
**Safety devices for protection against
excessive pressure —**

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

*Dispositifs de sécurité pour protection contre les pressions
excessives —*

*Partie 5: Dispositifs de sûreté à décharge contrôlés contre les
surpressions (DSDCS)*

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Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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

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

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

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

ISO 4126-5 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).

This first edition of ISO 4126-5, together with those of ISO 4126-2, ISO 4126-3, ISO 4126-4 and ISO 4126-6, cancels and replaces ISO 6718:1991, of which it constitutes a technical revision.

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

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, the CEN annex regarding fulfilment of European Council Directives has been removed.

It should be noted that, with regard to the corresponding EN standard, the designations given in Clause 10 have been adapted to the needs of international standardization.

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Foreword

This document (EN ISO 4126-5:2004) 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, 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 5. 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 the requirements for Controlled Safety Pressure Relief Systems irrespective of the fluid for which they are designed.

It is applicable for main valves having a flow diameter of 6 mm and above which are for use at 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.

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 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).*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety related systems.*

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

controlled safety pressure relief system (CSPRS)

system consisting of a main valve in combination with control units (see Figure 1a, 1b and 1c)

NOTE On reaching the set pressure the controlling forces on the main valve are by means of the control unit automatically applied, released or so reduced that a main valve discharges a specified quantity of the fluid so as to prevent the predetermined

pressure being exceeded. The system is so designed that the main valve re-closes and prevents a further flow of fluid after normal pressure conditions of service have been restored.

**3.1.1
main valve**

valve, including the body and actuator, which opens without the assistance of any energy other than that of the fluid to be relieved under the principle of 3.1.1.1 or 3.1.1.2 (see Figure 2)

**3.1.1.1
relieving principle**

principle in which a main valve opens when the controlling force is released or reduced, and in which the main valve closes when the controlling force is re-applied (see Figure 2 type 1)

**3.1.1.2
loading principle**

principle in which a main valve opens when the controlling force is applied, and in which the main valve closes when the controlling force is removed (see Figure 2 type 2)

**3.1.2
control unit**

unit which establishes the opening and closing of the main valve

NOTE The arrangement shall consist of at least two individual control systems in operation. The individual control system may consist of pressure tapping line, pressure sensor, sensing line, control module and control line (see Figures 1a, 1b and 1c).

**3.1.2.1
pressure tapping line**

line to the pressure sensor

**3.1.2.2
sensing line**

line between the pressure sensor and control module

**3.1.2.3
control line**

line between the control module and the main valve

**3.1.2.4
pressure sensor**

comparator in which a predetermined adjustable value of pressure is compared with the actual system pressure

NOTE On reaching the predetermined pressure a signal is transmitted to the control unit. The signal to the control unit is removed when the system pressure has been lowered to a predetermined pressure.

**3.1.2.5
control module**

module which transforms the signal from the pressure sensor into a force to operate the actuator of the main valve

**3.1.3
circuit principle of the control unit**

**3.1.3.1
closed circuit principle**

principle characterized by the fact that on failure of the external control energy the control unit effects the loading or relief of the main valve

**3.1.3.2
open circuit principle**

principle characterized by the fact that on failure of the external control energy the control unit does not change the loading or relief of the main valve

3.1.4**controlling force**

force which causes the main valve to operate and can be created by the fluid itself, mechanically e.g. springs or weight, hydraulically, pneumatically or electrically

3.2**pressure****3.2.1****set pressure of a CSPRS**

predetermined pressure at which a CSPRS under operating conditions commences to open

NOTE It is the gauge pressure measured at the main valve inlet at which the pressure forces tending to open the main valve for the specified service conditions are in equilibrium with the forces retaining the main 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 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 CSPRS.

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 the main valve is set to commence to open on the test bench

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

3.2.6**relieving pressure**

pressure used for the sizing of a CSPRS 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 the main valve caused by flow through the valve and the discharge system

3.2.8**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.

