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Safety devices for protection against excessive pressure - Part 1: Safety valves (ISO 4126-1:2004)

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Sicherheitseinrichtungen gegen unzulässigen Überdruck - Teil 1: Sicherheitsventile (ISO 4126-1:2004)

This European Standard was approved by CEN on 16 May 2003.

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Contents

Foreword

This document (EN ISO 4126-1:2004) has been prepared by Technical Committee CEN/TC 69 “Industrial valves”, the secretariat of which is held by AFNOR, in collaboration with Technical Committee ISO/TC 185 “Safety devices for protection against excessive pressure”.

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of an identical text or by endorsement, at the latest by August 2004, and conflicting national standards shall be withdrawn at the latest by August 2004 .

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive.

For relationship with EU Directive, see informative annex ZA, which is an integral part of this document.

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

This standard for safety devices for protection against excessive pressure consists of seven parts of which this is Part 1. The various parts are:

— *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 7 contains data that is common to more than one of the parts of this standard to avoid unnecessary repetition.

1 Scope

This part of this European Standard specifies general requirements for safety valves irrespective of the fluid for which they are designed.

It is applicable to safety valves having a flow diameter of 6 mm and above which are for use at set pressures of 0,1 bar gauge and above. No limitation is placed on temperature.

This is a product standard and is not concerned with applications for safety valves.

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 1092-1, *Flanges and their joints – Circular flanges for pipes, valves, fittings and accessories PN designated – Part 1: Steel flanges.*

EN 1092-2, *Flanges and their joints – Circular flanges for pipes, valves, fittings and accessories PN designated – Part 2: Cast iron flanges.*

EN 1092-3 , *Flanges and their joints – Circular flanges for pipes, valves, fittings and accessories PN designated – Part 3: Copper alloy flanges.*

prEN 1759-1, *Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, Class designated - Part 1: Steel flanges NPS 1/2 to 24.*

EN 12516-3, *Valves – Shell design strength – Part 3: Experimental method.*

EN 12627, *Industrial Valves – Butt welding ends for steel valves.*

EN 12760, *Valves – Socket welding ends for steel valves.*

EN ISO 6708, *Pipework components – Definition and selection of DN (nominal size) (ISO 6708:1995).*

ISO 7-1, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation.*

ANSI B1.20.1, *NPT threads.*

3 Terms and definitions

For the purposes of this European Standard, the following terms and definitions apply.

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 The valve can be characterised either by pop action (rapid opening) or by opening in proportion (not necessarily linear) to the increase in pressure over the set pressure.

3.1.1
types of safety valve

3.1.1.1
direct loaded safety valve
safety valve in which the loading due to the fluid pressure underneath the valve disc is opposed only by a direct mechanical loading device such as a weight, lever and weight, or a spring

3.1.1.2
assisted safety valve
safety valve which, by means of a powered assistance mechanism, may additionally be lifted at a pressure lower than the set pressure and will, even in the event of failure of the assistance mechanism, comply with all the requirements for safety valves given in this standard

3.1.1.3
supplementary loaded safety valve
safety valve which has, until the pressure at the inlet to the safety valve reaches the set pressure, an additional force which increases the sealing force

NOTE 1 This additional force (supplementary load), which may be provided by means of an extraneous power source, is reliably released when the pressure at the inlet of the safety valve reaches the set pressure. The amount of supplementary loading is so arranged that if such supplementary loading is not released, the safety valve will attain its certified discharge capacity at a pressure not greater than 1,1 times the maximum allowable pressure of the equipment to be protected.

NOTE 2 Other types of supplementary loaded safety devices are dealt with in Part 5 of this standard.

3.1.1.4
pilot operated safety valve
safety valve, the operation of which is initiated and controlled by the fluid discharged from a pilot valve which is itself a direct loaded safety valve subject to the requirement of this standard

NOTE Other types of pilot operated safety valves with flowing, non-flowing and modulating pilots are in Part 4 of this standard.

3.2
pressure
pressure unit used in this standard is the bar (1 bar = 10^5 Pa), quoted as gauge (relative to atmospheric pressure) or absolute as appropriate

3.2.1
set pressure
predetermined pressure at which a safety valve under operating conditions commences to open

NOTE 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.

3.2.2
maximum allowable pressure, PS
maximum pressure for which the equipment is designed as specified by the manufacturer

3.2.3
overpressure
pressure increase over the set pressure, at which the safety valve attains the lift specified by the manufacturer, usually expressed as a percentage of the set pressure

NOTE This is the overpressure used to certify the safety valve.

3.2.4
reseating pressure
value of the inlet static pressure at which the disc re-establishes contact with the seat or at which the lift becomes zero

3.2.5
cold differential test pressure
inlet static pressure at which a safety valve is set to commence to open on the test bench

NOTE This test pressure includes corrections for service conditions, e.g. back pressure and/or temperature.

3.2.6
relieving pressure
pressure used for the sizing of a safety valve which is greater than or equal to the set pressure plus overpressure

3.2.7
built-up back pressure
pressure existing at the outlet of a safety valve caused by flow through the valve and the discharge system

3.2.8
superimposed back pressure
pressure existing at the outlet of a safety valve at the time when the device is required to operate

NOTE It is the result of pressure in the discharge system from other sources.

