INTERNATIONAL STANDARD

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Safety devices for protection against excessive pressure —

Part 4: **Pilot-operated safety valves**

Dispositifs de sécurité pour protection contre les pressions excessives —

Partie 4: Soupapes de sûreté pilotées

Reference number
ISO 4126-4:2004(E)

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Foreword

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

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

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

ISO 4126-4 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 185, *Safety devices for protection against excessive pressure*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this document, read "...this European Standard..." to mean "...this International Standard...".

ISO 4126-4 cancels and replaces ISO 6718:1991, which has been technically revised.

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

— *Part 1: Safety valves*

— *Part 2: Bursting disc safety devices*

— *Part 3: Safety valves and bursting disc safety devices in combination*

— *Part 4: Pilot-operated safety valves*

— *Part 5: Controlled safety pressure relief systems (CSPRS)*

— *Part 6: Application, selection and installation of bursting disc safety devices*

— *Part 7: Common data*

For the purposes of this part of ISO 4126-4, the CEN annex regarding fulfilment of European Council Directives has been removed.

Contents

Foreword

This document (EN ISO 4126-4:2004) 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.

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

This standard for safety devices for protection against excessive pressure consists of seven parts of which this is Part 4. 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.

Annex A is informative.

1 Scope

This part of this European Standard specifies general requirements for pilot operated safety valves, other than those covered in Part 1, irrespective of the fluid for which they are designed. In all cases, the operation is carried out by the fluid in the system to be protected.

It is applicable to pilot operated safety valves having a valve 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 it is not concerned with applications for pilot operated 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 and composite flanges.*

prEN 1759-1, *Flanges and their joints – Circular flanges for pipes, valves, fittings and accessories, Class designated – Part 1: Steel flanges NPS1/2 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.*

ASME B1.20.1, *NPT threads.*

3 Terms and definitions

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

3.1
pilot operated safety valve
self actuated device comprising a valve and an attached pilot

NOTE The pilot responds to the pressure of the fluid without any other energy than the fluid itself and controls the operation of the valve. The valve opens when the fluid pressure that keeps it closed is removed or reduced. The valve re-closes when the pressure is re-applied.

3.1.1
types of pilot

3.1.1.1
flowing pilot
pilot which discharges the fluid throughout the relieving cycle of the pilot operated safety valve

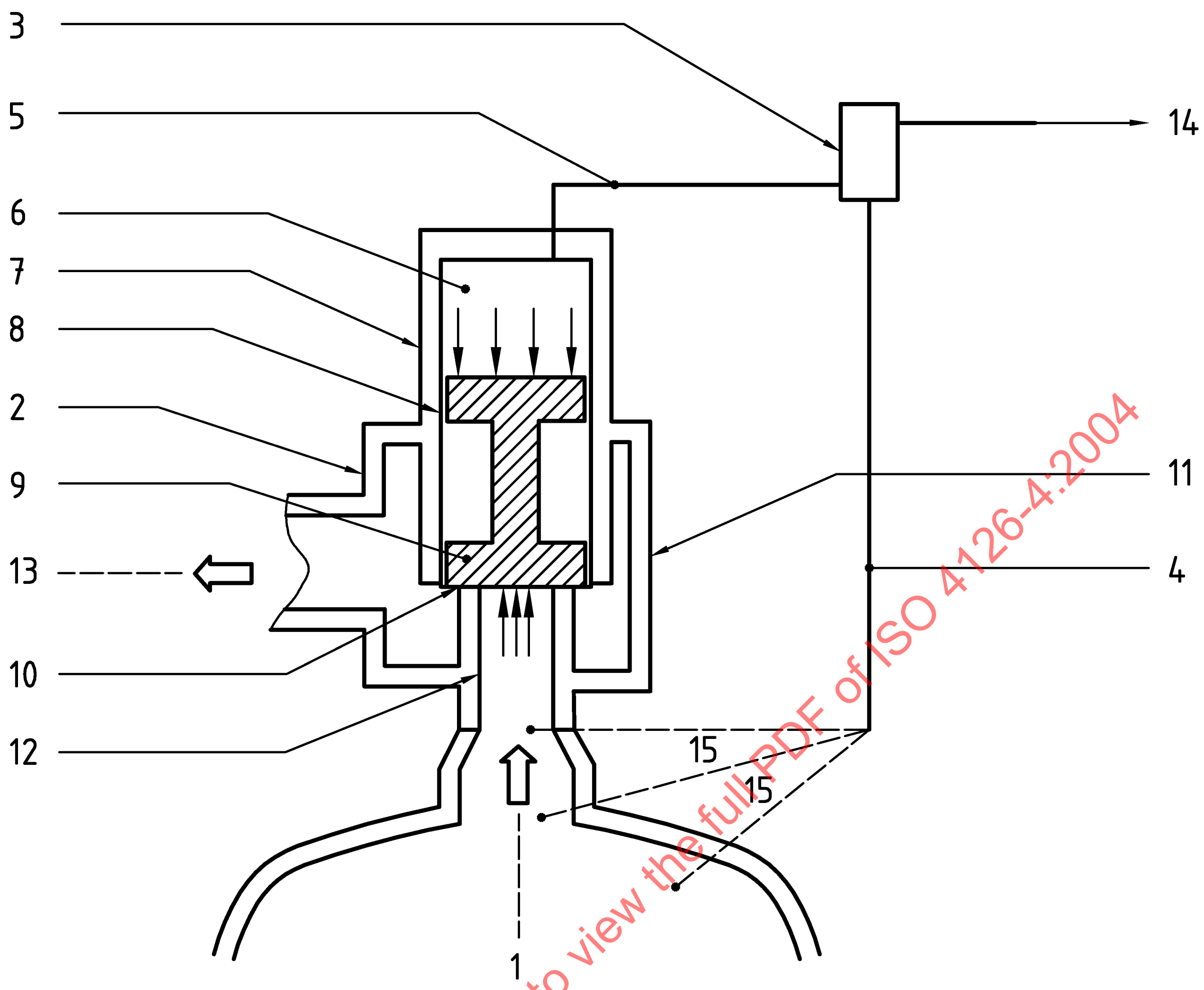
3.1.1.2
non-flowing pilot
pilot in which the fluid flows only during the opening and/or closing of the pilot operated safety valve