3.2.9**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

3.2.10**opening sensing pressure**

predetermined pressure which activates the pressure sensor

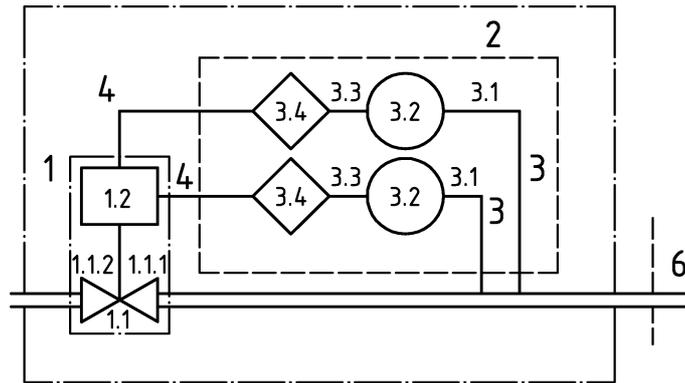


Figure 1 a) — Two control lines, relieving principle

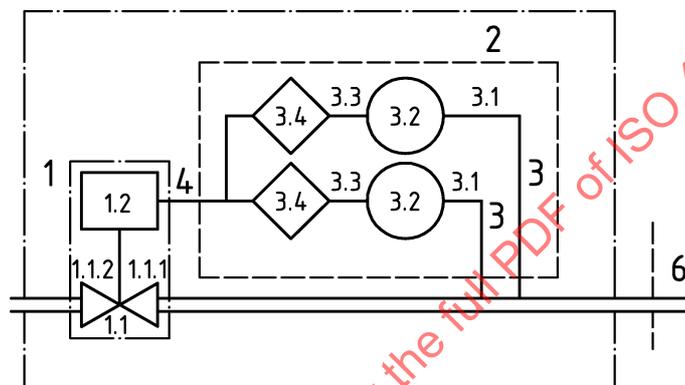


Figure 1 b) — One control line, relieving principle

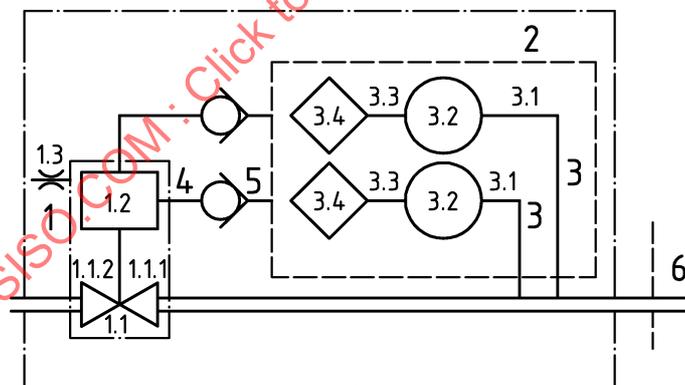


Figure 1 c) — Two control lines, loading principle

Key

- | | | | |
|-------|---------------------------|-----|-----------------------|
| 1 | Main valve | 3.1 | Pressure tapping line |
| 1.1 | Body | 3.2 | Pressure sensor |
| 1.1.1 | Inlet port | 3.3 | Sensing line |
| 1.1.2 | Outlet port | 3.4 | Control module |
| 1.2 | Actuator | 4 | Control line |
| 1.3 | Vent | 5 | Check valve |
| 2 | Control unit | 6 | Protected system |
| 3 | Individual control system | | |