3.2.9
balanced bellows
bellows device which minimises the effect of superimposed back pressure on the set pressure of a safety valve

3.2.10
blowdown
difference between set and reseating pressures, normally stated as a percentage of set pressure except for pressures of less than 3 bar when the blowdown is expressed in bar

3.3
lift
actual travel of the valve disc away from the closed position

3.4
flow area
minimum cross-sectional flow area (but not the curtain area) between inlet and seat which is used to calculate the theoretical flow capacity, with no deduction for any obstruction

NOTE The symbol is A.

3.5
flow diameter
diameter corresponding to the flow area

3.6
discharge capacity

3.6.1
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

3.6.2
coefficient of discharge
value of actual flowing capacity (from tests) divided by the theoretical flowing capacity (from calculation)

3.6.3
certified (discharge) capacity
that portion of the measured capacity permitted to be used as a basis for the application of a safety valve

NOTE It may, for example, equal the :

a) measured capacity times the derating factor ; or

b) theoretical capacity times the coefficient of discharge times the derating factor ; or

c) theoretical capacity times the certified derated coefficient of discharge.

3.7
DN (nominal size)
see EN ISO 6708

4 Symbols and units

Table 1 — Symbols and their descriptions

Symbol	Description	Unit
A	Flow area of a safety valve (not curtain area)	mm^2
C	Function of the isentropic exponent	–
K_b	Theoretical capacity correction factor for subcritical flow	–
K_d	Coefficient of discharge [a]	–
K_{dr}	Certified derated coefficient of discharge ($K_d \times 0,9$) [a]	–
K_v	Viscosity correction factor	–
k	Isentropic exponent	–
M	Molar mass	kg/kmol
n	Number of tests	–
p_o	Relieving pressure	bar (abs.)
p_b	Back pressure	bar (abs.)
p_c	Critical pressure	bar (abs.)
Q_m	Mass flow rate	kg/h
q_m	Theoretical specific discharge capacity	$kg/(h \cdot mm^2)$
q'_m	Specific discharge capacity determined by tests	$kg/(h \cdot mm^2)$
R	Universal gas constant	–
T_o	Relieving temperature	K
T_c	Critical temperature	K
μ	Dynamic viscosity	Pa·s
v	Specific volume at actual relieving pressure and temperature	m^3/kg
x	Dryness fraction of wet steam at the valve inlet at actual relieving pressure and temperature [b]	–
Z	Compressibility factor at actual relieving pressure and temperature	–

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

[b] x is expressed as 0,xx.

5 Design

5.1 General

5.1.1 The design shall incorporate guiding arrangements necessary to ensure consistent operation and seat tightness.

5.1.2 The seat of a safety valve, other than when it is an integral part of the valve shell, shall be fastened securely to prevent the seat becoming loose in service.

5.1.3 In the case of valves where the lift can be reduced to conform to the required discharge capacity, restriction of the lift shall not interfere with the operation of the valve. The lift restricting device shall be designed so that, if adjustable, the adjustable feature can be mechanically locked and access sealed. The lift restricting device shall be installed and sealed by the valve manufacturer.

Valve lift shall not be restricted to a value less than 30 % of unrestricted lift or 1 mm whichever is the greater.

5.1.4 Means shall be provided to lock and/or to seal all external adjustments in such a manner so as to prevent or reveal unauthorised adjustments of the safety valve.

5.1.5 Safety valves for toxic or flammable fluids shall be of the closed bonnet type to prevent leakage to atmosphere or if vented it shall be disposed of to a safe place.

5.1.6 Provision shall be made to prevent liquid collecting on the discharge side of the safety valve shell.

5.1.7 The design stress of load carrying parts shall not exceed that specified in the appropriate European Standard e.g. EN 12516-3.

5.1.8 In the case of failure of a balanced bellows, if any, the safety valve shall discharge its certified capacity at not more than 1,1 times the maximum allowable pressure of the equipment being protected.

5.1.9 The materials for adjacent sliding surfaces such as guide(s) and disc/disc holder/spindle shall be selected to ensure corrosion resistance and to minimise wear and avoid galling.

5.1.10 Sealing elements, which may adversely affect the operating characteristics by frictional forces, are not permitted.

5.1.11 Easing gear shall be provided when specified.

5.1.12 Safety valves shall be so constructed that breakage of any part, or failure of any device, will not obstruct free and full discharge through the valve.

5.2 End connections

5.2.1 Types

The types of end connections shall be as follows:

Butt welding	EN 12627 ;
Socket welding	EN 12760 ;
Flanged	EN 1092-1 ;
	EN 1092-2 ;
	EN 1092-3 ;
	prEN 1759-1;
Threaded	ISO 7-1 or ANSI B1.20.1.

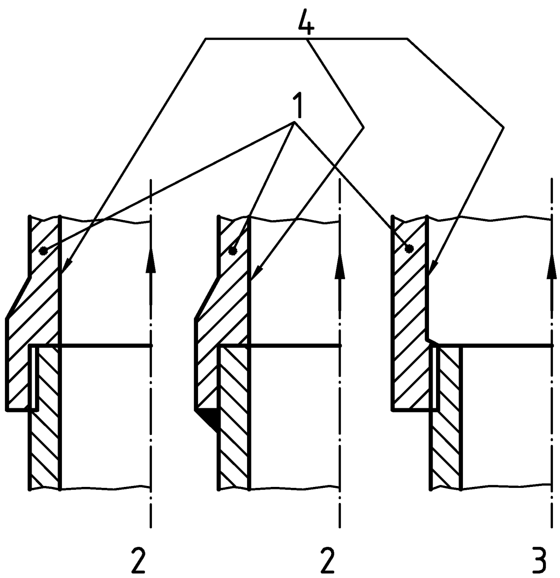
Other types of end connections are possible by agreement between the manufacturer and purchaser.

