for critical and sub-critical flow is calculated from:

$$Q_m = 0,2883\times C \times A \times K_{dr}\times K_b\times\sqrt{\frac{p_o}{v_o}} \quad [kg/h] \tag{15}$$

$$Q_{md} < Q_m < 1,25\times Q_{md} \Rightarrow Q_{md'} = Q_{md}$$

$$Q_m \geq 1,25\times Q_{md} \Rightarrow Q_{md'} = Q_m / 1,25$$

The flow area A_c is calculated from the minimum required discharge capacity of refrigerant $Q_{md'}$ according to Formulae (1), (6) and (7) as follows:

$$A_c = \frac{Q_{md'}}{0,2883\times C\times K_{dr}\times K_b\times\sqrt{\frac{p_0}{v_o}}} = 3,469\times\frac{Q_{md'}}{C\times K_{dr}\times K_b}\times\sqrt{\frac{v_o}{p_o}} \quad [mm^2] \tag{16}$$

where for critical flow $K_b = 1$.

For the specific volume v_o the value pertaining to pressure p_o is to be inserted.

Values of C as a function of K are given in Table A.2. Values of K_b as a function of p_b/p_o are given in Table A.3 for various values of K.

7.3 Calculation of capacity and flow area of bursting discs or fusible plugs

Domed bursting discs shall be designed so that they burst due to tensile forces when the bursting pressure is applied to the concave side of the bursting disc. They shall be domed such that no further plastic flow will occur initially when the bursting disc is subject to its intended operating condition.

The discharge capacity of a bursting disc or fusible plug shall be calculated from the formula given in 7.2.5.2. The following values for K_{dr} shall be the maximum used depending on how the pipe between the vessel and the bursting disc or fusible plug is mounted on the vessel:

a) flush or flared connection (see Table A.4): K_{dr} = 0,70;

b) inserted connection (see Table A.4): K_{dr} = 0,55.

If the K_{dr} -value of the bursting disc or fusible plug itself is lower than the maximum value given above, then the smaller value shall be used in the calculation.

7.4 Pressure loss in upstream/downstream lines

7.4.1 General

To ensure correct operation of pressure relief valves the pressure loss at minimum required capacity (i.e. p_o = 1,1 x p_{set} + 1) in both upstream and downstream lines, including any changeover device shall not exceed the following:

- the values stated by the supplier of the pressure relief valve, or;
- upstream line (including changeover device): $\Delta p_{in} \leq 0{,}03 \times p_o$ [bar];
- downstream line (back pressure dependent): $\Delta p_{out} \leq 0{,}10 \times p_o$ [bar];
- downstream line (back pressure independent): $\Delta p_{out} \leq 0{,}20 \times p_o$ [bar].

The velocity in the up- / downstream line shall not reach critical speed (sonic velocity).

The flow area (A_{in}) of the up- / downstream line shall not be less than the actual flow area (A) of the pressure relief valve.

7.4.2 Pressure loss in components

The pressure loss in components, e.g. changeover devices, can be calculated by means of K_{vs}-values or ζ-values.

Calculation of pressure loss by means of K_{vs}-values is given by:

$$\Delta p = v_o \times \left[\frac{Q_{md'}}{K_{VS}} \right]^2 \times 10^{-3} \text{ [bar]} \quad (17)$$

The flow area (A_{in}) of all components in up- / downstream line shall not be less than the actual flow area (A) of the pressure relief valve.

Calculation of pressure loss by means of ζ – values is given by:

$$\Delta p = 0{,}3858 \times \zeta \times v_{\mathrm{o}} \times \left[\frac{Q_{\mathrm{md'}}}{A_{\mathrm{R}}} \right]^2 \text{ [bar]} \tag{18}$$

where

$$\zeta = \sum_{n=1}^{n} \zeta_n$$

and from Formulae (17) and (18) the pressure loss coefficient is given by:

$$\zeta = 2{,}592 \times \left[\frac{A_{\mathrm{R}}}{K_{\mathrm{VS}}} \right]^2 \times 10^{-3} \text{ [-]} \tag{19}$$

If the manufacturer provides the pressure loss coefficient ζ_{DN} for devices (valves) related to the nominal diameter (DN), it is converted to the pressure loss coefficient ζ for the actual internal diameter of the pipe from Formula (20):

$$\zeta = \left[\frac{d_{\mathrm{R}}}{DN} \right]^4 \times \zeta_{\mathrm{DN}} \qquad [–] \tag{20}$$

NOTE ζ results from A_{R}, d_{R},/ ζ_{DN} results from A_{DN}, DN.