Figure 1 — Typical examples of redundant individual control systems

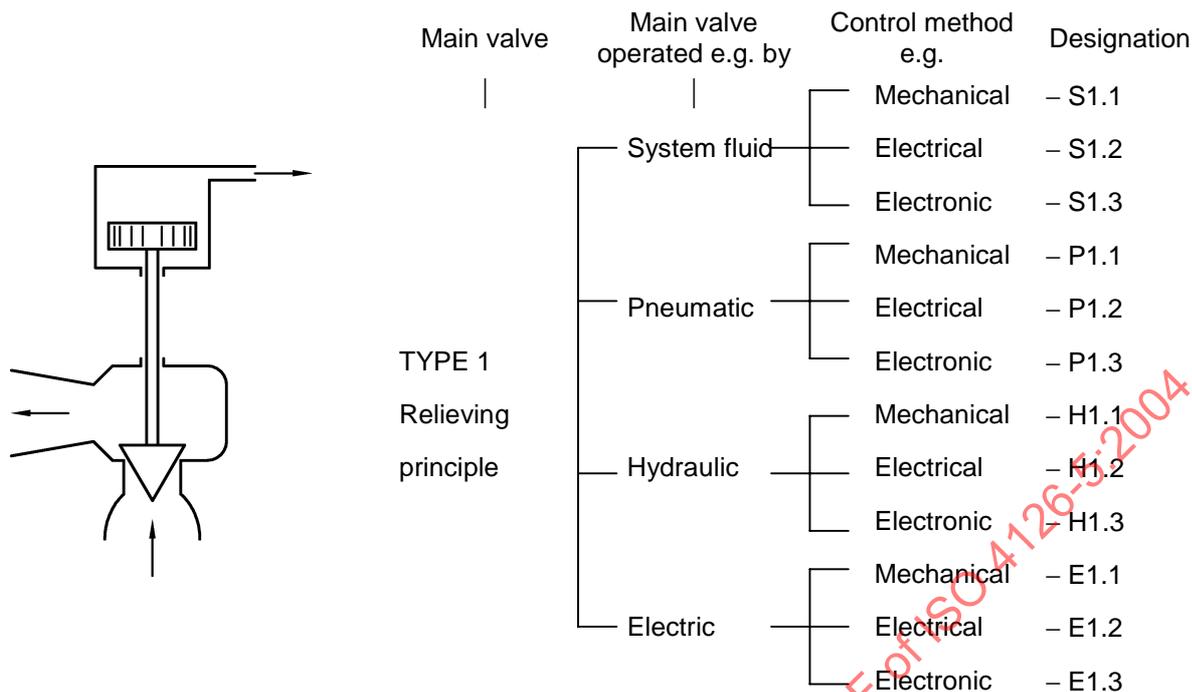


Figure 2 a) — Type 1 : Relieving principle

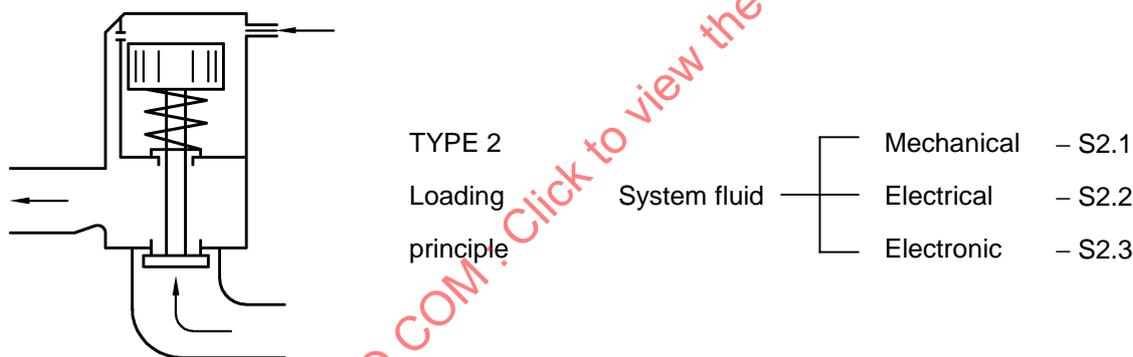


Figure 2 b) — Type 2 : Loading principle

Figure 2 — Operating principle of the main valve

3.2.11

closing sensing pressure

predetermined pressure which deactivates the pressure sensor

3.3

lift

actual travel of the main 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 the main 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 the CSPRS

NOTE It may, for example, equal :

- a) the measured capacity times the derating factor ; or
- b) the theoretical capacity times the coefficient of discharge times the derating factor ; or
- c) the theoretical capacity times the certified derated coefficient of discharge.

3.7

DN (nominal size)

see EN ISO 6708

3.8

functional times

3.8.1

opening time

time interval for the main valve to move from the closed to the fully open position

3.8.2

reseating time

time interval for the main valve to move from the fully open to the closed position

3.8.3

opening dead time

time interval from the detection of the opening sensing pressure and the commencement of the opening of the main valve

3.8.4

reseating dead time

time interval from the detection of the closing sensing pressure and the commencement of the closing of the main valve

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·mm ²)
q'_m	Specific discharge capacity determined by tests	kg/(h·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	–
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 any valve in the system other than where it is an integral part of the valve shell shall be fastened securely to prevent the seat becoming loose in service.

5.1.3 All external adjustments shall be locked and/or sealed in such a manner so as to prevent or reveal unauthorised adjustments of the CSPRS.

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 manufacturer.

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

5.1.5 Any CSPRS for toxic or flammable fluids shall be so designed to prevent leakage to atmosphere or if vented it shall be disposed of to a safe place.

5.1.6 The main valve shall be provided with a drain connection at the lowest point where liquid could 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 The material of guiding surfaces shall be corrosion resistant and shall be selected to minimize the possibility of galling or seizure.

