



BSI Standards Publication

Safety devices for protection against excessive pressure

Part 10: Sizing of safety valves and bursting discs for gas/liquid two-phase flow

National foreword

This British Standard is the UK implementation of EN ISO 4126-10:2024. It is identical to ISO 4126-10:2024. It supersedes BS ISO 4126-10:2010, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PSE/18/6, Industrial valves, steam traps, actuators and safety devices against excessive pressure - Safety devices against excessive pressure.

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

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Part 10: Sizing of safety valves and bursting discs for
gas/liquid two-phase flow (ISO 4126-10:2024)

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Sicherheitseinrichtungen gegen unzulässigen Überdruck - Teil 10: Auslegung von Sicherheitsventilen und Berstscheiben bei Zweiphasenströmung (flüssig/gas) (ISO 4126-10:2024)

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN ISO 4126-10:2024) has been prepared by Technical Committee ISO/TC 185 "Safety devices for protection against excessive pressure" in collaboration with Technical Committee CEN/TC 69 "Industrial valves" 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of an identical text or by endorsement, at the latest by October 2024, and conflicting national standards shall be withdrawn at the latest by October 2024.

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

This document has been prepared under a standardization request addressed to CEN by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

For the relationship with EU Legislation, see informative Annex ZA, which is an integral part of this document.

Any feedback and questions on this document should be directed to the users' national standards body/national committee. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

Endorsement notice

The text of ISO 4126-10:2024 has been approved by CEN as EN ISO 4126-10:2024 without any modification.

Annex ZA
(informative)

Relationship between this European Standard and the essential safety requirements of Directive 2014/68/EU (Pressure Equipment Directive) aimed to be covered

This European Standard has been prepared under a Commission’s standardization request M/601 to provide one voluntary means of conforming to essential safety requirements of Directive 2014/68/EU on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment.

Once this standard is cited in the Official Journal of the European Union under that Directive 2014/68/EU, compliance with the normative clauses of this standard given in Table ZA.1 and application of the edition of the normatively referenced standards as given in Table ZA.2 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding essential safety requirements of that Directive 2014/68/EU, and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Annex I of Directive 2014/68/EU

Essential Safety Requirements of Directive 2014/68/EU	Clause(s)/sub-clause(s) of this EN	Remarks/Notes
2.11.2	6.3.3, 6.5.2, 6.5.3, 6.5.4 (except last paragraph), 6.5.6, 6.7 (paragraph 1)	Pressure limiting devices

Table ZA.2 — Applicable Standards to confer presumption of conformity as described in this Annex ZA

Column 1 Reference in Clause 2	Column 2 International Standard Edition	Column 3 Title	Column 4 Corresponding European Standard Edition
ISO 4126-7	ISO 4126-7:2013 ISO 4126-7:2013/Amd 1:2016	Safety devices for protection against excessive pressure - Part 7: Common data	EN ISO 4126-7:2013 EN ISO 4126-7:2013/A1:2016

The documents listed in the Column 1 of Table ZA.2, in whole or in part, are normatively referenced in this document, i.e. are indispensable for its application. The achievement of the presumption of conformity is subject to the application of the edition of Standards as listed in Column 4 or, if no European Standard Edition exists, the International Standard Edition given in Column 2 of Table ZA.2.

WARNING 1 — Presumption of conformity stays valid only as long as a reference to this European Standard is maintained in the list published in the Official Journal of the European Union. Users of this standard should consult frequently the latest list published in the Official Journal of the European Union.

WARNING 2 — Other Union legislation may be applicable to the product(s) falling within the scope of this standard.

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 185, *Safety devices for protection against excessive pressure*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 69, *Industrial valves*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 4126-10:2010), which has been technically revised.

The main changes are as follows:

- opening of the method for sizing of bursting discs;
- more thorough iteration for the calculation of the flow rate;
- allowing for slip;
- allowing for velocity in the outlet line and pressure losses in front and after the safety device;
- added an example for flow rate to be discharged ([Annex B](#));
- added an example for dischargeable mass flow rate added and method to estimate pressure drop in pipe flow ([Annex C](#));
- various correction.

A list of all parts in the ISO 4126 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Well-established recommendations exist for the sizing of safety valves and bursting discs and the connected inlet and outlet lines for steady-state, single-phase gas/vapour or liquid flow. However, in the case of a two-phase vapour/liquid flow, the required relieving area to protect a system from overpressure is larger than that required for single-phase flow when the same vessel condition and heat release are considered. The requirement for a larger relief area results from the fact that, in two-phase flow, the liquid partially blocks the relieving area for the vapour flow, by which most of the energy is removed by evaporation from the vessel.

This document includes a widely applicable method for the sizing of the most typical safety valves and bursting discs in fluid services encountered in various industrial fields (see [Table 1](#)). It is based on the omega parameter method, which is extended by a thermodynamic non-equilibrium parameter. A balance is attempted between the accuracy of the method and the unavoidable uncertainties in the input and property data under the actual sizing conditions.

In case of two-phase flow, the safety device size can influence the fluid state and, hence, the mass flow rate to be discharged. Furthermore, the two-phase mass flow rate through a safety device essentially depends on the mass flow quality (mass fraction of vapour) of the fluid at the inlet of the device. Because these parameters are, in most cases, not readily at hand during the design procedure of a relief device, this document also includes a comprehensive procedure that covers the determination of the fluid-phase composition at the safety device inlet. This fluid-phase composition depends on a scenario that leads to the pressure increase. Therefore, the recommended sizing procedure starts with the definition of the sizing case and includes a method for the prediction of the mass flow rate required to be discharged and the resulting mass flow quality at the inlet of the safety device.

