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Safety devices for protection against excessive pressure —

Part 7:
Common data

Dispositifs de sécurité pour protection contre les pressions excessives —
Partie 7: Données communes

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 4126-7 was prepared by Technical Committee ISO/TC 185, *Safety devices for protection against excessive pressure*.

This second edition cancels and replaces the first edition (ISO 4126-7:2004), which has been technically revised. It also incorporates the Technical Corrigendum ISO 4126-7:2004/Cor.1:2006.

ISO 4126 consists of the following parts, under the general title *Safety devices for protection against excessive pressure*:

- *Part 1: Safety valves*
- *Part 2: Bursting disc safety devices*
- *Part 3: Safety valves and bursting disc safety devices in combination*
- *Part 4: Pilot-operated safety valves*
- *Part 5: Controlled safety pressure relief systems (CSPRS)*
- *Part 6: Application, selection and installation of bursting disc safety devices*
- *Part 7: Common data*
- *Part 9: Application and installation of safety devices excluding stand-alone bursting disc safety devices*
- *Part 10: Sizing of safety valves for gas/liquid two-phase flow*
- *Part 11: Performance testing*[1]

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[1] Under preparation.

Safety devices for protection against excessive pressure —

Part 7:
Common data

1 Scope

This part of ISO 4126 specifies requirements for safety valves. It contains information which is common to ISO 4126-1 to ISO 4126-6 to avoid unnecessary repetition.

For flashing liquids or two-phase mixtures, see ISO 4126-10.

The user is cautioned that it is not recommended to use the ideal gas formula presented in 6.3 when the relieving temperature is greater than 90 % of the thermodynamic critical temperature and the relieving pressure is greater than 50 % of the thermodynamic critical pressure. Additionally, condensation is not considered. If condensation occurs, the method presented in 6.3 should not be used.

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.

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

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

ISO 4126-4, *Safety devices for protection against excessive pressure — Part 4: Pilot operated safety valves*

ISO 4126-5, *Safety devices for protection against excessive pressure — Part 5: Controlled safety pressure relief systems (CSPRS)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4126-1, ISO 4126-2, ISO 4126-4 ISO 4126-5 and the following apply.

NOTE Pressure unit used in ISO 4126-7 is the bar (1 bar = 10^5 Pa), quoted as gauge (relative to atmospheric pressure) or absolute as appropriate.

3.1
safety valve

valve which automatically, without the assistance of any energy other than that of the fluid concerned, discharges a quantity of the fluid so as to prevent a predetermined safe pressure being exceeded, and which is designed to re-close and prevent further flow of fluid after normal pressure conditions of service have been restored

Note 1 to entry: The valve can be characterized either by pop action (rapid opening) or by opening in proportion (not necessarily linear) to the increase in pressure over the set pressure. The use of the term safety valve in this part of ISO 4126 applies to other valve types as covered in ISO 4126-1, ISO 4126-4 and ISO 4126-5.

3.2
set pressure
predetermined pressure at which a safety valve under operating conditions 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.

3.3
maximum allowable pressure, PS
maximum pressure for which the protected equipment is designed

3.4
overpressure
pressure increase over set pressure, usually expressed as a percentage of the set pressure

3.5
relieving pressure
pressure used for the sizing of a safety valve which is greater than or equal to the set pressure plus overpressure

3.6
back pressure
pressure that exists at the outlet of a safety valve as a result of the pressure in the discharge system

Note 1 to entry: The back pressure is the sum of the superimposed and built-up back pressures.

3.7
built-up back pressure
pressure existing at the outlet of a safety valve caused by flow through the valve and the discharge system

3.8
superimposed back pressure
pressure existing at the outlet of a safety valve at the time when the device is required to operate

Note 1 to entry: It is the result of pressure in the discharge system from other sources.

3.9
flow area
minimum cross-sectional flow area (but not the smallest area between the disc and seat) between inlet and seat which is used to calculate the theoretical flow capacity, with no deduction for any obstruction

Note 1 to entry: The symbol is A.