7.4.3 Pressure loss in the upsteam line

The pressure loss in the upstream line is given by:

$$\Delta p_{\mathrm{in}} = 0{,}0320 \times \left[\frac{A_{\mathrm{c}}}{A_{\mathrm{in}}} \times C \times K_{\mathrm{dr}} \times K_{\mathrm{b}} \times \right]^2 \times \zeta \times p_{\mathrm{o}} \text{ [bar]} \tag{21}$$

For limiting values of Δp_{in} reference shall be made to 7.4.1.

7.4.4 Pressure loss in the downstream line

The pressure loss in the downstream line is given by:

$$\Delta p_{\mathrm{out}} = p_1 - p_2 \text{ [bar]} \tag{22}$$

where subscripts 1 and 2 indicate the start and end of the downstream line respectively. Assuming isothermal flow of a compressible medium, p_1 can be calculated from:

$$\frac{p_1^2 - p_2^2}{2 \times p_1} = \zeta \times \rho 1 \times \frac{w_1^2}{2} \text{ [bar]} \tag{23}$$

or

$$p1 = \sqrt{0{,}064 \times \zeta \times \left[\frac{A_{\text{c}}}{A_{\text{out}}} \times C \times K_{\text{dr}} \times K_{\text{b}} \times p_{\text{o}} \right]^2 + p_2^2} \quad \text{[bar]} \tag{24}$$

For limiting values of Δp_{out} reference shall be made to 7.4.1.

Annex A
(normative)

Values of functions, factors and properties of refrigerants

Table A.1 — Properties of refrigerants

Refrigerant number[a]	**Description** Composition = % weight	**Formula**	**Isentropic exponent**[b] K	**Critical pressure ratio**[b] (p_b/p_o)	**Function of the isentropic exponent**[b] C
R-11	Trichlorofluoromethane	CCl_3F	1,10	0,59	2,48
R-12	Dichlorodifluoromethane	CCl_2F_2	1,12	0,58	2,49
R-12B1	Bromochlorodifluoromethane	$CBrClF_2$	1,11	0,58	2,49
R-13	Chlorotrifluoromethane	$CClF_3$	1,14	0,58	2,51
R-13B1	Bromotrifluoromethane	$CBrF_3$	1,13	0,58	2,50
R-22	Chlorodifluoromethane	$CHClF_2$	1,17	0,57	2,54
R-23	Trifluoromethane	CHF_3	1,19	0,57	2,55
R-30	Methylene chloride	CH_2Cl_2	1,15	0,57	2,52
R-32	Difluoromethane	CH_2F_2	1,24	0,56	2,59
R-40	Methylchloride	CH_3Cl	1,27	0,55	2,61
R-50	Methane	CH_4	1,31	0,54	2,64
R-113	1,1,2-Trichloro-1,2,2-Trifluoroethane	CCl_2FCClF_2	1,06	0,59	2,45
R-114	1,2-Dichloro-1,1,2,2-Tetrafluoroethane	$CClF_2CClF_2$	1,04	0,60	2,43
R-115	2-Chloro-1,1,1,2,2-Pentafluoroethane	CF_3CClF_2	1,09	0,59	2,47
R-123	2,2-Dichloro-1,1,1-Trifluoroethane	CF_3CHCl_2	1,10	0,59	2,48
R-124	2-Chloro-1,1,1,2-Tetrafluoroethane	CF_3CHClF	1,10	0,58	2,48
R-125	Pentafluoroethane	CF_3CHF_2	1,10	0,58	2,48
R-134a	1,1,1,2-Tetrafluoroethane	CF_3CH_2F	1,12	0,58	2,50
R-141b	1,1-Dichloro-1-Fluoroethane	CCl_2FCH_3	1,10	0,58	2,48
R-142b	1-Chloro-1,1-Difluoroethane	$CClF_2CH_3$	1,12	0,58	2,50
R-143a	1,1,1-Trifluoroethane	CF_3CH_3	1,13	0,58	2,50
R-152a	1,1-Difluoroethane	CHF_2CH_3	1,15	0,57	2,52
R-160	Ethylchloride	CH_3CH_2Cl	1,16	0,57	2,53
R-170	Ethane	CH_3CH_3	1,20	0,56	2,56
R-218	Octafluoropropane	C_3F_8	1,07	0,59	2,45
R-290	Propane	$CH_3CH_2CH_3$	1,19	0,57	2,55