The formulae of ISO 4126-7:2013/Amd 1:2016 for single-phase flow up to the narrowest flow cross-section are included in this document, modified to SI units, to calculate the flow rates at the limiting conditions of single-phase gas and liquid flow.

In this document, the unit bar for pressures is being used $100\,000\text{ Pa} = 1\text{ bar}$.

Table 1 — Possible fluid state at the inlet of the safety valve or bursting disc that can result in two-phase flow

Fluid state at device inlet	Cases	Examples
liquid	subcooled (possibly flashing in the safety device) saturated with dissolved gas	cold water boiling water CO ₂ /water
gas/vapour	near saturated vapour (possibly condensing in the safety device)	steam
gas/liquid	vapour/liquid non-evaporating liquid and non-condensable gas (constant quality) gas/liquid mixture, when gas is desorbed or produced	steam/water air/water

Safety devices for protection against excessive pressure —

Part 10:

Sizing of safety valves and bursting discs for gas/liquid two-phase flow

1 Scope

This document specifies the sizing of safety valves and bursting discs for gas/liquid two-phase flow in pressurized systems such as reactors, storage tanks, columns, heat exchangers, piping systems or transportation tanks/containers, see [Figure 2](#). The possible fluid states at the safety device inlet that can result in two-phase flow are given in [Table 1](#).

NOTE The pressures used in this document are absolute pressures, not gauge pressures.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4126-7:2013/Amd 1:2016, *Safety devices for protection against excessive pressure — Part 7: Common data*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4126-7:2013/Amd 1:2016 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 General

3.1.1

pressurized system

equipment being protected against excessive pressure accumulation by a safety device

EXAMPLE Equipment can be reactors, storage tanks, columns, heat exchangers, piping systems and transport tanks/containers, etc.

3.1.2

critical filling threshold

ϕ_{limit}

maximum initial liquid filling threshold (liquid hold-up) in the *pressurized system* ([3.1.1](#)) at sizing conditions, up to where vapour disengagement occurs and single-phase gas or vapour flow can be expected

Note 1 to entry: The critical filling threshold is expressed as a ratio of the total volume of the system.

Note 2 to entry: For filling levels above the critical filling threshold, two-phase flow is assumed to occur.

3.1.3

initial liquid filling level

ϕ_0

liquid hold-up in the *pressurized system* (3.1.1) at the sizing conditions

Note 1 to entry: The initial liquid filling level is expressed as a ratio of the total volume of the system.

3.1.4

inlet line

pipework and associated fittings connecting the *pressurized system* (3.1.1) to the safety device inlet

3.1.5

outlet line

pipework and associated fittings connecting the safety device outlet to a containment system or the atmosphere

3.1.6

vent line system

combination of safety device, *inlet line* (3.1.4) and *outlet line* (3.1.5)

3.1.7

cryogenic vessel

vacuum jacketed vessel intended for application at low temperature involving liquefied gases

3.2 Pressure

3.2.1

maximum allowable working pressure

p_{MAW}

maximum pressure permissible at the top of a *pressurized system* (3.1.1) in its operating position for designated temperature

3.2.2

maximum allowable accumulated pressure

p_{MAA}

sum of the *maximum allowable working pressure* (3.2.1) and the *maximum allowable accumulation* (3.2.3)

Note 1 to entry: The maximum allowable accumulation is established by applicable code for operating and fire contingencies.

3.2.3

maximum allowable accumulation

Δp_{MAA}

pressure increase over the *maximum allowable working pressure* (3.2.1) of a *pressurized system* (3.1.1) during discharge through the safety device

Note 1 to entry: The maximum allowable accumulation is expressed in pressure units or as a percentage of the maximum allowable working pressure.

3.2.4

opening pressure

p_{open}

predetermined absolute pressure at which a safety valve under operating conditions at the latest commences to open

3.2.5

absolute overpressure

Δp_{over}

pressure increase over the *opening pressure* (3.2.4), p_{open} , of the safety device

Note 1 to entry: The maximum absolute overpressure is the same as the maximum accumulation, Δp_{MAA} , when the opening pressure of the safety valve is set at the *maximum allowable working pressure* (3.2.1) of the *pressurized system* (3.1.1).

Note 2 to entry: The absolute overpressure is expressed in pressure units or as a percentage of the opening pressure.

3.2.6 overpressure

p_{over}
maximum pressure in the *pressurized system* (3.1.1) during relief, i.e. pressure less or equal to the maximum accumulated pressure

3.2.7 sizing pressure

p_0
pressure at which all property data, especially the compressibility coefficient, ω , are calculated for sizing the safety device

Note 1 to entry: In the case of tempered and hybrid reactive systems, the sizing pressure shall be as low as reasonable possible, but should not affect the normal operation. In the case of non-reactive and *gassy systems* (3.5.3), the designer may choose a higher value for the sizing pressure, but it shall not exceed the *maximum allowable accumulated pressure* (3.2.2).

3.2.8 critical pressure

p_{crit}
fluid-dynamic critical pressure occurring in the narrowest flow cross-section of the safety valve and/or at an area enlargement in the *outlet line* (3.1.5)

Note 1 to entry: At this pressure, the mass flow rate approaches a maximum at a given sizing condition in the *pressurized system* (3.1.1). Any further decrease of the downstream pressure does not increase the flow rate further. Usually, the critical pressure occurs in the safety valve, either in the valve seat, inlet nozzle and/or valve body. In the bursting disc, critical pressure can occur downstream of the device at a minimum flow area, at the exit of the vessel or a change in pipe diameter. In long safety device outlet lines, multiple critical pressures can also occur.