5.2.2 Design of valve end connections

The design of valve end connections, whatever their type, shall be such that the internal area of the external pipe or stub connection at the safety valve inlet is at least equal to that of the valve inlet connection (see Figure 1 a).

The internal area of the external pipe connection at the safety valve outlet shall be at least equal to that of the valve outlet, except those valves with female threaded outlet connections (see Figure 1 b).

NOTE See clause 7 regarding type testing.



Key

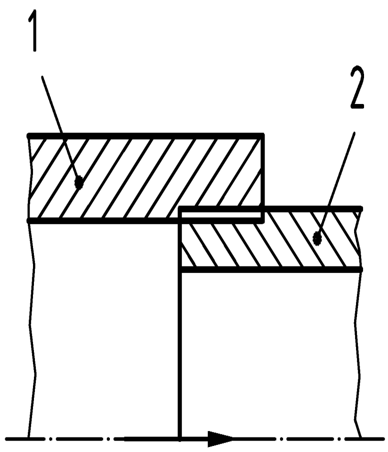
1 Valve

2 Satisfactory

3 Unsatisfactory

4 Required internal diameter of the safety valve for the valve to function properly

Figure 1 a) — Inlet



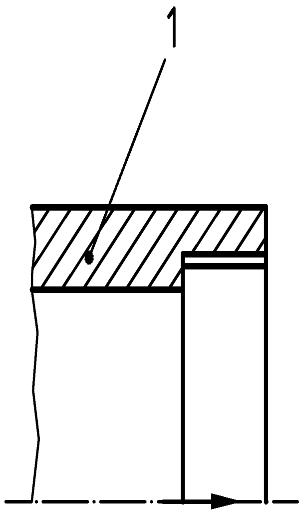
Key

1 Valve

2 The nominal diameter of the pipe to be equal to the nominal diameter of the valve outlet

With this construction at the valve outlet, a suitable pipe shall be fitted during testing as specified in 7.1.5

Figure 1 b) — Outlet



Key

1 Valve

With this construction at the valve outlet, no pipe is required during testing as specified in 7.1.5

Figure 1 c) — Outlet

Figure 1 — Design of end connections

5.3 Minimum requirements for springs

Springs shall be in accordance with Part 7 of this standard.

5.4 Materials

The materials for pressure retaining shells shall be in accordance with Part 7 of this standard.

6 Production testing

6.1 Purpose

The purpose of these tests is to ensure that all safety valves meet the requirements for which they have been designed without exhibiting any form of leakage from pressure retaining components or joints.

6.2 General

It is permissible to adopt an alternative test of equal validity (e.g. proof of design tests associated with statistical sampling) to the hydrostatic test for valve shells with:

— threaded ends ; and

— a maximum inlet diameter of 32 mm ; and

— a ratio of bursting pressure to design pressure of at least 8 ; and

— a design pressure equal to or less than 40 bar ; and

— for use with non-hazardous fluids ;

and also for valves as above but with :

— a design pressure greater than 40 bar ; and

— a ratio of bursting pressure to design pressure of at least 10 ; and

— material which is either wrought or forged.

All temporary pipes and connections and blanking devices shall be adequate to safely withstand the test pressure.

Any temporary welded-on attachments shall be carefully removed and the resulting weld scars shall be ground flush with the parent material. After grinding, all such scars shall be inspected by using magnetic particle or fluid penetrant techniques.

6.3 Hydrostatic testing

6.3.1 Application

The portion of the valve from the inlet to the seat shall be tested to a pressure 1,5 times the manufacturer's stated maximum pressure for which the safety valve is designed.

The shell on the discharge side of the seat shall be tested to 1,5 times the manufacturer's stated maximum back pressure for which the valve is designed.

6.3.2 Duration

The test pressure shall be applied and maintained at the required magnitude for a sufficient length of time to permit a visual examination to be made of all surfaces and joints, but in any case for not less than the times given in Table 2. For tests on the discharge side of the seat, the testing time shall be based on the pressure specified in 6.3.1 and the discharge size.

Table 2 — Minimum duration of hydrostatic test

Nominal size DN	Pressure rating		
	Up to 40 bar (4 MPa)	**Greater than 40 bar (4 MPa) up to 63 bar (6,3 MPa)**	**Greater than 63 bar (6,3 MPa)**
	Minimum duration in minutes		
DN ≤ 50	2	2	3
50 < DN ≤ 65	2	2	4
65 < DN ≤ 80	2	3	4
80 < DN ≤ 100	2	4	5
100 < DN ≤ 125	2	4	6
125 < DN ≤ 150	2	5	7
150 < DN ≤ 200	3	5	9
200 < DN ≤ 250	3	6	11
250 < DN ≤ 300	4	7	13
300 < DN ≤ 350	4	8	15
350 < DN ≤ 400	4	9	17
400 < DN ≤ 450	4	9	19
450 < DN ≤ 500	5	10	22
500 < DN ≤ 600	5	12	24

6.3.3 Acceptance criteria

No leakage from the tested parts as defined in 6.3.1 is accepted.

6.3.4 Safety requirements

Water shall normally be used as the test medium. Where other liquids are used, additional precautions may be necessary. Valve bodies shall be properly vented to remove entrapped air.

