SLOVENSKI STANDARD
SIST EN 13136:2002

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Hladilni sistemi in toplotne črpalke - Tlačne varnostne naprave in njihove napeljave - Metode za izračun

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

Kälteanlagen und Wärmepumpen - Druckentlastungseinrichtungen und zugehörige Leitungen - Berechnungsverfahren

Systemes de réfrigération et pompes a chaleur - Dispositifs de surpression et tuyauteries associées - Méthodes de calcul

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

Systèmes de réfrigération et pompes à chaleur - Dispositifs de surpression et tuyauteries associées - Méthodes de calcul

Kälteanlagen und Wärmepumpen - Druckentlastungseinrichtungen und zugehörige Leitungen - Berechnungsverfahren

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Foreword

This European Standard 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of an identical text or by endorsement, at the latest by November 2001, and conflicting national standards shall be withdrawn at the latest by November 2001.

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 the EU Directive(s).

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

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, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

This European Standard is based on ISO/DIS 4126-1:1995 modified to suit the specific requirements, and to include the data, for refrigerating systems. It provides means of satisfying the pressure relief requirements of EN 378-1 and EN 378-2.

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 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 design and 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.

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).

EN 378-1
Refrigerating systems and heat pumps – Safety and environmental requirements – Part 1: Basic requirements, definitions, classification and selection criteria

EN 378-2
Refrigerating systems and heat pumps – Safety and environmental requirements – Part 2: Design, construction, testing, marking and documentation

EN 764
Pressure equipment – Terminology and symbols – Pressure, temperature, volume

prEN 12284:1996
Refrigerating systems and heat pumps – Valves – Requirements, testing and marking

ISO/DIS 4126-1:1995
Safety devices for protection against excessive pressure – Part 1: Safety valves

prEN ISO 4126-2:1998
Safety devices for protection against excessive pressure – Part 2: Bursting disc safety devices (ISO/DIS 4126-2:1998)

3 Terms and definitions

For the purposes of this standard the definitions given in EN 378-1, prEN 12284:1996, ISO/DIS 4126-1:1995, prEN ISO 4126-2:1998 and EN 764 apply.

4 Symbols

For the purposes of this standard the following symbols are used:

Symbol	Designation	Unit
A	Flow area of the pressure relief valve $\left(A = \frac{\pi \times d^2}{4}\right)$	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 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 vaporization calculated at 1,1 times the set pressure of the pressure relief device	kJ/kg
K_b	Theoretical capacity correction factor for sub-critical flow (table A.3)	–
K_d	Certified coefficient of discharge	–
K_{dr}	Derated coefficient of discharge ($K_{dr} = K_d$ X 0,9)	–
K_{drl}	Derated coefficient of discharge for liquid ($K_{drl} \approx K_{dr}$ X 0,8)	–
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 at the relieving inlet	–
L	Length of tube	mm
L_{in}	Length of inlet tube	mm
L_{out}	Length of outlet tube	mm
n	Rotational frequency	min^{-1}

(continued)

Symbol	Designation	Unit
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 predetermined 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 mass flow rate	kg/h
q_m	Theoretical discharge capacity	kg/h · mm²
q'_m	Actual discharge capacity determined by tests	kg/h · mm²
Q_{md}	Minimum required discharge capacity, of refrigerant, of the pressure relief device	kg/h
Q_{vap}	Flow of vapour after expansion	kg/h
R	Bending radius of tube (table A.4)	mm
Re	Reynolds number	–
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	–
	(continued)	

Symbol	Designation	Unit
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 ($\varrho = {}^1/v_o$)	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
[a] The Pressure Equipment Directive 97/23/EC identifies the maximum allowable pressure by the symbol "PS".		

5 General

The requirements for protection against excessive pressure in refrigerating systems and heat pumps are given in EN 378-2. Devices selected in accordance with this standard shall be designed and manufactured in accordance with prEN 12284:1996, ISO/DIS 4126-1:1995 and prEN ISO 4126-2:1998.

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 purposes of this standard h_{vap} is calculated at 1,1 times the set pressure of the pressure relief device.

6.2 Excessive pressure caused by heat sources

6.2.1 External heat sources

The minimum required discharge capacity of the pressure relief device for each pressure vessel shall be determined by the following:

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

In this standard φ is assumed to be 10 kW/m^2 but a higher figure shall be used if necessary.

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

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:

$$Q_{md} = 3600 \times \frac{Q_h}{h_{vap}} \quad [kg/h] \tag{2}$$

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:

$$Q_{md} = 60 \times V \times n \times \varrho_{10} \times \eta_v \quad \text{[kg/h]} \tag{3}$$

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.

NOTE 4 The setting of a compressor pressure limiter will be above the maximum allowable pressure of the system and does therefore not serve as protection of the entire system.

NOTE 5 prEN 12693:1996 covers compressors which can run against a closed discharge valve. prEN 12693:1996 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 Liquid expansion

The effective area [$A \cdot K_{dr}$] 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.

NOTE 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 with maximum back pressure meet the following requirements:

$$p_o \leq 1{,}1 \times p_{set} + p_{atm} \quad \text{[bar]} \tag{4}$$

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, see also ISO/DIS 4126-1:1995.

7.2 Determination of pressure relief valve performance

7.2.1 Determination of coefficient of discharge

The coefficient of discharge is calculated from:

$$K_d = \frac{q'_m}{q_m} \quad [-] \tag{5}$$

The derated coefficient of discharge is calculated from:

$$K_{dr} = 0{,}9 \times K_d \qquad [–] \tag{6}$$

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 $\frac{p_b}{p_o} \leq \left[\frac{2}{k+1}\right]^{k/(k-1)}$ [–] (7)

and sub-critical flow occurs when $\frac{p_b}{p_o} > \left[\frac{2}{k+1}\right]^{k/(k-1)}$ [–] (8)

in accordance with ISO/DIS 4126-1:1995, where the validity of Rankine's law is assumed. If the flow is critical K_b = 1, and if the flow is sub-critical, the correction factor shall be calculated according to formula (10) in 7.2.4 oder taken from table A.3.

7.2.3 Function of the isentropic exponent (C)

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

$$C = 3{,}948 \times \sqrt{k \times \left[\frac{2}{k+1}\right]^{[k+1]/(k-1)}} \qquad [–] \tag{9}$$

For this calculation the value of k shall be as measured at 25 °C. 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:

$$K_b = \sqrt{\frac{\frac{2\,k}{k-1} \times \left[\left(\frac{p_b}{p_o}\right)^{2/k} - \left(\frac{p_b}{p_o}\right)^{(k+1)/k}\right]}{k \times \left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}}} \qquad [–] \tag{10}$$

For this calculation the value of k shall be as measured at 25 °C. Values of K_b as a function of p_b/p_o are given in table A.3 for various values of k.

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 · 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, on request, supply specific information.

7.2.5.2 Calculation of the mass flow

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

$$Q_m = 0{,}2883 \times C \times A \times K_{dr} \times K_b \times \sqrt{\frac{p_o}{v_o}} \qquad \text{[kg/h]} \qquad (11)$$

The flow area A_c is calculated from the minimum required discharge capacity of refrigerant Q_{md} according to equations (1) to (3) as follows:

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

$[\text{mm}^2]$ (12)

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.

It is not recommended to use an extremely oversized pressure relief valve (Q_m much higher than Q_{md}) because the diameter of the up- and downstream lines then unintendedly has to be much increased in order to prevent unacceptable pressure drops.

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 equation 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.