3.2.9 stagnation condition

condition when fluid is at rest

EXAMPLE Fluid in large vessels, where the flow velocity is almost zero, even in case of a discharge of mass.

3.2.10 critical pressure ratio

η_{crit}
ratio of *critical pressure* (3.2.8) to the *sizing pressure* (3.2.7)

3.2.11 thermodynamic critical pressure

p_c
state property, together with *thermodynamic critical temperature* (3.6.1), at the thermodynamic critical point

3.2.12 back pressure

p_b
pressure that exists at the outlet of a safety device as a result of pressure in the discharge system

Note 1 to entry: Back pressure can be either constant or variable; it is the sum of superimposed and *built-up back pressure* (3.2.13).

3.2.13 built-up back pressure

pressure existing at the outlet of the safety device caused by flow through the valve or bursting disc and discharge system

3.2.14**inlet pressure loss** Δp_{loss}

irrecoverable pressure decrease due to flow in the piping from the equipment that is protected to the inlet of the safety device

3.2.15**blowdown** Δp_{BD}

difference between *opening pressure* (3.2.4) and reseating pressure of a safety valve

Note 1 to entry: Blowdown is normally stated as a percentage of the opening pressure.

3.2.16**dimensionless reduced pressure** p_{red}

local pressure divided by the *thermodynamic critical pressure* (3.2.11) of the substance

3.3 Flow rate**3.3.1****mass flow rate required to be discharged from a pressurized system** $Q_{\text{m,out}}$

mass flow rate required to avoid that the pressure exceeds the *maximum allowable accumulated pressure* (3.2.2) in the *pressurized system* (3.1.1) during relief

3.3.2**feed mass flow rate into the pressurized system** $Q_{\text{m,feed}}$

maximum mass flow rate through a feed line or control valve fed into the *pressurized system* (3.1.1) being protected

3.3.3**dischargeable mass flux through the safety device** $\dot{m}_{\text{SD}}$

mass flow rate per area through a safety device at the sizing conditions calculated by means of the certified discharge coefficients for gas and liquid flow

Note 1 to entry: See [Formula \(48\)](#).

3.3.4**certified valve discharge coefficient for single-phase gas/vapour respectively liquid flow** $K_{\text{dr,g}}$ (gas) $K_{\text{dr,l}}$ (liquid)

correction factor defined by the ratio of the theoretically *dischargeable mass flux through the safety device* (3.3.3) to an experimentally determined mass flux through a device of the same manufacturer's type

Note 1 to entry: The discharge coefficient of a safety valve is related to the valve seat cross-section and accounts for the imperfection of flow through the device compared to that through a reference model (ideal nozzle). Certified values for gas and liquid flow, K_{d} , are usually supplied by valve manufacturers or determined by experiment. Rated discharge coefficients K_{dr} , equal to 0,9 K_{d} , are used to calculate the safety valve sizing area.

Note 2 to entry: The discharge coefficient of a bursting disc is related to the disc cross-section and accounts for the imperfection of flow through the device compared to that through a reference model.

3.4 Flow area

3.4.1

safety device sizing area

A_0

most essential result of the sizing procedure in accordance with this document required to select an adequately sized safety device and defined as the minimum cross-section of flow area

Note 1 to entry: It is important that the *dischargeable mass flux through the safety device* (3.3.3) be related to this specific area.

3.4.2

effective flow area of the feed line or the control valve

A_{feed}

discharge flow area of a feed line or control valve in the line to the *pressurized system* (3.1.1)

3.5 Fluid state

3.5.1

gas/liquid mixture

fluid mixture composed of both a liquid part and a gas part, in which the gas is not necessarily of the same chemical composition as the liquid

3.5.2

tempered system

fluid system in which some energy is removed from the liquid phase by evaporation or flashing

3.5.3

gassy system

fluid system in which permanent gas is generated (e.g. by chemical reaction or by evolution from solution) and in which no significant amount of energy is removed from the liquid by evaporation at the sizing conditions

3.5.4

hybrid system

fluid system that exhibits characteristics of both tempered and *gassy systems* (3.5.3) to a significant extent at the sizing conditions

3.5.5

thermal runaway reaction

uncontrolled or undesired exothermic chemical reaction

3.6 Temperature

3.6.1

thermodynamic critical temperature

T_c

state property, together with *thermodynamic critical pressure* (3.2.11), at the thermodynamic critical point

3.6.2

sizing temperature

T_0

temperature of the *pressurized system* (3.1.1) at the sizing conditions

3.6.3

overtemperature

T_{over}

maximum temperature in the *pressurized system* (3.1.1) during relief

3.6.4**saturation temperature difference** ΔT_{over}

difference between the saturation temperature at the maximum pressure during relief, p_{over} , and the saturation temperature at the *sizing pressure* (3.2.7), p_0

3.6.5**dimensionless reduced temperature** T_{red}

local temperature divided by the *thermodynamic critical temperature* (3.6.1) of the substance