If materials which are liable to failure by brittle fracture are incorporated in that part of the safety valve which is to be hydrostatically tested, then both the safety valve, or part thereof, and the testing medium shall be at a sufficient temperature to prevent the possibility of such failure.

No valve or part thereof undergoing pressure testing shall be subjected to any form of shock loading, for example hammer testing.

6.4 Pneumatic testing

6.4.1 Application and duration of test

Pressure testing with air or other suitable gas may be carried out in place of the standard shell hydrostatic test with the agreement of all parties involved in the following cases:

a) valves of such design and construction that it is not practicable for them to be filled with liquid ; and/or

b) valves that are to be used in service where even small traces of water cannot be tolerated.

The test pressure and duration of application shall be as specified in 6.3.

6.4.2 Safety requirements

The hazards involved in pneumatic pressure testing shall be considered and adequate precautions taken.

Particular attention is drawn to some relevant factors as follows:

a) if a major rupture of the valve should occur at some stage during application of pressure, considerable energy will be released; hence no personnel should be in the immediate vicinity during pressure raising (for example a given volume of air contains 200 times the amount of energy that a similar volume of water contains, when both are at the same pressure) ;

b) the risk of brittle failure under test conditions shall have been critically assessed at the design stage and the choice of materials for valves that are to be pneumatically tested shall be such as to avoid the risk of brittle failure during test. This necessitates provision of an adequate margin between the transition temperature of all parts and the metal temperature during testing ;

c) attention is drawn to the fact that if there is a reduction in gas pressure between the high pressure storage and the valve under test, the temperature will decrease.

6.5 Adjustment of cold differential test pressure

Before adjusting a safety valve to the cold differential test pressure using air or other gas as the test medium, it shall previously be subjected to a hydrostatic test (see 6.3).

6.6 Seat leakage test

The seat leakage test of a safety valve shall be carried out. The test procedure and leakage rate shall be agreed between the manufacturer and the purchaser.

7 Type testing

7.1 General

7.1.1 Introduction

The operating and flow characteristics of safety valves shall be determined by type tests in conformity with this clause.

7.1.2 Application

This subclause applies to the types of safety devices defined in 3.1.1. For other types see:

— part 4 of this standard for other types of pilot operated safety valves ;

— part 5 of this standard for controlled safety pressure relief systems (CSPRS).

7.1.3 Tests

The tests to determine the operating characteristics shall be in accordance with 7.2 and the tests to determine the flow characteristics shall be in accordance with 7.3.

When these tests are carried out separately, the parts of the valve which influence fluid flow shall be complete and installed in the valve.

The testing procedure, test rig and equipment shall be such that the operability and capacity at the relieving pressure can be established in the conditions of back pressure.

7.1.4 Objective of tests

The objective of the tests is to determine, under specific operating conditions, the following characteristics of the valves before opening, while discharging and at closing. These are the major characteristics, there may be others:

a) set pressure ;

b) overpressure ;

c) reseating pressure ;

d) reproducibility of valve performance ;

e) mechanical characteristics of the valves determined by sight or hearing such as :

  — ability to reseat satisfactorily ;

  — absence of chatter, flutter, sticking and/or harmful vibration ;

f) lift at overpressure.

7.1.5 Procedure for testing

The tests shall provide suitable data from which the operational and flow characteristics may be determined. For valves with internally screwed connections on the outlet with a configuration as shown in Figure 1 b) a pipe, of appropriate thickness, at least five diameters long shall be fitted during the test.

7.1.6 Results calculated from the tests

The theoretical flowing capacity is calculated in accordance with 8.3 or 8.4 and 8.5 as applicable, using this value together with the actual flowing capacity at relieving pressure, the coefficient of discharge of the valve is calculated in accordance with 8.1.

7.1.7 Design changes

When changes are made in the design of a safety valve in such a manner as to affect the flow path, lift or performance characteristics, new tests shall be carried out in accordance with clause 7.

7.2 Tests to determine operating characteristics

7.2.1 General requirements

The set pressures at which the operating characteristics are determined shall be the minimum and maximum set pressures for which the spring is designed. Valves for air or other gas service shall be tested using superheated steam with minimum 10°C superheat, air or other gas of known characteristics. Valves for any steam service shall be tested on steam, air or other gas of known characteristics. Valves for liquid service shall be tested on water or other liquids of known characteristics.

The allowable tolerances or limits as applicable on the operating characteristics are as follows:

a) set pressure : ± 3 % of set pressure or ± 0,15 bar whichever is the greater ;

b) lift : not lower than the value specified by the manufacturer ;

c) overpressure : the value stated by the manufacturer but not exceeding 10 % of set pressure or 0,1 bar whichever is greater ;

d) blowdown : not greater than the value stated by the manufacturer, but within the following limits :

compressible fluids :	minimum : 2,0 % (not applicable to safety valves with proportional opening characteristics according to 7.2.1 f) ;
	maximum : 15 % or 0,3 bar, whichever is greater ;
incompressible fluids :	minimum : 2,5 % (not applicable to valves with proportional opening characteristics according to 7.2.1 f) ;
	maximum : 20 % or 0,6 bar, whichever is greater ;

e) overpressure and blowdown of restricted lift valves shall have the same tolerances or limits as the unrestricted lift valves ;

f) overpressure and blowdown of valves with proportional opening characteristic shall be verified and be stable for various lifts between the minimum and maximum stated by the manufacturer. A curve shall be established for valve lift versus overpressure.