3.10
theoretical discharge capacity
calculated capacity expressed in mass or volumetric units of a theoretically perfect nozzle having a cross-sectional flow area equal to the flow area of a safety valve

3.11
coefficient of discharge
value of actual discharge capacity (from tests) divided by the theoretical discharge capacity (from calculation)

3.12
certified (discharge) capacity
that portion of the measured capacity permitted to be used as a basis for the application of a safety valve

Note 1 to entry: It may, for example, equal the a)measured capacity times the de-rating factor of 0,9, or b)theoretical capacity times the coefficient of discharge times the de-rating factor of 0,9, or c)theoretical capacity times the certified de-rated coefficient of discharge.

3.13
dryness fraction
steam quality
measure of the relative vapour/liquid content of a steam quantity or stream. Expressed as the mass fraction or percentage of vapour

4 Symbols and units

Table 1 — Symbols and their descriptions

Symbol	Description	Unit
A	Flow area of a safety valve (not smallest area between the disc and seat)	mm^2
C	Function of the isentropic exponent, k	–
K_b	Theoretical capacity correction factor for subcritical flow	–
K_d	Coefficient of discharge [a]	–
K_{dr}	Certified de-rated coefficient of discharge (K_d × 0,9) [a]	–
K_v	Viscosity correction factor	–
k	Isentropic exponent at relieving pressure and temperature	–
M	Molar mass	kg/kmol
n	Number of tests	–
p_o	Relieving pressure - absolute	bar (abs)
p_b	Back pressure - absolute	bar (abs)
p_c	Thermodynamic critical pressure - absolute	bar (abs)
p_r	Reduced pressure	–
PS	Maximum allowable pressure	bar (abs)
$\dot{Q}_m$	Mass flow rate	kg/h
q_m	Theoretical specific discharge capacity	kg/(h·mm^2)
q'_m	Specific discharge capacity determined by tests	kg/(h·mm^2)
R	Universal gas constant	J/K-mol
Re	Reynolds number	–
T_o	Relieving temperature	K
T_c	Thermodynamic critical temperature	K
T_r	Reduced temperature	–
μ_0	Dynamic viscosity	Pa·s
v_o	Specific volume at relieving pressure and temperature	m^3/kg
x_0	Dryness fraction of wet steam at the valve inlet at relieving pressure and temperature [b]	–
k_s	Steam pressure coefficient	h·mm^2 bar (abs)/ kg
Z	Compressibility factor at relieving pressure and temperature	–

[a] K_d and K_{dr} are expressed as 0,xxx.

[b] x_0 is expressed as 0,xx.

5 Determination of safety valve performance

5.1 Determination of coefficient of discharge

The coefficient of discharge, K_d, is calculated from the following:

$$K_d = \frac{\sum_{1}^{n}\left(\frac{q'_m}{q_m}\right)}{n} \tag{1}$$

K_d shall be calculated up to three significant decimal places. Any rounding shall be down.

5.2 Critical and subcritical flow

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

Critical flow occurs when

$$\frac{p_b}{p_o} \le \left(\frac{2}{k+1}\right)^{(k/(k-1))} \tag{2}$$

and subcritical flow occurs when

$$\frac{p_b}{p_o} > \left(\frac{2}{k+1}\right)^{(k/(k-1))} \tag{3}$$

5.3 Discharge capacity at critical flow

5.3.1 Discharge capacity for steam

$$q_m = 0{,}2883\, C \sqrt{\frac{p_o}{v_o}} \tag{4}$$

Formula (4) allows the use of steam tables to obtain the specific volume of steam at various pressures and temperatures. The user is cautioned that the direct use of this equation can lead to an error of more than 20 % as the temperature approaches the saturated or supercritical condition. An error of less than 1 % can only be achieved at a steam temperature at least higher than 30 °C above saturation condition or higher than the result of 30+(p_0-200), in °C, using p_0 in bar above saturation or supercritical condition. A method including lower temperatures is described hereafter.

Alternatively, the above equation can be rearranged as follows:

$$q_m = \frac{p_o}{k_s} \tag{5}$$

where k_s is the steam pressure coefficient.

$$k_s = \frac{\sqrt{p_o v_o}}{0{,}2883\, C} \tag{6}$$

NOTE 1 $$0,2883 = \frac{\sqrt{R}}{10} = \frac{\sqrt{8,3143}}{10} \qquad (7)$$

Values for the steam pressure coefficient, k_S, can be obtained in Table 2. See 6.3.1 for background on the development of Table 2.