Table A.1 *(continued)*

R-401A	R-22/152a/124 (53/13/34)	$CHClF_2$+ CHF_2CH_3+ CF_3CHClF	1,15	0,57	2,52
R-401B	R-22/152a/124 (61/11/28)	$CHClF_2$+ CHF_2CH_3+ CF_3CHClF	1,16	0,57	2,53
R-401C	R-22/152a/124 (33/15/52)	$CHClF_2$+ CHF_2CH_3+ CF_3CHClF	1,14	0,58	2,51
R-402A	R-125/290/22	CF_3CHF_2+ $CH_3CH_2CH_3$+ $CHClF_2$	1,13	0,58	2,51
R-402B	R-125/290/22 (38/2/60)	CF_3CHF_2+ $CH_3CH_2CH_2$+ $CHClF_2$	1,15	0,57	2,52
R-403A	R-22/218/290 (75/29/5)	$CHClF_2$+ C_3F_8+C_3H_8	1,15	0,57	2,52
R-403B	R-22/218/290 (56/39/5)	$CHClF_2$+ C_3F_8+C_3H_8	1,13	0,58	2,50
R-404A	R-125/143a/134a (44/52/4)	CF_3CHF_2+ CF_3CH_3+ CF_3CH_2F	1,12	0,58	2,49
R-406A	R-22/142b/600a (55/41/4)	$CHClF_2$+ $CClF_2CH_3$+ $CH(CH_3)_3$	1,10	0,58	2,48
R-407A	R-32/125/134a (20/40/40)	CH_2F_2+ CF_3CHF_2+ CF_3CH_2F	1,14	0,58	2,51
R-407B	R-32/125/134a (10/70/20)	CH_2F_2+ CF_3CHF_2+ CF_3CH_2F	1,12	0,58	2,50
R-407C	R-32/125/134a (23/25/52)	CH_2F_2+ CF_3CHF_2+ CF_3CH_2F	1,14	0,58	2,51
R-408A	R-125/143a/22 (7/46/47)	CF_3CHF_2+ CF_3CH_3+ $CHClF_2$	1,15	0,58	2,52

Table A.1 *(continued)*

R-409A	R-22/124/142b (60/25/15)	$CHClF_2$+ CF_3CHClF+ CH_3CClF_2	1,15	0,57	2,52
R-409B	R-22/124/142b (65/25/10)	$CHClF_2$+ CF_3CHClF+ CH_3CClF_2	1,16	0,57	2,53
R-410A	R-32/125 (50/50)	CH_2F_2+ CF_3CHF_2	1,17	0,57	2,54
R-410B	R-32/125 (45/55)	CH_2F_2+ CF_3CHF_2	1,17	0,57	2,53
R-412A	R-22/218/142b (70/5/25)	$CHClF_2$+ C_3F_8+ $CClF_2CH_3$	1,16	0,57	2,53
R-500	R-12/152a (73,8/26,2)	CCl_2F_2+ CHF_2CH_3	1,12	0,58	2,49
R-501	R-12/22 (25/75)	CCl_2F_2+ $CHClF_2$	1,18	0,57	2,54
R-502	R-22/115 (48,8/51,2)	$CHClF_2$+ CF_3CClF_2	0,98	0,61	2,38
R-503	R-13/23 (59,9/40,1)	$CClF_3$+CHF_3	1,16	0,57	2,53
R-507	R-125/143a (50/50)	CF_3CHF_2+ CF_3CH_3	1,10	0,58	2,48
R-508A	R-23/116 (39/61)	CHF_3+C_2F_6			
R-508B	R-23/116 (46/54)	CHF_3+C_2F_6	1,14	0,58	2,51
R-509	R-22/218 (44/56)	$CHClF_2$+C_3F_8	1,11	0,58	2,49
R-600	Butane	C_4H_{10}	1,10	0,58	2,48
R-600a	Isobutane	$CH(CH_3)_3$	1,10	0,58	2,48
R-611	Methylformate	$C_2H_4O_2$	1,12	0,58	2,50
R-717	Ammonia	NH_3	1,31	0,54	2,64
R-718	Water [c]	H_2O	1,32	0,54	2,65
R-744	Carbon dioxide	CO_2	1,30	0,55	2,63
R-764	Sulfur dioxide[c]	SO_2	1,27	0,55	2,61
R-1130	1,2-Dichloroethylene[d]	CHCl=CHCl	1,14	0,58	2,51
R-1150	Ethylene	CH_2=CH_2	1,25	0,55	2,60
R-1270	Propylene	C_3H_6	1,14	0,58	2,51
R-C318	Octafluorocyclobutane	C_4F_8	1,07	0,59	2,45

Table A.1 *(continued)*

–	Dimethylether	CH_3OCH_3	1,16	0,57	2,53

[a] The R-numbers are in accordance with ISO 817.

[b] The figures are based on 25 °C and 1,013 absolute bar.

[c] The figures are based on 100 °C and 1,013 absolute bar.

[d] The figures are based on 0 °C and 1,013 absolute bar.