7.2.2 Safety valve opening characteristics

The manufacturer shall specify the lift characteristic for all safety valves.

7.2.3 Test equipment

The error of pressure measuring equipment used during the test shall be not more than 0,6 % of the full-scale reading.

In the case of analogue pressure gauges, based on a Bourdon tube, the scale (range) for steady pressures shall be chosen as follows:

— the minimum working pressure shall be not less than 35 % of the maximum scale value ;

and

— the maximum working pressure shall not exceed 75 % of the maximum scale value.

7.2.4 Valves used in the test programme

The safety valves tested shall be representative of the design, pressure and size range of valves for which operating characteristics are required. The ratio of valve inlet to flow area and the ratio of flow area to valve outlet shall be taken into account.

For size ranges containing seven or more sizes, tests shall be carried out on three sizes. If the size range contains not more than six sizes, the number of sizes tested may be reduced to two.

When a size range is extended so that the safety valves tested previously are no longer representative of the range, further tests on the appropriate number of sizes shall be carried out.

The tests shall be carried out using three significantly different springs for each size of valve tested. This may be achieved by testing either one valve with three significantly different springs or three valves of the same size with three significantly different springs. Each test shall be carried out a minimum of three times in order to establish and confirm acceptable reproducibility of performance.

In the case of valves of which one size only at various pressure ratings is being manufactured, tests shall be carried out using four different springs, which shall cover the range of pressures for which the valve is to be used.

Where the size range cannot be adequately covered then scale models shall be used having a flow-diameter not less than the original flow diameter times 0,2 or 50 mm, whichever is the greater.

All dimensions of the flow path in the model shall be strictly to scale with the corresponding dimensions of the actual valve.

All dimensions of the parts that can affect the overall thrust exercised by the medium on the moving parts shall be to scale.

In the case of bellows, it is permitted that the effective area only need be to scale.

NOTE Effective area is the area of the bellows from which end loads are calculated (piston area).

The overall spring rate of spring plus bellows, if any, of the model shall be to scale with the overall rate of the actual valve.

The roughness of all surfaces of the flow path of the model shall not be less than that of the corresponding surfaces of the actual valve.

Before tests are carried out it shall be verified that the model conforms to the above.

7.3 Tests to determine flow characteristics

7.3.1 Test requirements

After the operating characteristics (see 7.2) have been satisfactorily established, it is acceptable to use steam, air or other gas of known characteristics as the fluid for flow characteristic tests except for valves designed for liquid service. Valves for use with liquids shall be tested with water or other liquid of known characteristics. Further, when discharged quantities are being assessed, the valve disc shall be held at the lift as determined by the operating characteristics test (see 7.2.1 b).

7.3.2 Valves used in the test programme

The safety valves tested shall be the same as, or identical to, those used for the operating characteristics tests (see 7.2.4).

7.3.3 Test procedure

7.3.3.1 Test conditions

A travel stop maybe fitted to limit the lift to that determined in accordance with 7.2.1 b).

The tests can be carried out with or without the spring fitted. When the spring is in the flow path, the test shall be carried out with the spring fitted.

Tests shall be conducted at various pressures to establish that no variations of the coefficient of discharge with the relevant positions(s) of the adjusting ring(s), if any, occurs.

7.3.3.2 Number of test valves

The tests shall be carried out at three different pressures for each of three sizes of a given valve design unless the size range contains not more than six sizes, when the number of sizes tested may be reduced to two.

When a size range is extended from one containing less than seven sizes to one containing seven or more sizes, then tests on three sizes of valves (a total of nine tests) shall be carried out.

In the case of valves of either novel or special design of which one size only at various pressure ratings is being manufactured, tests shall be carried out at four different set pressures which shall cover the range of pressures for which the valves will be used, or as determined by the limits of the test facility.

7.3.3.3 Restricted lift valves

For restricted lift valves the capacity at restricted lift may be determined immediately following the tests to determine flow characteristics at full lift or determined later.

In the case of restricted lift, or valves with a proportional opening characteristic, a curve shall be established for the coefficient of discharge versus valve lift.

7.3.3.4 Value of test pressure

Flow tests on a valve with the spring installed shall be carried out at a set pressure plus overpressure as used to determine operating characteristics with atmospheric back pressure.

When valves are tested without the spring, and a travel stop is fitted as in 7.3.3.1, the test pressure may be reduced down to where the ratio of absolute back pressure to absolute relieving pressure is less than 0,25. Tests at three different pressure ratios less than 0,25 shall then be carried out with atmospheric back pressure.

For compressible fluids when the ratio of absolute back pressure to absolute relieving pressure exceeds the value of 0,25, the coefficient of discharge can be largely dependent upon this ratio. Then tests shall be conducted at ratios between the pressure ratio of 0,25 and the maximum pressure ratio required to obtain curves or tables of coefficient of discharge versus the ratio of absolute back pressure and absolute relieving pressure, this curve may be extended to cover the tests with pressure ratios less than 0,25.

This curve shall be used for establishing the coefficient of discharge at any set pressure and overpressure, it shall also be used for establishing the coefficient of discharge under back pressure conditions.

7.3.3.5 Flow testing acceptance tolerance

In all the methods described for flow characteristics testing, all final results shall be within ± 5 % of the arithmetic average.

Where these tolerances are not achieved when testing, to produce the curve of coefficient of discharge versus the ratio of absolute back pressure and absolute relieving pressure greater than 0,25, the curve illustrating the lowest coefficient of discharge versus this ratio shall be accepted for the range of valves tested.