This is applicable to dry saturated and superheated steam. Dry saturated steam in this context refers to steam with a minimum dryness fraction of 98 % where C is a function of the isentropic exponent at the relieving conditions.

$$C = 3,948\sqrt{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \qquad (8)$$

NOTE 2 $$3,948 = \frac{3600}{\sqrt{10^5 \times \sqrt{R}}} \qquad (9)$$

The value of k used to determine C shall be based on the actual flowing conditions at the pressure relief device inlet and shall be determined from Table 3.

5.3.2 Discharge capacity for any gas under critical flow conditions

$$q_m = p_o C\sqrt{\frac{M}{ZT_o}} = 0,2883\, C\sqrt{\frac{p_o}{v_o}} \qquad (10)$$

See Figure 1 for values of Z.

$$C = 3,948\sqrt{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \qquad (11)$$

See Table 3 for rounded values for C.

5.4 Discharge capacity for any gas at subcritical flow

$$q_m = p_o C K_b\sqrt{\frac{M}{ZT_o}} = 0,2883\, C K_b\sqrt{\frac{p_o}{v_o}} \qquad (12)$$

$$K_b = \sqrt{\frac{\frac{2k}{k-1}\left[\left(\frac{p_b}{p_o}\right)^{\frac{2}{k}} - \left(\frac{p_b}{p_o}\right)^{\frac{k+1}{k}}\right]}{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}}} \qquad (13)$$

See Table 4 for K_b values.

5.5 Discharge capacity for non-flashing liquid as the test medium in the turbulent zone where the Reynolds number *Re* is equal to or greater than 80 000

$$q_m = 1,61\sqrt{\left(\frac{p_o - p_b}{v_o}\right)} \qquad (14)$$

NOTE

$$1{,}61 = \frac{3600\sqrt{2}}{10\sqrt{10^5}} \tag{15}$$

6 Sizing of safety valves

6.1 General

The certified de-rated coefficient of discharge K_{dr} of the safety valve shall be not greater than 90 % of the coefficient of discharge K_{d} determined by test:

$$K_{\mathrm{dr}} \leq 0{,}9\ K_{\mathrm{d}} \tag{16}$$

It is not permitted to calculate the capacity with a lower overpressure than that at which the tests to determine flow characteristics were carried out although it is permissible to calculate the capacity at a higher relieving pressure.

Valves having a certified de-rated coefficient of discharge established on critical flow at the test back pressure may not have the same certified de-rated coefficient of discharge at a higher back pressure; see ISO 4126-1, ISO 4126-3, ISO 4126-4 or ISO 4126-5, as applicable, for requirements for the certification of the coefficient of discharge of various valve types.

6.2 Valves for gas or vapour relief

No distinction is made between substances commonly referred to as vapours: the term “gas” is used to describe both gas and vapour.

To calculate the capacity for any gas, the area and the coefficient of discharge shall be assumed to be constant and the equations given in Clause 5 shall be used.

6.3 Calculation of capacity

The ideal gas formula presented in 6.3 should not be used when the relieving temperature is greater than 90 % of the thermodynamic critical temperature and the relieving pressure is greater than 50 % of the thermodynamic critical pressure. Additionally, condensation is not considered. If condensation occurs, the method presented in 6.3 should not be used.

NOTE 1 The equation to be applied depends on the fluid to be discharged.

NOTE 2 See Annex A for example calculations.

6.3.1 Capacity calculation for (saturated, superheated or supercritical) steam at critical flow

$$\dot{Q}_{\mathrm{m}} = 0{,}2883\ C A K_{\mathrm{dr}} \sqrt{\frac{p_{\mathrm{o}}}{v_{\mathrm{o}}}} \tag{17}$$

Formula (17) allows the use of steam tables to obtain the specific volume of steam at various pressures and temperatures. The user is cautioned that the direct use of this equation can lead to an error of more than 20 % as the temperature approaches the saturated or supercritical condition. An error of less than 1 % can only be achieved at a steam temperature at least higher than 30°C above saturation condition or higher than the result of 30+(p_0-200), in °C, using p_0 in bar above saturation or supercritical condition. A method including lower temperatures is described hereafter.