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 main valve inlet is at least equal to that of the valve inlet connection (see Figure 3a).

The internal area of the external pipe connection at the main valve outlet shall be at least equal to that of the valve outlet except those valves with female threaded outlet connections (according to Figure 3b).

NOTE See clause 7 regarding type testing.

5.3 Minimum requirements for springs

Springs for the main valve if applicable shall be in accordance with Part 7 of this standard.

5.4 Materials

5.4.1 All materials shall be compatible with the system fluid, the adjoining components and the environment in which the CSPRS is to be used. Temperature variations shall be considered.

5.4.2 Materials for pressure-retaining shells shall be in accordance with Part 7 of this standard.

5.5 Requirements and procedures

5.5.1 Each individual control system shall be so designed that the relevant main valve will operate reliably in case of failure of the other individual control systems. IEC 61508 if applicable shall be taken into consideration. At least three control systems each independent of each other shall be in operation. At least two control systems shall be in accordance with the closed circuit principle.

5.5.2 For test purposes it shall be possible to operate the main valve by overriding the control unit.

5.5.3 It is permissible to operate more than one main valve from a single control unit subject to its application. Redundancy of individual control systems shall be in accordance with this standard. If one control system has to be made inactive for performance testing during operation, three control systems shall be provided.

For main valves and valves used as control module where the system pressure or control medium acts on the valve disc in the direction of closing, the opening force shall be rated such that the valve opens completely with twice the system pressure.

5.5.3.1 When operating the main valve other than by electrical means, there shall be two control lines. These lines shall not be installed in near proximity to each other in order to avoid simultaneous damage. The only exception is as described in 5.5.3.2.

5.5.3.2 With a CSPRS operating under the relieving principle and with filtered control fluid, which is not the system fluid, it is permissible to use only one control line (see Figure 1b) providing that:

- a) the pipe is at least 15 mm bore to avoid the risk of blockage;
- b) the pipe is of sufficient thickness to ensure that if it is crushed the remaining flow area is at least 20 % of the original flow area ;
- c) this area of 20 % of the original is sufficient to ensure that the specified maximum opening time of the main valve shall not be exceeded ;
- d) the opening time shall be determined by test.

5.5.3.3 When operating the main valve under the loading principle each control line shall be fitted with a check valve close to the actuator (see Figure 1c).

5.5.4 It shall be possible to test at any time the functionality of all the control systems of a CSPRS to verify the performance of the main valve and the functionality of the individual control system.

If tests under operating conditions are required a locking system is necessary which ensures that according to 3.1.2 at least two individual control systems stay in operation.

5.5.5 Only non-corrosive fluids shall be used in the control unit. In the event that the system fluid is not clean or is corrosive then a suitable "barrier" (e.g. syphon, diaphragm) shall be provided to ensure that the control unit can function reliably. The formation of condensate in any gaseous fluid or vapour shall not be allowed if it affects the functionality of the control unit.

6 Production testing

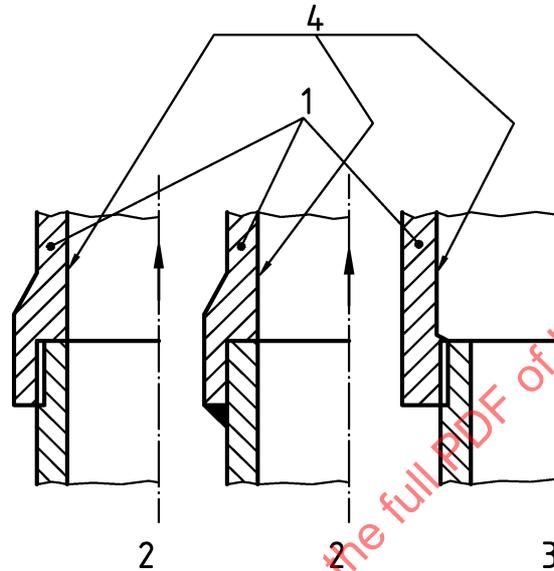
6.1 Purpose

The purpose of these tests is to ensure that each and every CSPRS meets the requirement for which it has been designed without exhibiting any form of leakage of pressure retaining components or joints.

6.2 General

It is permissible to test the main valve independently from the control unit. All temporary pipes and connections and blanking devices shall be adequate to withstand the test pressure.