7.3.4 Adjustment during test

No adjustment to the valve shall be made during the tests. Following any changes or deviation in the test conditions, a sufficient period of time shall be allowed to permit the rate of flow, temperature and pressure to reach stable conditions before readings are taken.

7.3.5 Records and test results

The test records shall include all observations, measurements, instrument readings and instrument calibration records (if required) for the objective(s) of the tests. Original test records shall remain in the custody of the test establishment that conducted the tests. Copies of all test records shall be supplied to each of the parties concerned with the tests. Corrections and corrected values shall be entered separately in the test record.

The manufacturer or his authorised representative shall keep a copy of the test records and their additions for a period of ten years after the last of the safety valves has been manufactured.

7.3.6 Flow test equipment

The test equipment shall be designed and operated such that the actual test flowing capacity measurements shall be accurate to within ± 2 %.

7.4 Determination of the coefficient of discharge

For the determination of the coefficient of discharge K_d see 8.1.

7.5 Certification of coefficient of discharge

The certified derated 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 :

$$K_{\mathrm{dr}} = 0{,}9\, K_{\mathrm{d}}$$

Neither the coefficient of discharge nor the certified derated coefficient of discharge can be used to calculate the capacity at a lower overpressure than that at which the tests to determine the flow characteristics (see 7.3) were carried out, although they can be used to calculate the capacity at any higher overpressure.

8 Determination of safety valve performance

8.1 Determination of coefficient of discharge

The coefficient of discharge K_{d} is calculated from the following:

$$K_{\mathrm{d}} = \frac{\sum_{1}^{n} \left(\frac{q'_{\mathrm{m}}}{q_{\mathrm{m}}} \right)}{n}$$

8.2 Critical and subcritical flow

The 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:

$$\frac{p_{\mathrm{b}}}{p_{\mathrm{o}}} \le \left(\frac{2}{k+1} \right)^{(k/(k-1))}$$

and subcritical flow occurs when:

$$\frac{p_{\mathrm{b}}}{p_{\mathrm{o}}} > \left(\frac{2}{k+1} \right)^{(k/(k-1))}$$

8.3 Discharge capacity at critical flow

8.3.1 Discharge capacity for steam

$$q_{\mathrm{m}} = 0{,}2883\, C \sqrt{\frac{p_{\mathrm{o}}}{v}}$$

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

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.

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

NOTE 2 $3{,}948 = \dfrac{3\ 600}{\sqrt{10^5}\ \sqrt{R}}$

The value of k used to determine C shall be based on the actual flowing conditions at the safety valve inlet and shall be determined from Table 1 in part 7 of this standard.

8.3.2 Discharge capacity for any gas under critical flow conditions

$$q_{\mathrm{m}} = p_{\mathrm{o}}\, C \sqrt{\frac{M}{Z T_{\mathrm{o}}}} = 0{,}2883\ C \sqrt{\frac{p_{\mathrm{o}}}{v}}$$

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

(see Table 2 in part 7 of this standard for rounded figures).

8.4 Discharge capacity for any gas at subcritical flow

$$q_{\mathrm{m}} = p_{\mathrm{o}}\, C\, K_{\mathrm{b}} \sqrt{\frac{M}{Z T_{\mathrm{o}}}} = 0{,}2883\ C\ K_{\mathrm{b}} \sqrt{\frac{p_{\mathrm{o}}}{v}}$$

$$K_{\mathrm{b}} = \sqrt{\frac{\dfrac{2k}{k-1}\left[\left(\dfrac{p_{\mathrm{b}}}{p_{\mathrm{o}}}\right)^{2/k} - \left(\dfrac{p_{\mathrm{b}}}{p_{\mathrm{o}}}\right)^{(k+1)/k}\right]}{k\left(\dfrac{2}{k+1}\right)^{(k+1)/(k-1)}}}$$

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

$$q_{\mathrm{m}} = 1{,}61 \sqrt{\left(\frac{p_{\mathrm{o}} - p_{\mathrm{b}}}{v}\right)}$$

NOTE $1{,}61 = \dfrac{3600\sqrt{2}}{10\sqrt{10^5}}$

9 Sizing of safety valves

9.1 General

It is not permitted to calculate the capacity at 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 any higher overpressure (see 7.5).

Valves having a certified derated coefficient of discharge established on critical flow at the test back pressure may not have the same certified derated coefficient of discharge at a higher back pressure, see 7.3.3.4.

9.2 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 8 shall be used.

9.3 Calculation of capacity

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

NOTE 2 See annex A for calculations.

9.3.1 Capacity calculation for (saturated or superheated) steam at critical flow

$$Q_{\mathrm{m}} = 0{,}2883\, C\, A\, K_{\mathrm{dr}} \sqrt{\frac{p_{\mathrm{o}}}{v}}$$

9.3.2 Capacity calculations for wet steam

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

$$Q_{\mathrm{m}} = \frac{0{,}2883\, C\, A\, K_{\mathrm{dr}} \sqrt{\dfrac{p_{\mathrm{o}}}{v}}}{\sqrt{\mathrm{x}}}$$