3.1.2
types of action of the pilot operated safety valve

3.1.2.1
ON/OFF
action characterised by stable operation resulting in fully open or fully closed main valve position

3.1.2.2
modulating
action characterised by a gradual opening and closing of the disc of the main valve which is a function of the pressure, proportional but not necessarily linear

3.2
list of main components
see Figure 1



Key

1 Equipment to be protected
2 Main valve
3 Pilot valve
4 Sensing line
5 Loading/unloading line
6 Pressure chamber
7 Cover
8 Guide
9 Disc
10 Seat
11 Body
12 Inlet
13 Outlet
14 Pilot outlet
15 Connection of the sensing line : see the following note

NOTE The sensing line from the pilot can be either connected to the main valve inlet or connected directly to the equipment to be protected. In cases where the sensing line is not connected to the main valve inlet, considerations should be given to the length and to the protection from damage of the sensing line.

Figure 1 — Nomenclature of main components of a pilot operated safety valve

3.3
pressure

3.3.1
set pressure
predetermined pressure at which the valve of a pilot operated 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.

3.3.2
maximum allowable pressure, PS
maximum pressure for which the equipment is designed as specified by the manufacturer

3.3.3
opening sensing pressure
pressure at which the pilot commences to open in order to achieve the set pressure

3.3.4
overpressure (of a pilot operated safety valve)
pressure increase over the set pressure, at which the main 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 pilot operated safety valve.

3.3.5
reseating pressure (of a pilot operated safety valve)
value of the inlet static pressure at which the disc re-establishes contact with the seat or at which the lift becomes zero

3.3.6
cold differential test pressure
inlet static pressure at which a pilot operated 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.

3.3.7
relieving pressure
pressure used for the sizing of a pilot operated safety valve which is greater than or equal to the set pressure plus overpressure

3.3.8
built-up back pressure
pressure existing at the outlet of the main valve caused by flow through the main valve and the discharge system

3.3.9
superimposed back pressure
pressure existing at the outlet of the main 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.

3.3.10
blowdown (of a pilot operated safety valve)
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

3.4
lift
actual travel of the main valve disc away from the closed position

3.5
flow area
minimum cross-sectional flow area (but not the curtain area) between inlet and seat which is used to calculate the theoretical flowing capacity of the main valve, with no deduction for any obstruction

NOTE The symbol is A.

3.6
flow diameter
diameter corresponding to the flow area

3.7
discharge capacity

3.7.1
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 main valve

3.7.2
coefficient of discharge
value of actual flowing capacity (from tests) divided by the theoretical flowing capacity (from calculation)

3.7.3
certified (discharge) capacity
that portion of the measured capacity permitted to be used as a basis for the application of a pilot operated safety valve

NOTE It may, for example, equal the :

a) measured flow rate times the derating factor ; or

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

c) theoretical flow rate times the certified derated coefficient of discharge.