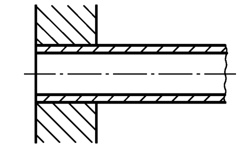
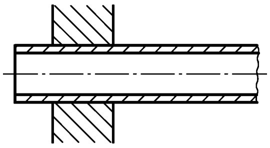
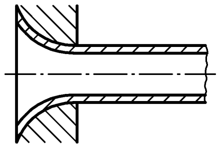
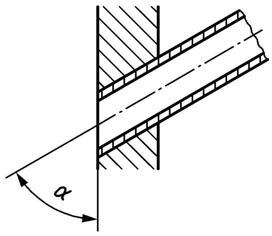
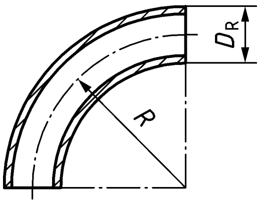
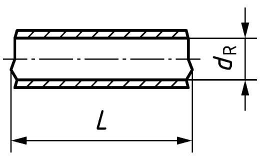
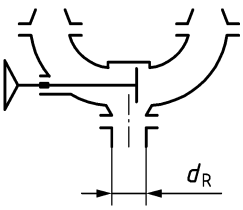
Table A.2 — Values of *C* as a function of *K*

K	*C*
0,90	2,30
0,92	2,32
0,94	2,34
0,96	2,36
0,98	2,38
1,00	2,39
1,02	2,41
1,04	2,43
1,06	2,45
1,08	2,46
1,10	2,48
1,12	2,50
1,14	2,51
1,16	2,53
1,18	2,54
1,20	2,56
1,22	2,58
1,24	2,59
1,26	2,61
1,28	2,62
1,30	2,63
1,32	2,65
1,34	2,66
1,36	2,68
1,38	2,69
1,40	2,70
1,42	2,72
1,44	2,73
1,46	2,74
1,48	2,76
1,50	2,77
1,52	2,78

Table A.3 — Theoretical capacity correction factors for subcritical flow K_b

p_b/p_o	Isentropic exponent K												
	0,90	**0,95**	**1,00**	**1,05**	**1,10**	**1,15**	**1,20**	**1,25**	**1,30**	**1,35**	**1,40**	**1,45**	**1,50**
	Theoretical capacity correction factors for subcritical flow K_b												
0,45													
0,50												0,999	1,000
0,55						0,999	0,999	1,000	1,000	1,000	0,999	0,998	0,997
0,60		0,999	1,000	1,000	0,999	0,998	0,997	0,995	0,993	0,991	0,989	0,986	0,983
0,65	0,999	0,997	0,995	0,992	0,989	0,985	0,982	0,978	0,974	0,971	0,967	0,963	0,959
0,70	0,985	0,980	0,975	0,969	0,964	0,959	0,953	0,948	0,943	0,937	0,932	0,927	0,922
0,75	0,953	0,945	0,938	0,931	0,923	0,916	0,909	0,903	0,896	0,890	0,884	0,878	0,872
0,80	0,900	0,890	0,881	0,872	0,864	0,855	0,847	0,840	0,833	0,826	0,819	0,812	0,806
0,82	0,872	0,862	0,852	0,842	0,833	0,825	0,817	0,809	0,801	0,794	0,787	0,781	0,774
0,84	0,839	0,828	0,818	0,808	0,799	0,790	0,782	0,774	0,766	0,759	0,752	0,745	0,739
0,86	0,800	0,789	0,779	0,769	0,759	0,751	0,742	0,734	0,727	0,719	0,712	0,706	0,700
0,88	0,755	0,744	0,733	0,724	0,714	0,706	0,697	0,689	0,682	0,675	0,668	0,661	0,655
0,90	0,703	0,692	0,681	0,671	0,662	0,654	0,645	0,638	0,631	0,624	0,617	0,611	0,605
0,92	0,640	0,629	0,619	0,610	0,601	0,593	0,585	0,578	0,571	0,565	0,559	0,553	0,547
0,94	0,565	0,554	0,545	0,537	0,528	0,521	0,514	0,507	0,501	0,495	0,489	0,484	0,479
0,96	0,469	0,460	0,452	0,445	0,438	0,431	0,425	0,419	0,414	0,409	0,404	0,400	0,395
0,98	0,337	0,331	0,325	0,319	0,314	0,309	0,305	0,300	0,296	0,292	0,289	0,286	0,282
1,00	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Table A.4 — Pressure loss coefficients of a single component ζ_n

		Flush connection	Very sharp edged $\zeta_n = 0{,}5$ Broken edge $\zeta_n = 0{,}25$
		Inserted connection	Very sharp edged $\zeta_n = 1$ Broken edge $\zeta_n = 0{,}56$
		Flared connection	According to the radius: Between $\zeta_n = 0{,}005$ and $\zeta_n = 0{,}06$ normally $\zeta_n = 0{,}05$ is used
Pipe elements		Angled flush connection	$\zeta_n = 0{,}5 + 0{,}3 \cos\alpha + 0{,}2 \cos^2\alpha$
		Pipe bend 90°	$R = 2D_R$ $\zeta_n = 0{,}3$ $R = 3D_R$ $\zeta_n = 0{,}25$ $R = 4D_R$ $\zeta_n = 0{,}23$ $R = 5D_R$ $\zeta_n = 0{,}18$
		Straight pipe	$\zeta_n = \lambda \times \frac{L}{d_R}$ Steel pipe $\lambda = 0{,}02$
		Valves and changeover valves	$\zeta = 2{,}592 \times \left[\frac{A_R}{K_{VS}}\right]^2 \times 10^{-3}$ $Ar = \frac{\pi \times d_R{}^2}{4}$ K_{vs} or ζ shall be indicated by the manufacturer

