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Safety devices for protection against excessive pressure — Part 10: Sizing of safety valves and bursting discs for gas/liquid two-phase flow

Contents

Foreword

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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 ~~documents~~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).

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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 ~~compared to the previous edition~~ 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 Pa = 1 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

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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 terminologicalterminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at httphttps://www.electropedia.org/

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

3.23.1 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
piping and associated fittings connecting the *pressurized system* (3.1.1) to the safety device inlet

3.1.5
outlet line
piping 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

3.33.2 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.~~8~~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.~~12~~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.~~10~~11) of the substance

~~3.4~~3.3 Flow rate

3.3.1
mass flow rate required to be discharged from a pressurized system
$Q_{m,out}$
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
$Q_{m,feed}$

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
$\dot{m}_{SD}$
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 (49).

3.3.4
certified valve discharge coefficient ~~of the safety device~~ for single-phase gas/vapour respectively liquid flow
$K_{dr,g}$ ⟨gas~~/vapour~~⟩
$K_{dr,l}$ ⟨liquid⟩
correction factor defined by the ratio of ~~experimentally determined mass flux through the safety device to~~ 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 ~~device~~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 ~~(ideal nozzle).~~ .

~~Note 2 to entry: Certified values for gas and liquid flow, K_{dr}, are used to calculate the minimum required safety device area A_0 and are usually supplied by the manufacturer of the safety device. They are equal to 0,9 times the experimentally determined and averaged values K_d.~~

~~3.6~~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)

~~3.7~~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