4 Symbols and abbreviated terms and figures**4.1 Symbols**

Variable	Definition	Unit
A_{feed}	effective flow area of the feed line or the control valve	m ²
A_{fire}	The wetted surface area to be considered for the heat transfer due to fire. In detail, it is the partial surface area of a vertical cylindrical vessel wetted by internal liquid and located within 7,5 m vertically from ground or from any surface capable of sustaining a pool fire. Depending on the fire case considered it may either include the wall of the bottom or the bottom wall of the vessel is not included.	m ²
A_{heat}	area of heat exchange in the pressurized system in case of external heat input	m ²
A_0	minimum required safety device area (safety device sizing area). In general, for safety valves it is the safety valve seat area and for bursting discs the minimum net flow area.	m ²
A_R	cross-sectional area in a vertical cylindrical vessel	m ²
B_{heat}	(maximum) overall heat transfer coefficient, see Formula (24)	W/(m ² ·K)
C	dimensionless mass flow rate	—
C_1	flow conversion factor 1	—
C_2	flow conversion factor 2	—
c_p	specific heat capacity at constant pressure	J/(kg·K)
D	inner vessel diameter of a vertical cylindrical vessel	m
d	diameter	m
$\frac{dp}{dt}$	rate of pressure increase in the pressurized system	Pa/s
$\frac{dT}{dt}$	reaction self-heat rate inside the pressurized system	K/s
F	environmental factor for heat input from fire (see 6.4.3.2)	—
g	acceleration due to gravity	m/s ²
H_l	height of liquid level in a vertical cylindrical vessel (bottom of vessel to liquid level)	m
H_{fire}	maximum height of flames above ground	m
H_{vessel}	height of the bottom of the vessel flames above ground	m
k_{∞}	correlating parameter to calculate the characteristic bubble-rise velocity	—
$K_{\text{dr},2\text{ph}}$	two-phase flow valve discharge coefficient	—
$K_{\text{dr},g}$	certified valve discharge coefficient for single-phase gas/vapour flow	—
$K_{\text{dr},l}$	certified valve discharge coefficient for single-phase liquid flow	—
K_R	velocity head loss for bursting disc	—

Variable	Definition	Unit
K_{vs}	Liquid discharge factor for fully opened control valve in the feed line, which characterizes A_{feed} of the feed line or control valve of a frictionless valve with the same pressure difference for the same flow rate.	m^3/h
L	Vertical length of a flow restriction to account for potential energy change. For safety valves and bursting discs L may be set to 0. For inlet and outlet lines the heights of the system shall be considered.	m
$\dot{m}$	mass flux	$kg/(m^2 \cdot s)$
$\dot{m}_{SD}$	dischargeable mass flux through the safety device	$kg/(m^2 \cdot s)$
M_0	total liquid mass in the pressurized system at the sizing conditions	kg
M	molecular mass	kg/kmol
N	boiling delay factor accounting for thermodynamic non-equilibrium	—
p	pressure in the pressurized system	Pa
p_b	back pressure	Pa
p_c	thermodynamic critical pressure	Pa
p_{crit}	fluid-dynamic critical pressure	Pa
p_{MAW}	maximum allowable working pressure	Pa
p_{MAA}	maximum allowable accumulated pressure	Pa
p_0	sizing pressure	Pa
p_{over}	maximum pressure in a pressurized system during relief, see Figure 1	Pa
p_{open}	opening pressure	Pa
$\dot{q}_{fire}$	dimensionless fire exposure flux	—
$Q_{m,out}$	mass flow rate required to be discharged from a pressurized system	kg/s
$Q_{m,feed}$	feed mass flow rate into the pressurized system	kg/s
$Q_{m,SD}$	dischargeable mass flow rate through the safety device	kg/s
$\dot{Q}$	heat input into the pressurized system, either by runaway reaction or by external heating	W
$\dot{Q}_{acc}^*$	ratio of the sensible heat to the latent heat	—
$\dot{Q}_{in}^*$	ratio of total heat input to energy flow removed by evaporation	—
R	universal gas constant (8 314,2 J/(kmol·K))	J/(kmol·K)
R_{2ph}	two-phase multiplier	—
T	temperature in the pressurized system	K
T_c	thermodynamic critical temperature	K
T_{heat}	maximum possible temperature of the external heat source	K
T_0	temperature of the pressurized system at the sizing conditions	K
T_{over}	maximum temperature in the pressurized system during relief	K
$u_{g,0}$	superficial gas velocity in the free-board gas volume of a vertical cylindrical vessel at the sizing conditions	m/s
u_{∞}	characteristic bubble-rise velocity of the gas/vapour in the liquid	m/s
u^*	dimensionless bubble-rise velocity	—
v	specific volume in the pressurized system	m^3/kg
V	volume of the pressurized system	m^3
$\dot{x}$	mass flow quality, i.e. the ratio of the gas mass flow rate to the total mass flow rate of a two-phase mixture	—
Z	real gas factor	—
β	ratio of the vent inlet diameter to the throat diameter	—