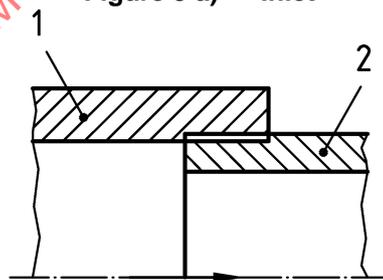
Any temporary welded-on attachments shall be carefully removed and the resulting weld scars shall be ground flush with the parent material. After grinding, all such scars shall be inspected by e.g. magnetic particle or fluid penetrant techniques.



Key

- 1 Main valve
- 2 Satisfactory
- 3 Unsatisfactory
- 4 Required internal diameter of the main valve for the CSPRS to function properly

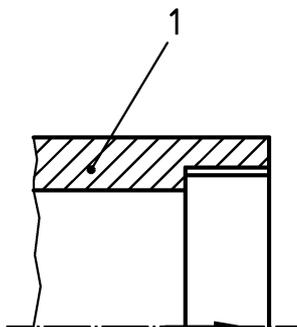
Figure 3 a) — Inlet



Key

- 1 Main valve
 - 2 The nominal diameter of the pipe to be equal to the nominal diameter of the main valve outlet
- With this construction at the main valve outlet, a suitable pipe shall be fitted during testing as specified in 6.1.4

Figure 3 b) — Outlet



Key

1 Main valve

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

Figure 3 c) — Outlet

Figure 3 — Design of end connections

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 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 test on the discharge side of the seat, the testing time shall be based on the pressure specified in 6.3.1 and 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 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 valve which is to be hydrostatically tested, then both the 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 CSPRS to the cold differential test pressure using air or other gas as the test medium, it shall previously be subjected to a standard hydrostatic test (see 6.3).

6.6 Seat leakage test

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

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 Introduction

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

7.1.2 Application

This clause applies to the types of safety devices defined in 3.1.

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 main 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 particular characteristics of the CSPRS. The following characteristics are examples, there may be others:

- a) set pressure ;
- b) overpressure ;
- c) functional times ;
- d) relieving pressure ;
- e) reseating pressure ;
- f) blowdown ;
- g) reproducibility of CSPRS performance ;
- h) mechanical characteristics of the CSPRS such as :
 - ability to reseat satisfactorily ;
 - absence or presence of chatter, flutter, sticking and/or vibration.
- i) 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 3b a pipe, of appropriate thickness, at least five diameters long shall be fitted during the test.

7.1.6 Results calculated from 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 main valve is calculated in accordance with 8.1.

7.1.7 Design changes

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

7.2 Tests to determine operating characteristics

7.2.1 General requirements

7.2.1.1 Test fluid(s)

CSPRS for air or other gas service shall be tested using superheated steam, air or gas of known characteristics. CSPRS for any steam service shall be tested on steam, air or other gas of known characteristics. CSPRS for liquid service shall be tested on water or other liquid of known characteristics.

7.2.1.2 Overpressure

The overpressure is the value stated by the manufacturer but not exceeding 10 % of set pressure or 0,1 bar, whichever is greater.

7.2.1.3 Lift

The lift of the main valve shall not be lower than the value as stated by the manufacturer.

7.2.1.4 Limits to initiate closing

The closing sensing pressure shall be not less than 93 % of set pressure.

All actual values shall be certified.

7.2.2 Carrying out of tests

7.2.2.1 CSPRS used in the test programme

The CSPRS tested shall be representative of the design, pressure, and main valve size range for which operating characteristics are determined within the capability of the test laboratory. The ratio of main valve inlet area to flow area and the ratio of flow area to main valve outlet area 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 main valves tested previously are no longer representative of the range, further tests on the appropriate number of sizes shall be carried out.

The same control unit may be used for a number of main valve tests.

7.2.2.2 Set pressure

The set pressures at which the operating characteristics are determined shall be within the range of set pressures for which the CSPRS is designed and within the capability of the test laboratory.

The tests shall be carried out using three significantly different set pressures for each size of the main valve. 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 a main valve or a control unit of either novel or special design, of which one size only at one pressure rating is being manufactured, tests at a single set pressure are permitted by agreement.

In the case of a main valve or control unit of which one size only at various pressure ratings is being manufactured, tests shall be carried out using four different set pressures, which shall cover the range of pressure for which the CSPRS shall be used.

The precise range may be decided by the capability of the test laboratory.

The allowable tolerance on set pressure is $\pm 3\%$ of set pressure or $\pm 0,15$ bar whichever is greater.

7.2.2.3 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.