3.8
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
Tc	Actual critical temperature	K
μ	Dynamic viscosity	Pa·s
v_o	Specific volume at actual relieving pressure and temperature	m^3/kg
x_o	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 the main 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 Means shall be provided to lock and/or to seal all external adjustments in such a manner so as to prevent or reveal unauthorized adjustments of the pilot operated safety valve.

5.1.4 In the case of main valves with restricted lift, the lift restricting device shall limit the main valve lift but shall not otherwise interfere with the operation of the main valve. The lift restricting device shall be designed so that, if adjustable, the adjustable feature can be mechanically locked and 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 1 mm.

5.1.5 Pilot operated safety valves for toxic or flammable fluids shall have the pilot vented to a safe place.

5.1.6 The main valve shall be provided with a drain connection at the lowest point where liquid can collect unless other provisions for draining are provided.

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 any sealing elements, the pilot operated safety valve shall discharge its certified capacity at not over 1,1 times the maximum allowable pressure of the equipment to be protected.

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

5.1.10 In the case of reasonably foreseeable damage to connections between the various components the resulting flow areas shall be such that the pilot operated safety valve will discharge its certified capacity at not more than 1,1 times the maximum allowable pressure.

5.1.11 When the superimposed back pressure is higher than the inlet pressure, means shall be provided that the main valve shall not open.

5.1.12 The fitting of any additional device to a pilot and valve combination shall not prevent the pressurized system from being protected under any circumstances.

5.2 End connections

5.2.1 Types

The types of end connections for pilot operated safety valves 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 ASME B1.20.1.

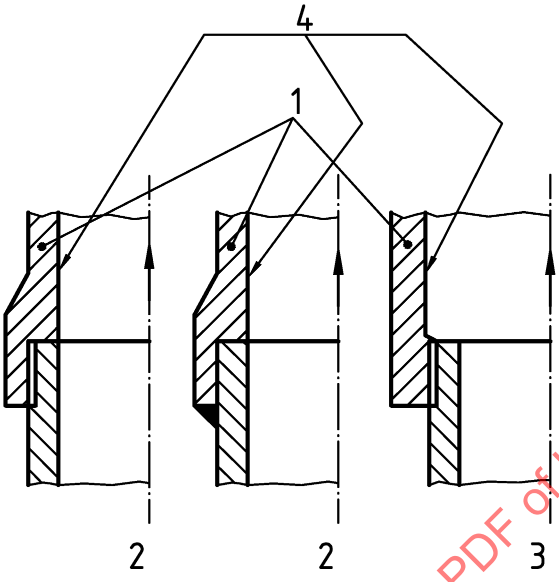
Other types of end connections are possible by agreement between the manufacturer and purchaser.

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 2a).

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 2b).

NOTE See clause 7 regarding type testing.



Key

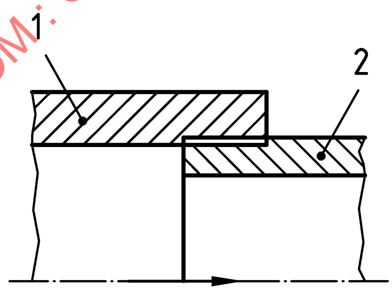
1 Valve

2 Satisfactory

3 Unsatisfactory

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

Figure 2 a) — Inlet



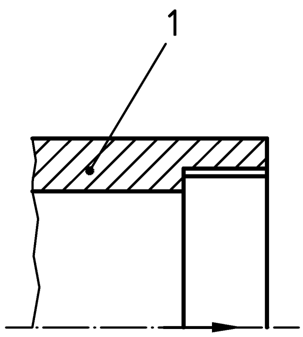
Key

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 7.1.4.

Figure 2 b) — Outlet



Key

1 Valve

With this construction at the valve outlet, no pipe is required during testing as specified in 7.1.4.

Figure 2 c) — Outlet

Figure 2 — 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 pilot operated 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

All temporary pipes, connections and blanking devices shall be adequate to 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 liquid penetrant techniques.

6.3 Hydrostatic testing

6.3.1 Application

The portion of the main 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 pilot operated 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. This pressure can be lower than that given by the outlet flange rating.

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 of suitable purity shall normally be used as the test medium. Where other testing media 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 pilot operated safety valve which is to be hydrostatically tested, then both the pilot operated 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 should be avoided but may be carried out in place of the standard body 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, duration of application and acceptance criteria 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 which 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.

Valves undergoing pneumatic test should not be approached for close inspection until after the pressure increase has been completed.

No valve undergoing pneumatic test shall be subject to any form of shock loading.

Precautions shall be taken against pressures generated in excess of test pressure.

6.5 Adjustment of set or cold differential test pressure

Each pilot operated safety valve shall be adjusted to its designated set or cold differential test pressure.