NOTE The values for ζ_n given in the table are generally accepted and used values. Slightly different values can be used providing their selection can be justified, e.g. by published papers.

Annex B
(informative)

Calculation of flow areas for non-evaporating and evaporating liquids

B.1 Calculation of the flow area for non-evaporating liquids

The flow area for a non-evaporating liquid is calculated as follows:

$$A_{\mathrm{c}} = 0{,}6211 \times \frac{Q_{\mathrm{md}}}{K_{\mathrm{drl}} \times K_{\upsilon}} \times \sqrt{\frac{1}{\rho \times (p_{\mathrm{o}} - p_{\mathrm{b}})}} \text{ [mm}^2\text{]} \quad \text{(B.1)}$$

where K_{drl} for liquids is approximately 20 % below the value of K_{dr} for gases and vapours.

The viscosity correction factor K_{v} is dependent on the Reynolds number and can be obtained from Figure B.1.

B.2 Calculation of the flow area for evaporating liquids

When calculating the flow areas for evaporating liquids (flashing due to pressure relief) the quantity is separated into two parts: liquid and vapour:

$$Q_{\mathrm{md}} = Q_{\mathrm{vap}} + Q_{\mathrm{liq}} \text{ [kg/h]} \quad \text{(B.2)}$$

where:

$$Q_{\mathrm{vap}} = x \times Q_{\mathrm{md}} \text{ [kg/h]} \quad \text{(B.3)}$$

the value of x being the vapour fraction at p_{C};

$$Q_{\mathrm{liq}} = Q_{\mathrm{md}} - Q_{\mathrm{vap}} \text{ [kg/h]} \quad \text{(B.4)}$$

$$A_{\mathrm{vap}} = 3{,}469 \times \frac{Q_{\mathrm{vap}}}{C \times K_{\mathrm{dr}} \times K_{\mathrm{b}}} \times \sqrt{\frac{v_{\mathrm{o}}}{p_{\mathrm{o}}}} \text{ [mm}^2\text{]} \quad \text{(B.5)}$$

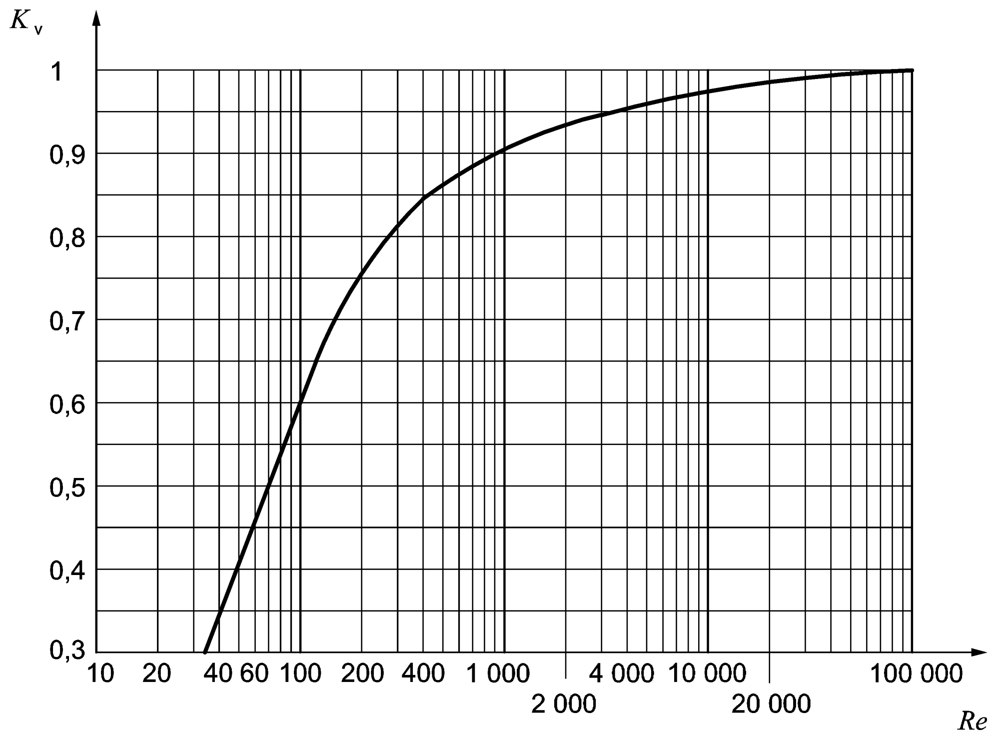
$$A_{\mathrm{liq}} = 0{,}6211 \times \frac{Q_{\mathrm{liq}}}{K_{\mathrm{dr}l} \times K_{\upsilon}} \times \sqrt{\frac{1}{\rho \times (p_{\mathrm{o}} - p_{\mathrm{b}})}} \text{ [mm}^2\text{]} \quad \text{(B.6)}$$