9.3.3 Capacity calculations for gaseous media

9.3.3.1 Capacity calculations for gaseous media at critical flow

$$Q_{\mathrm{m}} = p_{\mathrm{o}}\, C\, A\, K_{\mathrm{dr}} \sqrt{\frac{M}{Z T_{\mathrm{o}}}} = 0{,}2883\, C\, A\, K_{\mathrm{dr}} \sqrt{\frac{p_{\mathrm{o}}}{v}}$$

$$A = \frac{Q_{\mathrm{m}}}{p_{\mathrm{o}}\, C\, K_{\mathrm{dr}} \sqrt{\dfrac{M}{Z T_{\mathrm{o}}}}} = \frac{Q_{\mathrm{m}}}{0{,}2883\, C\, K_{\mathrm{dr}} \sqrt{\dfrac{p_{\mathrm{o}}}{v}}}$$

9.3.3.2 Capacity calculations for gaseous media at subcritical flow

$$Q_{\mathrm{m}} = p_{\mathrm{o}}\, C\, A\, K_{\mathrm{dr}}\, K_{\mathrm{b}} \sqrt{\frac{M}{Z T_{\mathrm{o}}}} = 0{,}2883\, C A K_{\mathrm{dr}}\, K_{\mathrm{b}} \sqrt{\frac{p_{\mathrm{o}}}{v}}$$

See equation in 8.4 and Table 3 in part 7 of this standard.

9.3.4 Capacity calculations for liquids

$$Q_{\mathrm{m}} = 1{,}61\, K_{\mathrm{dr}}\, K_{\mathrm{v}}\, A \sqrt{\frac{p_{\mathrm{o}} - p_{\mathrm{b}}}{v}}$$

10 Marking and sealing

10.1 Marking on the shell of a safety valve

Marking on the shell of a safety valve may be integral with the shell or on a plate securely fixed on the shell. The following minimum information shall be marked on all safety valves:

a) size designation (inlet), for example DN xxx ;

b) material designation of the shell ;

c) manufacturer's name or trade-mark ;

d) an arrow showing the direction of flow where the inlet and outlet connections have the same dimensions or the same pressure rating.

10.2 Marking on an identification plate

The following information shall be given on an identification plate securely fixed to the safety valve:

a) set pressure, in bar gauge ;

b) the number of this standard (EN ISO 4126-1) ;

c) manufacturer's type reference ;

d) certified derated coefficient of discharge indicating reference fluid :

‘G’ for gas, ‘S’ for steam and ‘L’ for liquid ;

NOTE The designation of the fluid may be placed either before or after the certified derated coefficient of discharge e.g. G-0,815.

e) flow area, in square millimetres ;

f) minimum value of the lift, in millimetres, and corresponding overpressure, expressed as, e.g. a percentage of set pressure.

10.3 Sealing of a safety valve

All external adjustments shall be sealed.

Annex A
(informative)

Examples of sizing calculations for various fluids

NOTE For symbols and units refer to clause 4.

A.1 Capacity calculations for gaseous media at critical flow (see 9.3.3.1)

EXAMPLE 1 Calculate the flow area of a safety valve to be used on a vessel holding nitrogen gas with a maximum allowable pressure, PS of 55 bar gauge.

Safety valve certified derated coefficient of discharge [K_{dr}] at 10 % overpressure = 0,87.

Molar mass of the gas [M]	= 28,02
Isentropic exponent of the gas [k]	= 1,40
Gas relieving temperature	= 20 °C
Required gas flow rate [Q_m]	= 18 000 kg/h
Set pressure	= 55 bar
Back pressure	atmospheric

$$T_o = 20 + 273 = 293\ \text{K}$$

$$p_o = [\,55 \times 1{,}1\,] + 1 = 61{,}5\ \text{bar (abs)}.$$

Since $\frac{p_b}{p_o} \leq \left(\frac{2}{k+1}\right)^{(k/(k-1))}$ the flow is critical.

The required area, $A = \dfrac{Q_m}{p_o\ C\ K_{dr} \sqrt{\dfrac{M}{Z\ T_o}}}$

$$C = 3{,}948 \sqrt{1{,}4 \times \left(\frac{2}{1{,}4+1}\right)^{(1{,}4\ +\ 1)/(1{,}4\ -\ 1)}} = 2{,}7$$

Compressibility factor may be estimated from published data.

The calculation involved is as follows:

Reduced pressure, $p_r = \dfrac{p_o}{p_c}$

where:

p_c is the critical pressure = 33,94 bar (abs.) (from a thermodynamics handbook).

Reduced temperature, $T_r = \frac{T_o}{T_c}$

where:

T_c is the critical temperature = 126,05 K (from a thermodynamics handbook).

$p_r = 61{,}5 / 33{,}94 = 1{,}81$

$T_r = 293 / 126{,}05 = 2{,}32$

Z = 0,975 (from Figure 1 of part 7 of this standard)

$$A = \frac{18\,000}{61{,}5 \times 2{,}7 \times 0{,}87 \times \sqrt{\frac{28{,}02}{0{,}975 \times 293}}} = 397{,}85 \text{ mm}^2$$

EXAMPLE 2 Where K_{dr} is certified at 5 % overpressure and the relieving overpressure remains at 10 % as in example 1.

Calculate the flow area of a safety valve to be used on a vessel holding nitrogen gas with a maximum allowable pressure, PS of 55 bar gauge:

Safety valve certified derated coefficient of discharge [K_{dr}] at 5 % overpressure = 0,87

Molar mass of the gas [M]	= 28,02
Isentropic exponent of the gas [k]	= 1,40
Gas relieving temperature	= 20 °C
Required gas flow rate [Q_m]	= 18 000 kg/h
Set pressure	= 55 bar
Back pressure	atmospheric

$T_o = 20 + 273 = 293 \text{ K}$

$p_o = [\,55 \times 1{,}1\,] + 1 = 61{,}5 \text{ bar (abs)}.$

Since $\frac{p_b}{p_o} \le \left(\frac{2}{k+1}\right)^{(k/(k-1))}$ the flow is critical.