It is not permissible to adjust the set or cold differential test pressure of a pilot operated safety valve using air or other gas as the test medium unless the pressure retaining parts have previously been subjected to a test in accordance with 6.3 or 6.4.

It is permissible to establish the set or cold differential test pressure by adjustment of the pilot only. In cases such as these, it shall be shown that the opening sensing pressure of the pilot achieves the required set pressure of the main valve.

6.6 Seat leakage test

6.6.1 General

The seat leakage test of the pilot operated safety valve shall be carried out after the adjustment of the set or the cold differential test pressure. The test procedure and the leakage rate shall be agreed between the manufacturer and the purchaser. When it is not the case, the values in 6.6.3 and 6.6.4 shall be used.

6.6.2 Test procedure

The pilot and the main valve can be tested separately. Blank off the outlet/s and using air or nitrogen gas, reduce the inlet pressure by 10 % or 0,35 bar below the value of set or cold differential test pressure, whichever the greater. The leakage rate up to 70 bar set pressure shall not exceed the values in 6.6.3 and 6.6.4. At pressure above 70 bar the leakage rate shall increase in direct proportion to the increase of set or cold differential test pressure.

When the pilot discharge is connected into the main valve outlet, the leakage rate through both the pilot and the main valve can be added together, and its measurement carried out at the main valve outlet.

Bubble leak measurement shall be carried out using 6 mm internal diameter pipe inserted 13 mm into a volume of water.

6.6.3 Pilot leakage rate

The leakage rate shall not exceed:

— elastomeric seat version 0 bubbles/min ;

— metal seat version 20 bubbles/min.

6.6.4 Main valve leakage rate

The leakage rate shall not exceed:

— elastomeric seat version 5 bubbles/min ;

— metal seat version 20 bubbles/min.

6.7 Pressure seals

All pressure seals between valve, loading/unloading line and sensing line shall be leak tested. If appropriate, hold for 1 min at 10 % or 0,35 bar whichever is the greater below set pressure, using air or nitrogen. Leakage is not acceptable.

7 Type testing

7.1 General

7.1.1 Application

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

This subclause applies to the types of devices defined in 3.1. For other types see:

— Part 1 for other types of pilot operated safety valves where the pilot is itself a direct loaded safety valve ;

— Part 5 for controlled safety pressure relief systems (CSPRS).

7.1.2 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.

7.1.3 Objectives of tests

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

a) set pressure ;

b) overpressure ;

c) reseating pressure / blowdown;

d) reproducibility of valve performance;

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

- ability to reseat satisfactorily;
- absence or presence of chatter, flutter, sticking and/or harmful vibration;

f) lift at overpressure.

7.1.4 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 2 b), a pipe of appropriate thickness, at least five diameters long, shall be fitted during the test.

7.1.5 Results calculated from the tests

The theoretical flowing capacity is calculated in accordance with 8.3 or 8.4 and 8.5 as applicable, and, 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.

7.1.6 Design changes

When changes are made in the design of a pilot operated 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

Valves for air or other gas service shall be tested using air, other gas of known characteristics or superheated steam with a minimum of 10 °C of superheat. 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) if the pilot is to be adjusted separately from the valve, the pressure to which the pilot is adjusted may not be the same as the set pressure. The opening sensing pressure shall be specified by the manufacturer. It shall be demonstrated that the pilot is adjusted in such a way that the above tolerance on set pressure shall be maintained;

c) lift : not less than the value stated by the manufacturer;

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

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

— compressible fluids : minimum : 2,0 % (not applicable for the pilot operated safety valves with modulating action, according to 7.2.1 g)
maximum : 15 % or 0,3 bar, whichever is greater;

— incompressible fluids : minimum : 2,5 % (not applicable for the pilot operated safety valves with modulating action, according to 7.2.1 g)
maximum : 20 % or 0,6 bar, whichever is greater;

f) overpressure and blowdown of restricted lift pilot operated safety valves shall have the same tolerances or limits as the unrestricted lift valves;

g) overpressure and blowdown of pilot operated safety valves with modulating action shall be verified and be stable for various lifts between the minimum and maximum stated by the manufacturer. A curve shall be established for main valve lift versus overpressure.

7.2.2 Pilot operated safety valve opening characteristics

The manufacturer shall specify the type of pilot and the type of action of the valve.

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 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 (pilot and main valve in combination)

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

For main valve 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 pilot operated 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 of the pilot and main valve as a combination, shall be carried out using three significantly different pilot settings for each size of valve tested. Where three test pressures are required from one valve size, this may be achieved by testing either one valve with three different pilot settings or three valves of the same size at three significantly different pilot settings. 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 pilot operated valves of which one size only at various pressure ratings is being manufactured, tests shall be carried out using four different pilot settings which shall cover the range of pressures for which the valve is to be used.