where K_{v} = 1,0 for refrigerants.

Therefore:

$$A_{\mathrm{c}} = 1{,}2 \times \left\lfloor A_{\mathrm{vap}} + A_{\mathrm{liq}} \right\rfloor \text{ [mm}^2\text{]} \quad \text{(B.7)}$$

The factor of 1,2 takes account of the difference between the actual flow of liquid/vapour mixture and the theoretical flow in this calculation.



Key

1 K_v viscosity correction factor

2 *Re* Reynolds number

Figure B.1 - Viscosity correction factor K_v as a function of the Reynolds number

The Reynolds number is calculated according to the formula:

$$\text{Re} = \frac{w_o \times d \times 10^{-3}}{\nu} \text{ [–]} \quad \text{(B.8)}$$

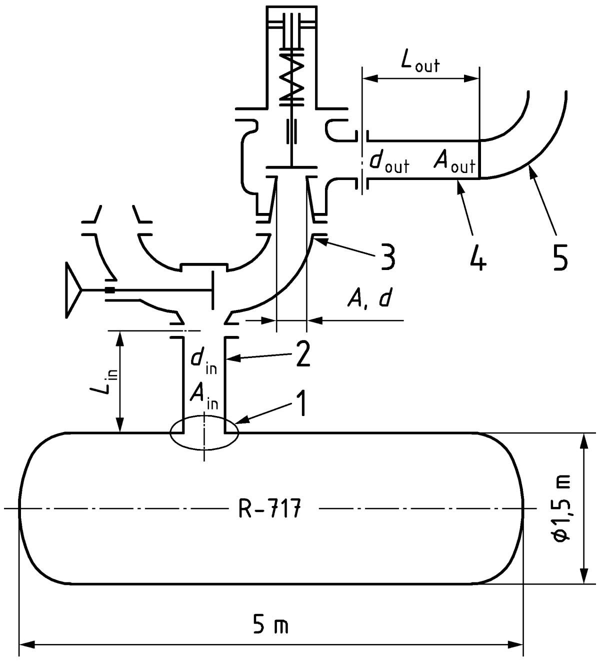
where

$$w_o = 353,68 \times \frac{Q_{md}}{\rho \times d^2} \text{ [m/s]} \quad \text{(B.9)}$$

The values for the kinematic viscosity ν (for definition see EN ISO 3104) are taken from the technical literature, and *d* the Actual most narrow flow diameter of the pressure relief valve.

Annex C
(informative)

Example of calculation for sizing pressure relief devices with the corresponding pipes



Key

1 inlet connection from vessel

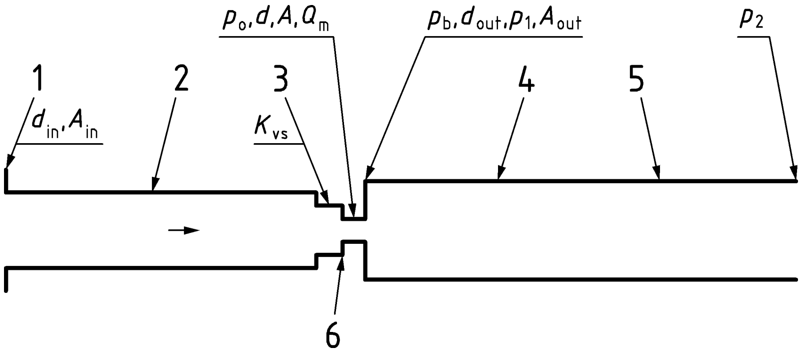
2 straight pipe (upstream)

3 changeover valve

4 straight pipe (downstream)

5 pipe bend (downstream)

Figure C.1 — Schematic diagram of pressure relief valve with changeover valve and connecting pipes, figures mark different conditions of the substance to be relieved



Key

1 inlet connection from vessel

2 straight pipe (upstream)

3 changeover valve

4 straight pipe (downstream)

5 pipe bend (downstream)

6 inlet pressure relief valve

Figure C.2 — Schematic diagram of different conditions of the substance to be relieved in piping's and valves according to Figure C.1