Variable	Definition	Unit
ε_0	void fraction in the pressurized system at the sizing conditions for a homogeneous two-phase mixture	—
$\varepsilon_{\text{seat}}$	void fraction in the narrowest cross-section, see Formula (50)	—
$\zeta_{\text{v,ref}}$	Resistance coefficient of reference, either inlet or outlet	—
η	pressure ratio, either η_{crit} or η_{b}	—
η_{b}	ratio of the safety valve back pressure to the sizing pressure	—
η_{crit}	critical pressure ratio	—
η_{S}	ratio of the saturation pressure corresponding to the sizing temperature and the sizing pressure (measure of liquid subcooling), see Formula (64)	—
θ	Angle of a vent line to the horizontal	°
κ	isentropic coefficient	—
ρ	fluid density	kg/m ³
$\rho_{\text{H}_2\text{O}}$	density of water during experiments to measure the K_{vs} value at a temperature of 5 °C	kg/m ³
σ	surface tension	N/m
ϕ_{limit}	critical filling threshold	—
ϕ_0	initial liquid filling level at the sizing conditions, i.e. the liquid volume divided by the total volume of the pressurized system considered	—
ω	compressibility coefficient	—
ω_{eq}	compressibility coefficient at equilibrium condition ($N = 1$)	—
Γ_{g}	gas production rate per liquid mass, i.e. the gas mass flow rate per liquid mass inventory in the pressurized system	kg/(s·kg)
Γ	dimensionless velocity ratio	—
Δh_{v}	latent heat of vaporization	J/kg
Δp	pressure drop in the inlet or outlet line	Pa
Δp_{MAA}	maximum allowable accumulation	Pa
Δp_{feed}	pressure loss between the outlet of the control valve in the feed line and the pressurized system	Pa
$\Delta p_{\text{H}_2\text{O}}$	pressure drop across a control valve during experiments to measure the K_{vs} value defined at a pressure difference of 10 ⁵ Pa	Pa
Δp_{loss}	inlet line pressure loss	Pa
Δp_{over}	absolute overpressure	Pa
ΔT_{over}	saturation temperature difference	K
ψ	Boiling area ratio	—
Ω	dynamic viscosity	Pa·s

4.2 Abbreviated terms

Index	Meaning
0	sizing condition
2ph	two-phase flow
b	back
CV	upstream of the control valve
c	thermodynamic critical property
crit	critical condition with respect to flow
ct	churn turbulent
feed	into the pressurized system
fire	heat externally by fire

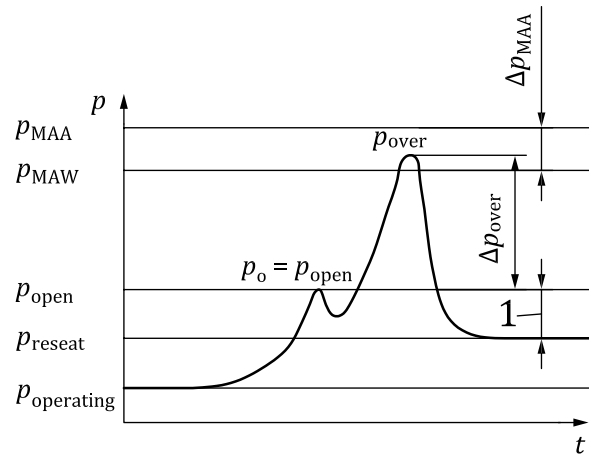
Index	Meaning
g	gas phase
HNE	Homogenous Non Equilibrium
H ₂ O	water
heat	external heat input (source)
<i>i</i>	liquid mixture component
ideal	theoretically perfect (adiabatic, frictionless)
in	inlet
is	isentropic
<i>j</i>	identification of a particular liquid mixture component
l	liquid phase
limit	limiting value (threshold)
loss	usually pressure loss
MAA	maximum allowable accumulated condition
MAW	maximum allowable working condition
max	maximal value
mean	average between set condition and condition at maximum allowable accumulated pressure
operating	operating condition
out	dischargeable from the pressurized system
over	overpressure or overtemperature
r	derated value (see 3.3.4)
red	reduced condition, i.e. condition related to the thermodynamic critical property
ref	reference cross-section, either inlet or outlet
resat	reseating condition
SD	through the safety device
sat	saturation condition of the liquid phase
seat	condition in the narrowest flow cross-section of the device, e.g. the valve seat or minimum flow area of a bursting disc
open	condition, at which a safety valve under operating conditions at the latest commences to open
s	subcooling
th	throat
vessel	bottom of the vessel
∞	characteristic bubble-rise property in the liquid phase

Exponent	Meaning
<i>a</i>	exponent in the formula for the boiling delay coefficient, <i>N</i> , see Formula (62)
*	dimensionless

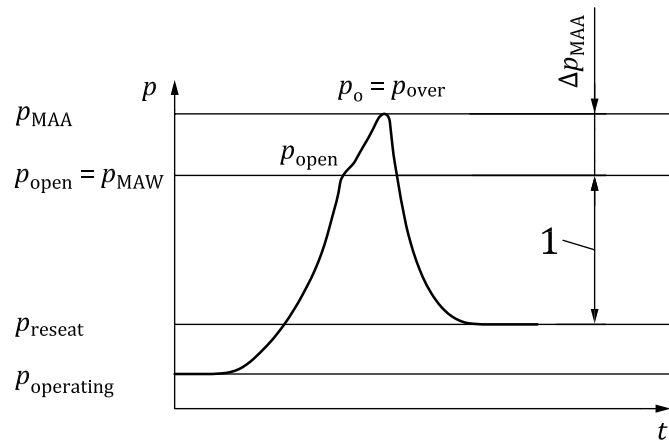
4.3 Figures

See [Figures 1 a\)](#) and [1 b\)](#) for an illustration of the relationship of the pressures defined in [3.2](#).

In contrast to the definition used in other parts of the ISO 4126 series (e.g. ISO 4126-7) all pressures are absolute pressures and not gauge pressures.