The required area, $A = \dfrac{Q_m}{p_o\ C\ K_{dr}\sqrt{\dfrac{M}{Z\ T_o}}}$

$$C = 3{,}948\sqrt{1{,}4 \times \left(\frac{2}{1{,}4+1}\right)^{(1{,}4+1)/(1{,}4-1)}} = 2{,}7$$

Compressibility factor may be estimated from published data. The calculation involved is as follows:

Reduced pressure, $p_r = \frac{p_o}{p_c}$

where:

p_c is the critical pressure = 33,94 bar (abs.) (from a thermodynamics handbook)

Reduced temperature, $T_r = \frac{T_o}{T_c}$

where:

T_c is the critical temperature = 126,05 K (from a thermodynamics handbook).

$p_r = 61{,}5 / 33{,}94 = 1{,}81$

$T_r = 293 / 126{,}05 = 2{,}32$

Z = 0,975 (from Figure 1 of part 7 of this standard)

$$A = \frac{18\,000}{61{,}5 \times 2{,}7 \times 0{,}87 \times \sqrt{\frac{28{,}02}{0{,}975 \times 293}}} = 397{,}85 \text{ mm}^2$$

A.2 Capacity calculations for gaseous media at subcritical flow (see 9.3.3.2)

EXAMPLE Using values from the previous example (i.e. critical flow) calculate the required discharge area if the back pressure is increased from atmospheric to 36,0 bar gauge and the certified derated coefficient of discharge is 0,80 in the new conditions.

Since $\frac{p_b}{p_o} > \left(\frac{2}{k+1}\right)^{(k/(k-1))}$ the flow is subcritical.

NOTE $\frac{p_b}{p_o} = \frac{36+1}{(55 \times 1{,}1)+1}$.

The required area:

$$A = \frac{Q_m}{p_o\, C\, K_{dr}\, K_b \sqrt{\frac{M}{Z\, T_o}}}$$

$$K_b = \sqrt{\frac{\frac{2k}{k-1}\left[\left(\frac{p_b}{p_o}\right)^{(2/k)} - \left(\frac{p_b}{p_o}\right)^{(k+1)/k}\right]}{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}}} = 0{,}989$$

(K_b can be either calculated or obtained from Table 3 of part 7 of this standard).

$$A = \frac{18\,000}{61{,}5 \times 2{,}7 \times 0{,}8 \times 0{,}989 \sqrt{\frac{28{,}02}{0{,}975 \times 293}}} = 437{,}471 \text{ mm}^2$$

A.3 Capacity calculations for liquids (see 9.3.4)

EXAMPLE Calculate the safety valve flow area, necessary to discharge oil given the following conditions.

Safety valve certified derated coefficient of discharge [K_{dr}] at 10 % overpressure = 0,65

Required oil flow capacity at 10 % overpressure [Q_m]	= 45 000 kg/h
Specific volume [v]	= 0,001 075 27 m^3/kg = 1/ density
Dynamic viscosity [μ]	= 0,5 Pa·s
Set pressure	= 30 bar gauge
Back pressure	= 3 bar gauge

Applicable equation

$$Q_m = 1{,}61\ K_{dr}\ K_v\ A\sqrt{\frac{p_o - p_b}{v}}$$

Calculate the flow area assuming a non-viscous fluid (i.e. neglecting viscosity).

$$K_v = 1$$

$$A = \left(\frac{Q_m}{1{,}61\ K_{dr}}\right)\sqrt{\frac{v}{p_o - p_b}}$$

$$p_o - p_b = [30 \times (1 + 10/100) + 1] - (3 + 1) = 30 \text{ bar}$$

$$A = \left(\frac{45\,000}{1{,}61 \times 0{,}65}\right)\sqrt{\frac{0{,}001\ 075\,27}{30}} = 257{,}43 \text{ mm}^2$$

1) Select the next larger orifice A', in this case: A' = 380 mm^2 and obtain the minimum value of the viscosity correction factor.

$$K_{vm} = 257{,}43 / 380 = 0{,}68$$

2) Calculate the Reynolds number (R_e) for the given flow capacity and the selected orifice.

$$R_e = \left(\frac{Q_m}{3{,}6\,\mu}\right)\sqrt{\frac{4}{\pi\ A'}}$$

$$= \left(\frac{45000}{3{,}6 \times 0{,}5}\right)\sqrt{\frac{4}{\pi \times 380}} = 1447$$

From graph in part 7 of this standard

$$K_v = 0{,}92 > 0{,}68$$

3) If, as in the example above, $K_{vm} \le K_v$ the selected area is sufficient to discharge the given flow rate. If this is not true, repeat 1) and 2) above.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 97/23/EC (PED)

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 97/23/EC (PED).

Once this standard is cited in the Official Journal of the European Communities under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Directive 97/23/EC (PED)

Sub-clauses of this EN	Essential Requirements of Directive 97/23/EC (PED)	
	Essential Requirements	**Annex I of PED**
All	Safety accessories	2.11
5	Design for adequate strength	2.1
6	Proof test	3.2.2
7	Performance test	2.2.4
8 and 9	Calculation method	2.2.3
10	Marking and labelling	3.3

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.