Alternatively, the above equation can be rearranged as follows:

$$\dot{Q}_m = \frac{A\,K_{dr}\,p_o}{k_s} \tag{18}$$

where k_s is the steam pressure coefficient,

$$k_s = \frac{\sqrt{p_o\,v_o}}{0{,}2883\,C} \tag{19}$$

Values for the steam pressure coefficient, k_s, can be obtained in Table 2. The values of Table 2 were established by iterative calculations on nozzle flow using the following procedure:

a) Isentropic expansion from a nozzle inlet pressure to several assumed throat pressures was calculated.

b) The mass flow rate per unit throat area (the ratio of the nozzle throat velocity to the coincident specific volume) was calculated for each assumed throat pressure.

c) The actual thermodynamic properties of steam according to IAPWS-IF97[1] were used for each assumed throat pressure.

d) The iterative calculation procedure stops when the maximum of mass flow is detected, this value was used for establishing the value of k_s.

6.3.2 Capacity calculations for wet steam

The following equation is applicable only to homogenous wet steam of dryness fraction of 90 % and over.

$$\dot{Q}_m = \frac{0{,}2883\,C\,A\,K_{dr}\sqrt{\frac{p_o}{v_o}}}{\sqrt{x_o}} \tag{20}$$

Alternatively, the above equation can be rearranged as follows:

$$\dot{Q}_m = \frac{A\,K_{dr}\,p_o}{k_s\sqrt{x_o}} \tag{21}$$

where k_s is the steam pressure coefficient,

$$k_s = \frac{\sqrt{p_o\,v_o}}{0{,}2883\,C} \tag{22}$$

Values for the steam pressure coefficient, k_s, can be obtained in Table 2. The values of Table 2 were established by iterative calculations on nozzle flow using the following procedure:

a) Isentropic expansion from a nozzle inlet pressure to several assumed throat pressures was calculated.

b) The mass flow rate per unit throat area (the ratio of the nozzle throat velocity to the coincident specific volume) was calculated for each assumed throat pressure.

c) The actual thermodynamic properties of steam according to IAPWS-IF97[1] were used for each assumed throat pressure.

d) The iterative calculation procedure stops when the maximum of mass flow is detected, this value was used for establishing the value of k_s.

6.3.3 Capacity calculations for gaseous media

6.3.3.1 Capacity calculations for gaseous media at critical flow

$$\dot{Q}_{\mathrm{m}} = p_{\mathrm{o}} C A K_{\mathrm{dr}} \sqrt{\frac{M}{Z T_{\mathrm{o}}}} = 0{,}2883\, C A K_{\mathrm{dr}} \sqrt{\frac{p_{\mathrm{o}}}{v_{\mathrm{o}}}} \qquad (23)$$

$$A = \frac{\dot{Q}_{\mathrm{m}}}{p_{\mathrm{o}} C K_{\mathrm{dr}} \sqrt{\frac{M}{Z T_{\mathrm{o}}}}} = \frac{\dot{Q}_{\mathrm{m}}}{0{,}2883 C K_{\mathrm{dr}} \sqrt{\frac{p_{\mathrm{o}}}{v_{\mathrm{o}}}}} \qquad (24)$$

6.3.3.2 Capacity calculations for gaseous media at subcritical flow

$$\dot{Q}_{\mathrm{m}} = p_{\mathrm{o}} C A K_{\mathrm{dr}} K_{\mathrm{b}} \sqrt{\frac{M}{Z T_{\mathrm{o}}}} = 0{,}2883\, C A K_{\mathrm{dr}} K_{\mathrm{b}} \sqrt{\frac{p_{\mathrm{o}}}{v_{\mathrm{o}}}} \qquad (25)$$

NOTE To determine K_{b} see equation in 5.4 and Table 4.

See Figure 1 for values of Z.

6.3.4 Capacity calculations for liquids

$$\dot{Q}_{\mathrm{m}} = 1{,}61 K_{\mathrm{dr}} K_{\mathrm{v}} A \sqrt{\frac{p_{\mathrm{o}} - p_{\mathrm{b}}}{v_{\mathrm{o}}}} \qquad (26)$$

See Figure 2 for values of K_{v}.

7 Thermodynamic properties

7.1 Steam data

The steam pressure coefficient data are given in Table 2.

7.2 Value of *C* as a function of *k*

The values of factor C as a function of the isentropic exponent are given in Table 3.

7.3 Theoretical capacity correction factors for sub-critical flow (K_{b})

The theoretical capacity correction factors for sub-critical flow (K_{b}) are given in Table 4.