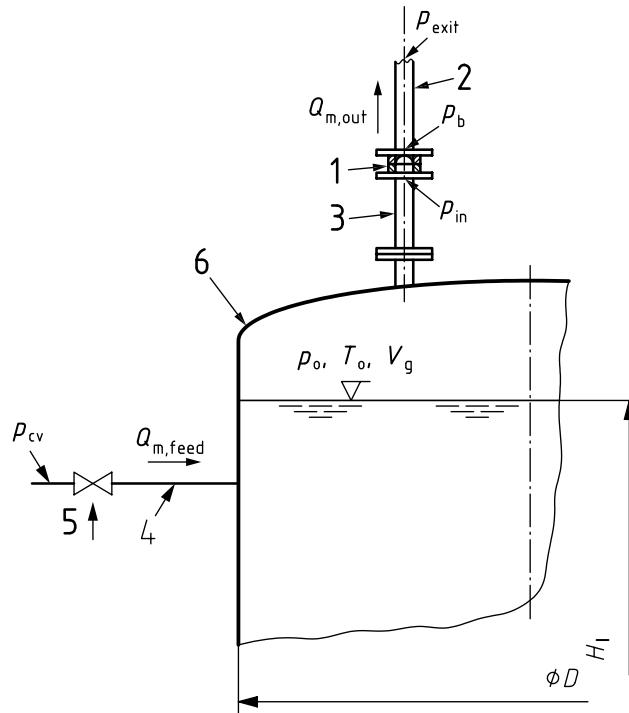
a) Pressure history of a typical tempered reaction system that is adequately sized



b) Typical pressure history for an externally heated gas vented system

Key			
p_{MAA}	maximum allowable accumulated pressure	p_0	sizing pressure equal to p_{open} as shown in Figure 1 a) and equal to p_{over} as shown in Figure 1 b)
p_{MAW}	maximum allowable working pressure	p_{over}	overpressure
p_{open}	opening pressure	Δp_{MAA}	maximum allowable accumulation
p_{reseat}	reseating pressure	Δp_{over}	change in overpressure
$p_{operating}$	operating pressure		
1	Δp_{BD} blowdown		

Figure 1 — Relationship of the defined pressures



Key

1	safety device	4	feed line
2	outlet line	5	control valve
3	inlet line	6	pressurized system

Figure 2 — Safety device in a pressurized system

5 Application range of the method

5.1 General

A homogeneous, non-equilibrium flow model for a single-component gas/liquid mixture is used for the safety device sizing. The flow is assumed to be in a quasi-steady-state. It is recommended to remain within the application range of the method, as given in 5.2 and 5.3.

5.2 Limitations of the method for calculating the two-phase mass flux in safety devices

5.2.1 Flashing flow

The method is accurate for vapour/liquid flashing systems in which either one or both of the following conditions is/are true.

- a) The overtemperature is less than 90 % of the fluid's thermodynamic critical temperature as given in [Formula \(1\)](#):

$$T_{\text{red}} = \frac{T_{\text{over}}}{T_c} < 0,9 \quad (1)$$

- b) The overpressure is less than 50 % of the fluid's thermodynamic critical pressure as given in [Formula \(2\)](#):

$$p_{\text{red}} = \frac{p_{\text{over}}}{p_c} < 0,5 \quad (2)$$

where

- T_{red} is the dimensionless reduced temperature;
- p_{red} is the dimensionless reduced pressure;
- T_{over} is the maximum temperature during relief, in K;
- p_{over} is the maximum pressure during relief (maximum accumulated pressure or less), in Pa;
- T_c is the thermodynamic critical temperature of the fluid, in K;
- p_c is the thermodynamic critical pressure of the fluid, in Pa.

If both the reduced pressure and temperature of a vapour/liquid flashing system are above the specified limits, the property data usually change too rapidly, which can lead to unacceptable errors.

The formulae used in the sizing method to predict the properties of the gas/liquid flow lead, in general, to an overestimation of the required flow area, when conditions above the limits in [Formulae \(1\)](#) and [\(2\)](#) up to the thermodynamic critical point are considered^[2]. Additional comments relative to the range of applicability of the method are given in [6.5.1](#)^[36].

The limitations on the model due to the linear approximation of the pressure density relation are discussed in Reference [\[26\]](#).

5.2.2 Condensing flow

Due to pressure drop in the safety device, even if there is single-phase gas flow at the inlet, condensation may occur resulting in two-phase flow. A formula of state for real gases should be used and the evaporation enthalpy should be considered. Further information is given in Reference [\[36\]](#).

5.2.3 Flashing flow for multi-component liquids

This method may be applied to multi-component flashing systems whose saturation temperature range does not exceed 100 K, as given in [Formula \(3\)](#) for mixtures of chemically similar liquids:

$$T_{\text{sat},i} - T_{\text{sat},j} < 100 \text{ K} \quad (3)$$

where $T_{\text{sat},i}$ and $T_{\text{sat},j}$ are the saturation temperatures at the sizing pressure for components i and j , in K.

Component i exhibits the highest saturation temperature, and component j the lowest saturation temperature of the mixture.

5.2.4 Dissolved gases

The method proposed shall not be applied directly to cases where significant quantities of gases are dissolved in the fluid being discharged, which is typical in cases of high pressure with gases such as nitrogen or hydrogen dissolved in a liquid.

The presence of dissolved gases can profoundly affect the mixture properties and the mass flow rate through the safety device and shall be taken into account. For example, the thermodynamic critical conditions of the mixture can be very different from the thermodynamic critical conditions of the pure components in a mixture. This leads to a change of the saturation line. Also, other properties, such as the heat of vaporization, the liquid mixture density (e.g. of polymers), or the liquid mixture viscosity, can be affected. Even small amounts of dissolved gases, which desorb due to the pressure decrease in a non-evaporating liquid flow through a safety device, can markedly reduce the mass flow rate compared to that in liquid flow only.