C.1 Assumptions for the calculation example

Refrigerant	R717
Set pressure	p_{set} = 20 bar
Actual absolute relieving pressure	p_o 1,1 X p_{set} + p_{atm} = 23 bar
Actual back pressure	$p_b = p_{atm}$
Heat of vaporisation (at 23 bar)	h_{vap} = 1 025 kJ/kg
Length of vessel	5 m
Diameter of vessel	1,5 m

C.2 Calculation of the required minimum discharge capacity, Q_{md} at standard heat flow rate

Density of heat flow rate:

φ = 10 kW/m^2

External surface of vessel:

$$A_{surf} = 2 \times \frac{1{,}5^2 \times \pi}{4} + 1{,}5 \times \pi \times 5{,}0 = 27{,}1 \quad \text{m}^2$$

In 6.2.1, Formula (1):

$$Q_{md} = \frac{3600 \times \varphi \times A_{surf}}{h_{vap}} \quad \text{[kg/h]}$$

$$Q_{md} = \frac{3600 \times 10 \times 27{,}1}{1025} = 952 \quad \text{[kg/h]}$$

C.3 Calculation of the required minimum discharge capacity Q_{md} at reduced heat flow rate

Reduced heat flow can be used when the vessel has a fire resistant insulated according to the requirements in 6.2.1.

Thickness of insulation:

s = 0,14 m

Density of heat flow rate:

$$\varphi_{red} = 10 \times \frac{0{,}04}{0{,}14} = 2{,}86 \quad \text{kW/m}^2$$

External surface of vessel:

$$A_{surf} = 2 \times \frac{1{,}5^2 \times \pi}{4} + 1{,}5 \times \pi \times 5{,}0 = 27{,}1 \quad \text{m}^2$$

In 6.2.1, Formula (1):

$$Q_{md} = \frac{3600 \times \varphi_{red} \times A_{surf}}{h_{vap}} \quad \text{[kg/h]}$$

$$Q_{md} = \frac{3600 \times 2{,}86 \times 27{,}1}{1025} = 272 \quad \text{[kg/h]}$$

C.4 Calculation of flow area A_c, selection of pressure relief valve

This example is based on standard heat flow rate φ = 10 kW/m^2.

The minimum required discharge capacity Q_{md} of the pressure relief valve should, under the above conditions, be at least 952 kg/h.

From Annex A, Table A.1 for R717:	K = 1,310, C = 2,64
From a "R717-table": specific volume at 23 bar:	v_o = 0,0557 m^3/kg
From Annex A, Table A.3 for:	p_b/p_o = 1/23 = 0,043 => K_b = 1

From a manufacturer's catalogue, a pressure relief valve is selected with the following data:

d = 15 mm, A = 177 mm^2, K_{dr} = 0,41

Calculation of discharge capacity from 7.2.5.2, Formula (15):

$$A_c = \frac{Q_{md}}{0,2883 \times C \times K_{dr} \times K_b \times \sqrt{\frac{p_0}{v_o}}} = 3,469 \times \frac{Q_{md}}{C \times K_{dr} \times K_b} \times \sqrt{\frac{v_o}{p_o}}$$

$$A_c = 3,469 \times \frac{952}{2,64 \times 0,41 \times 1,0} \times \sqrt{\frac{0,0557}{23}} = 150 \text{ mm}^2$$

$$Q_m = 0,2883 \times C \times A \times K_{dr} \times K_b \times \sqrt{\frac{p_o}{v_o}}$$

$$Q_m = 0,2883 \times 2,64 \times 177 \times 0,41 \times 1 \times \sqrt{\frac{23}{0,0557}}$$

$$Q_m = 1123 \text{ [kg/h]} \quad > Q_{md}$$

$$Q_{md} < Q_m < 1,25 \times Q_{md} => Q_{md'} = Q_{md}$$

C.5 Pressure loss in upstream line (from vessel to pressure relief valve)

In 7.4.3, Formula (21):

$$\Delta p_{in} = 0,0320 \times \left[\frac{A_c}{A_{in}} \times C \times K_{dr} \times K_b \times \right]^2 \times \zeta \times p_o \text{ [bar]}$$

Pipe: DN 25, d_{in} = 28,5 mm, A_{in} = 638 mm^2, A = 177 mm^2 (from catalogue).