For all tests, the pilot spring shall be used at the minimum pressure setting.

Where the size range cannot be adequately covered then scale models of the main valve shall be used. Reduced scale models shall have a minimum valve flow diameter of 50 mm.

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 mean effective diameter only need be to scale.

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

Before tests are carried out it shall be verified that the model complies with the above.

7.3 Tests to determine flow characteristics

7.3.1 Test requirements

After the operating characteristics 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. Pilot operated safety valves for use with liquids shall be tested with water or other liquid of known characteristics. Further, when discharged quantities are being assessed, the main valve disc shall be limited to the minimum lift as determined by the operating characteristics test at the chosen overpressure.

7.3.2 Valves used in the test programme

The main valve of the pilot operated 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

The testing procedure, test rig and equipment shall be approved before testing is undertaken.

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

The tests can be carried out with or without the pilot.

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 main 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 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 a curve shall be established, using a minimum of four points at all test pressures, for the coefficient of discharge versus valve lift.

7.3.3.4 Value of test pressure

Three tests shall be carried out on each main valve size at test pressures whereby the ratio of absolute back pressure to absolute relieving pressure is less than 0,25.

These tests shall be carried out with atmospheric back pressure.

For compressible fluids when the ratio of absolute back pressure versus absolute relieving pressure exceeds 0,25, the capacity of the main valve 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 of the coefficient of discharge K_d versus the ratio of absolute back pressure to absolute relieving pressure. This curve may be extended to cover the tests with pressure ratios less than 0,25.

The position of any external adjustment shall be the same as that for tests with atmospheric back pressure.

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 the coefficient of discharge versus the ratio of absolute back pressure to 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 main valves tested.

7.3.4 Adjustment during test

No adjustment to the main valve or pilot 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 which 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.

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 pilot operated safety valve shall be not greater than 90 % of the coefficient of discharge K_d determined by test:

$$K_{dr} = 0{,}9\, K_d$$

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 pilot operated safety valve performance

8.1 Determination of coefficient of discharge

The coefficient of discharge is calculated from the following:

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

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

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:

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

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

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

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 $3{,}948 = \frac{3\ 600}{\sqrt{10^5}\ \sqrt{R}}$

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

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

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

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

8.4 Discharge capacity for any gas at subcritical flow

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

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

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

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

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

9 Sizing of pilot operated 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 a 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

$$Q_m = 0{,}2883\, C\, A\, K_{dr} \sqrt{\frac{p_o}{v_o}}$$

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.

$$Q_m = \frac{0{,}2883\, C\, A\, K_{dr} \sqrt{\frac{p_o}{v_o}}}{\sqrt{x_o}}$$

9.3.3 Capacity calculations for gaseous media

9.3.3.1 Capacity calculations for gaseous media at critical flow

$$Q_m = p_o\, C\, A\, K_{dr} \sqrt{\frac{M}{Z\, T_o}} = 0{,}2883\, C\, A\, K_{dr} \sqrt{\frac{p_o}{v_o}}$$

$$A = \frac{Q_m}{p_o\, C\, K_{dr} \sqrt{\frac{M}{Z\, T_o}}} = \frac{Q_m}{0{,}2883\, C\, K_{dr} \sqrt{\frac{p_o}{v_o}}}$$

9.3.3.2 Capacity calculations for gaseous media at subcritical flow

$$Q_m = p_o\, C\, A\, K_{dr}\, K_b \sqrt{\frac{M}{Z\, T_o}} = 0{,}2883\, C\, A\, K_{dr}\, K_b \sqrt{\frac{p_o}{v_o}}$$

NOTE To determine K_b see equation in 8.4 and Table 3 in Part 7 of this standard.

9.3.4 Capacity calculations for liquids

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

10 Marking and sealing

10.1 Marking

10.1.1 Marking on the shell of the main valve

Marking on the shell of the main 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 main 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;

e) serial number.

10.1.2 Marking on the body of a pilot

Marking on the body of a pilot may be integral with the body or on a plate securely fixed on the body. The following minimum information shall be marked on the body of each pilot:

a) name and address or other means of identification of the manufacturer;

b) serial number;

c) material designation of the body of the pilot;

d) set pressure in bar gauge;

e) identification of the various ports directly on the body.

10.1.3 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 4126-4);

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.

10.2 Sealing of a pilot operated safety valve

All external adjustments shall be sealed. The pilot shall be sealed to the main valve.