If it is required to consider the desorption of gases, because they affect the thermodynamic critical properties or the saturation line, it is possible to use the design equations for gassy systems if no other reliable information is available. The time delay (in reaching equilibrium) during the desorption of gases

should be neglected. For a conservative calculation, the required safety device area should be estimated with a mass flow quality that would belong to the two-phase gas/liquid mixture in equilibrium at the lowest pressure in the narrowest flow cross-section (homogeneous equilibrium flow between device inlet and narrowest device area). This can be, for example, the critical pressure in the safety device area. Because the desorption time delay has been neglected, mass flow quality is overestimated and, hence, the required device area is oversized.

5.2.5 Compressibility coefficient ω

The method is accurate if the compressibility coefficient ω satisfies the relation: $0 \leq \omega \leq 100$.

5.3 Limitations of the method for calculating the mass flow rate required to be discharged

5.3.1 Rate of temperature and pressure increase

In case of a runaway reaction, the reaction self-heat rate at the maximum pressure, p_{over} , during relief should be limited to 2 K/s, as given in [Formula \(4\)](#):

$$\left. \frac{dT}{dt} \right|_{\text{over}} < 2 \text{ K/s} \quad (4)$$

This is limited by the method for the flow rate required to be discharged for tempered reactions in [6.4.4.2](#). Further, the rate of pressure increase is restricted to 20 kPa/s (12 bar/min), as given in [Formula \(5\)](#):

$$\left. \frac{dp}{dt} \right|_{\text{over}} < 20 \text{ kPa/s} \quad (5)$$

If the reaction self-heat rate and the rate of pressure increase are considerably higher than these values, unfeasible relief sizes can result.

Safety valves should not be used if there is an excessive pressure increase during valve-opening. Typical spring-loaded valve-opening times are between 80 ms to 120 ms. It is necessary that the rate of pressure increase is slow enough to allow for a full opening of the valve before p_{over} is reached. Therefore, the rate of pressure increase should be limited to at least 10 % absolute overpressure above p_{open} of the safety valve within the valve-opening time. In most cases, this leads to values higher than the recommended limiting value of 20 kPa/s. For even faster pressure increases, bursting discs can be suitable.

5.3.2 Immiscible liquids

The sizing method might not be directly applicable if immiscible liquids are present in the system, e.g. in the case of the venting of an emulsion polymerization reactor. In this case, the reaction kinetics developed from dedicated laboratory experiments depend on the particular agitation state, which, in general, cannot be scaled to a technical size^[22].

6 Sizing steps

6.1 General outline of sizing steps

The sizing of a vent line system includes the following essential steps ([Figure 3](#)).

Step 1: Identification of the sizing case, see [6.2](#).

All reasonably conceivable deviations from normal plant operation shall be considered to identify the sizing case for the valve. Whether or not it is required to consider malfunction as reasonably possible can depend on the hazard potential (local regulations can have requirements regarding this topic). The sizing case is of key importance for the dimensioning of a safety valve and often more important than the type of calculation method. Although it is beyond the scope of this document to outline the details of hazard analysis, an introduction is given in [6.2](#).

Step 2: Flow regime at the inlet of the vent line system, see 6.3.

Step 3: Calculation of the mass flow rate required to be discharged, see 6.4.

Step 4: Calculation of the dischargeable mass flux through and pressure change in the vent line system, see 6.5.

Step 5: Ensure proper operation of safety valve vent line systems under plant conditions, see 6.6.

In the preceding steps, the safety valve has been sized without considering any influence of the connected inlet and/or outlet line, which can lead to a deterioration of safety valve capacity or function. Low-frequency opening and closing (pumping) of the valve or a higher-frequency flutter (chatter) can occur. In the latter case, the valve and/or the inlet and outlet line can be damaged.

For the following sizing steps, recommendations and a computational procedure applicable to common engineering practice are given in 6.2 to 6.6.