Pressure loss coefficients ζ taken from Table A.4 at locations indicated in Figure C.1:

1. Inlet from vessel: (flush connection, broken edge) — ζ_1 =0,25

a) Straight pipe: $\zeta_2 = \lambda \times \frac{L_{in}}{d_{in}} = 0,02 \times \frac{500}{28,5} =$ 0,35

L_{in} = 500 mm

b) Changeover valve $\zeta = 2,592 \times \left[\frac{A_{in}}{K_{VS}} \right]^2 \times 10^{-3} = 2,592 \times \left[\frac{638}{20} \right]^2 \times 10^{-3} =$ 2,64

K_{vs} = 20 m^3/h

$$\zeta = \sum_{n=1}^{n=3} \zeta_{\mathrm{n}} = \qquad 3{,}24$$

$$\Delta p_{\mathrm{in}} = 0{,}0320 \times \left[\frac{150}{638} \times 2{,}64 \times 0{,}41 \times 1{,}0 \times \right]^2 \times 3{,}24 \times 23 = 0{,}155$$

$$\frac{\Delta p_{\mathrm{in}}}{p_{\mathrm{o}}} = \frac{0{,}155}{23} = 0{,}0067 < 0{,}03 \text{ (see 7.4.1)}$$

Therefore the height of the inlet pressure loss allows the use of the selected valve. If the loss of pressure is higher than as indicated in 7.4.1, the arrangement of valve and conveying pipe is modified with the aim of reducing the loss of pressure.

If the manufacturer provides the pressure loss coefficient ζ_{DN} for devices (valves) related to the nominal diameter (DN), it is converted to the pressure loss coefficient ζ for the actual internal diameter of the pipe from Formula (20):

$$\zeta = \left[\frac{d_{\mathrm{R}}}{DN} \right]^4 \times \zeta_{\mathrm{DN}}$$

C.6 Pressure loss in downstream line (from pressure relief valve to atmosphere)

In 7.4.4, Formula (24):

$$p_1 = \sqrt{0{,}064 \times \zeta \times \left[\frac{A_{\mathrm{c}}}{A_{\mathrm{out}}} \times C \times K_{\mathrm{dr}} \times K_{\mathrm{b}} \times p_{\mathrm{o}} \right]^2 + p_2^2} \text{ [bar]}$$

$$\Delta p_{\mathrm{out}} = p_1 - p_2$$

Pipe: DN 32, d_{out} = 37,2 mm, A_{out} = 1086 mm^2.

Pressure loss coefficients ζ taken from Table A.4 at locations indicated in Figure C.1:

a) Straight pipe:

L_{out} = 5 000 mm $\quad \zeta_4 = \lambda \times \frac{L_{\mathrm{out}}}{d_{\mathrm{out}}} = 0{,}02 \times \frac{5000}{37{,}2} =$ 2,69

b) Pipe bend (R = 3D_{R}) $\quad \zeta_5 =$ 0,25

$$\zeta = \sum_{n=4}^{n=5} \zeta_{\mathrm{n}} = \qquad 2{,}94$$

p_2 = atmospheric pressure (p_{atm}) = 1,0 bar

$$p_1 = \sqrt{0{,}064 \times 2{,}94 \times \left[\frac{150}{1086} \times 2{,}64 \times 0{,}41 \times 1{,}0 \times 23 \right]^2 + 1{,}0^2} = 1{,}796 \text{ [bar]}$$

$$\Delta p_{out} = 1{,}796 - 1{,}0 = 0{,}796 \text{ [bar]}$$

$$\frac{\Delta p_{out}}{p_o} = \frac{0{,}796}{23} = 0{,}0346 < 0{,}10 \text{ (see 7.4.1)}$$

Therefore the outlet pressure loss is such that the selected valve can be used. If the pressure loss is greater than that given in 7.4.1, the arrangement of valve and downstream line is altered to reduce the pressure loss.

The above calculation is based on the assumption: $p_b = p_2 = p_{atm}$.

If the calculated back pressure $p_b = p_2 + \Delta p_{out}$ results in reduction of the K_b-value (here K_b = 1,0) (see Table A.3), this reduced value is to be used for calculation of the discharge capacity of the pressure relief valve.

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 to provide a means of conforming to Essential Requirements of the New Approach Directive 97/23/EC of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment.

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 97/23/EC

Clauses/sub-clauses of this European Standard	Essential requirements (ERs) of Directive 97/23/EC	Qualifying remarks/Notes
6	2.10	Protection against exceeding the allowable limits of pressure equipment
6.2.1	2.12	External Fire
7	2.11.2	Pressure limiting devices

WARNING - Other requirements and other EU Directives may be applicable to the products falling within the scope of this standard.

Bibliography

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[2] EN 12693:2008, *Refrigerating systems and heat pumps — Safety and environmental requirements — Positive displacement refrigerant compressors*

[3] EN 13501-1:2007+A1:2009, *Fire classification of construction products and building elements — Part 1: Classification using data from reaction to fire tests*

[4] EN 60204-1:2006, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements (IEC 60204-1:2005, modified)*

[5] EN ISO 3104:1996, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity (ISO 3104:1994)*

[6] EN ISO 6708:1995, *Pipework components — Definition and selection of DN (nominal size) (ISO 6708:1995)*

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