7.3 Tests to determine flow characteristics

7.3.1 General requirements

7.3.1.1 Test fluid

After the operational characteristics have been satisfactorily established, it is acceptable to use steam, air or gas of known characteristics as the fluid for flow characteristics tests except for CSPRS designed for liquid service. CSPRS 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 mechanically held at the lift as determined by the operating characteristic test.

7.3.1.2 Flow test equipment

The test equipment shall be designed and operated such that the actual test flowing capacity measurement shall be accurate to be within $\pm 2\%$.

7.3.1.3 Flowing testing acceptance tolerance

In all the methods described for flow characteristic testing, all final results shall be within $\pm 5\%$ of the arithmetic average, or additional testing shall be required until this criterion is met.

7.3.1.4 Adjustments during test

No adjustments to the CSPRS shall be made during the test. 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.

7.3.1.5 Coefficient of discharge

The coefficient of discharge is determined in accordance with clause 8.

7.3.1.6 Flowing capacity for main valve

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

7.3.1.7 Flowing capacity for control unit

The discharge capacity (if any) through a control unit shall not be taken into account unless it represents more than 25% of the total flow.

7.3.2 Carrying out of test

7.3.2.1 CSPRS used in the test programme

The CSPRS shall be the same as or identical to those used during the tests for operational characteristics.

The lift shall be the same as found during the operational testing.

7.3.2.2 Set pressures and main valve sizes

The flow characteristic test for determination of the coefficient of discharge 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, then the number of sizes tested may be reduced to two.

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

In all cases of a single main valve design tests shall be carried out at four different pressures.

For compressible fluids when the ratio of absolute back pressure versus 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.

For incompressible fluids the coefficient of discharge does not depend on the ratio of absolute back pressure to absolute relieving pressure.

7.3.2.3 Reduced scale models

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 which 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 test are carried out it shall be verified that the model complies with the above.

7.3.2.4 Correlation of lift to coefficient of discharge

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

In the case of restricted lift a curve shall be established for the tests for the coefficient of discharge versus valve lift.

7.3.2.5 Methods of testing

For the case of CSPRS 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 CSPRS will be determined by the limits of the test laboratory.

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

Three geometrically similar models of different sizes of the main valve may be used to determine the coefficient of discharge. The proper function of at least one main valve of the design to be certified shall be demonstrated by test.

7.4 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 test. Copies of all test records shall be furnished to each of the parties concerned with the test. Corrections and corrected values shall be entered separately in the test record.

7.5 Determination of the coefficient of discharge

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

7.6 Certification of coefficient of discharge

The certified derated coefficient of discharge K_{dr} of the main 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.

7.7 Certification of CSPRS

When the main valve and the control unit, whether manufactured by the same company or not, are combined the system shall meet the requirements of 7.1.3 and the CSPRS shall be certified in accordance with the derated coefficient of discharge of the main valve.

8 Determination of CSPRS performance

8.1 Determination of coefficient of discharge

The coefficient of discharge K_d is calculated from the following.

$$K_d = \frac{\sum_1^n \left(\frac{q'_m}{q_m} \right)}{n}$$

8.2 Critical and subcritical flow

Critical flow occurs when :

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

and subcritical flow occurs when :

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

8.3 Discharge capacity at critical flow

8.3.1 Discharge capacity for steam

$$q_m = 0,2883 C \sqrt{\frac{p_o}{v}}$$

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

The value of k used to determine C shall be based on the actual flowing conditions at the main 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

$$q_m = p_o C \sqrt{\frac{M}{ZT_o}} = 0,2883 C \sqrt{\frac{p_o}{v}}$$

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

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

8.4 Discharge capacity for any gas at subcritical flow

$$q_m = p_o C K_b \sqrt{\frac{M}{ZT_o}} = 0,2883 C K_b \sqrt{\frac{p_o}{v}}$$

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

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

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

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

9 Sizing of main 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 7.6).

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

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

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.

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

9.3.3 Capacity calculations for gaseous media

9.3.3.1 Capacity calculations for gaseous media at critical flow

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

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

9.3.3.2 Capacity calculations for gaseous media at subcritical flow

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

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

9.3.4 Capacity calculations for liquids

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

10 Marking and sealing

10.1 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:

- size designation (inlet), for example DN xxx ;
- material designation of the shell ;
- manufacturer's name or trade-mark ;
- 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

10.2.1 Main valve

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

- set pressure, in bar gauge ;