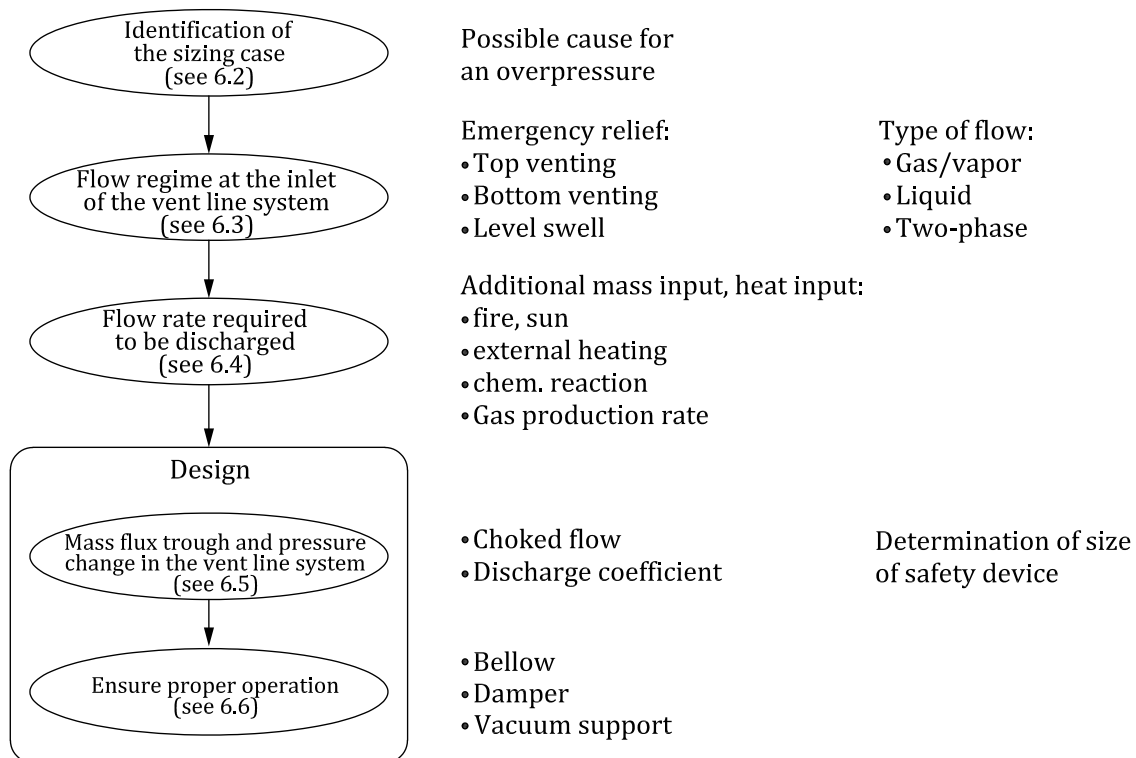


Figure 3 — Procedure of safety device sizing

6.2 Step 1 — Identification of the sizing case

The sizing case is of key importance for the dimensioning of a safety device and often more important than the type of calculation method.

Reasonably conceivable deviations from normal plant operation should be identified and evaluated relative to their hazardous risk potential (local regulations can have requirements regarding this topic) using a process hazard assessment and safety evaluation (PHASE)^[3]. Several well-established procedures, e.g.

- HAZOP (hazard and operability study)^[4],
- PHA (preliminary hazard analysis)^[5],
- LOPA (layer of protection analysis), or
- what-if analysis,

or the more quantitative methods, e.g.

- fault-tree analysis^[6] and
- event-tree analysis^[7]

are used in practice. These methods are often supplemented by checklists^[8] with several levels of detail. All these procedures provide a means to assess the causes for a pressure increase. These causes can be related to changes in mass and energy transfer to or from the pressurized system, or a deviation from the normal reaction system, e.g. when a thermal runaway reaction occurs.

In [Annex A](#), the most common causes for a pressure increase are summarized. Some of these can occur simultaneously or immediately after one another and, subsequently, it can be necessary to take one or more independent process deviations into account as possible sizing cases for the valve or bursting disc. The actual outline of the possible sizing cases depends on the risk and loss potential that can result from the deviations from normal plant operation. However, the deviations should not be quantified in a too conservative manner. Otherwise, the valve seat area or bursting disc is oversized. This can result in unnecessarily large release flow rates, overloads for the downstream process equipment and, possibly, additional environmental risks.

For further information, see ISO 23251.

6.3 Step 2 — Flow regime at the inlet of the vent line system

6.3.1 General

For the sizing, it is essential to know whether a two-phase flow occurs at the inlet of the vent line. Subsequently, criteria are given for the identification of the occurrence of two-phase flow.

6.3.2 Phenomenon of level swell

Safety devices are often mounted on the top (gas side) of a vessel. Consider, for example, a system capable of generating vapour during venting (tempered system): the pressure drops immediately when the device opens due to the release of vapour from the free-board vessel volume. An initially subcooled or saturated liquid superheats, i.e. the temperature remains above the saturation temperature corresponding to the actual pressure. If the vapour production rate exceeds the rate of vapour disengagement across the interface, after a boiling delay time (typically 0,1 s to 1,0 s), bulk evaporation of liquid starts and forces the level to swell. If the mixture reaches the valve inlet, the flow regime changes from single-phase gas to two-phase flow.

Level swell primarily occurs due to limited bubble-rise velocity; the characteristic rise velocity of the gas/vapour in the liquid is designated as u_{∞} . This phenomenon is especially common in highly viscous liquids and foam systems. Vessels with such contents are therefore emptied almost completely during emergency venting. For foaming and highly viscous fluids, this applies even for initial liquid filling levels down to about 15 %^[9].

In gas-desorbing or -producing systems, analogous phenomena, i.e. desorption delay, level swell, etc., also occur.

In externally heated vessels (e.g. non-reacting, non-heat-generating systems), the vapour bubbles are formed at the vessel wall, not in the bulk liquid. This can result in less level swell, with the possible consequence that single-phase flow relief occurs at higher initial liquid-filling levels^[37].

6.3.3 Influence of liquid viscosity and foaming behaviour on the flow regime

A criterion to distinguish between single-phase and two-phase flow makes use of initial liquid filling level, gas or vapour production rate, liquid viscosity and foaming behaviour. The liquid viscosity shall be considered at the conditions when p_{MAA} in the pressurized system is reached. For highly viscous liquids ($\eta_{l,0} > 0,1 \text{ Pa}\cdot\text{s}$), homogeneous venting shall be assumed of the pressurized system; see [Figure 4](#). In case of homogeneous venting of the pressurized system, the void fraction of the effluent is equal to the average void fraction in the vessel. Therefore, two-phase flow is to be considered at the safety device inlet.