
**Gas pressure safety and control
devices for use in gas transmission,
distribution and installations for
inlet pressures up to and including 10
MPa —**

**Part 2:
Gas pressure regulator**

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Published in Switzerland

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Foreword

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

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

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

This document was prepared by Technical Committee ISO/TC 161, *Controls and protective devices for gas and/or oil*.

A list of all parts in the ISO 23555 series can be found on the ISO website.

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

Introduction

This document is designed to be used in combination with ISO 23555-1. This document together with ISO 23555-1 establishes the complete standard as it applies to the specific control covered by the ISO 23555 series.

Where needed, this document adapts ISO 23555-1 by stating in the corresponding clause:

- “with the following modification”;
- “with the following addition”;
- “is replaced by the following”; or
- “is not applicable”.

In order to identify specific requirements that are particular to this document but not already covered by ISO 23555-1, this document can contain clauses or subclauses that are additional to the structure of ISO 23555-1. These subclauses are indicated by the introductory sentence: “Subclause (or Annex) specific to this document.”.

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Gas pressure safety and control devices for use in gas transmission, distribution and installations for inlet pressures up to and including 10 MPa —

Part 2: Gas pressure regulator

1 Scope

This document specifies safety, constructional, performance, testing and documentation requirements for gas pressure regulators for use in gas transmission and distribution installations (hereafter referred to as regulators).

This document is applicable to regulators with operating pressures greater than 500 kPa and up to and including 10 MPa (100 bar) and nominal diameters up to DN 400 for use with fuel gases as natural gas, manufactured gas, biomethane or liquefied petroleum gas (LPG).

This document is applicable to:

- test methods which are intended for product type test, routine tests and product surveillance tests;
- regulators which use the pipeline gas as a source of control energy unassisted by any external power source;
- regulators integrating on the same body a second regulator, used as monitor, complying with the requirements in this document;
- regulators integrating a safety shut off device (SSD) according to ISO 23555-3;
- regulators incorporating a creep (venting) relief device and/or a vent limiter complying with the requirements in this document.

This document does not apply to:

- regulators upstream from/on/in domestic gas-consuming appliances which are installed downstream of domestic gas meters;
- regulators designed to be incorporated into pressure control systems used in service lines (pipework from the main pipework in a gas infrastructure to the point of delivery of the gas) with declared volumetric flow rate $\leq 200 \text{ m}^3/\text{h}$ at normal conditions and declared inlet pressure $\leq 500 \text{ kPa}$ (5 bar);
- industrial process control valves, such as IEC 60534 (all parts);
- regulators used in aggressive/sour gas environments (gas environments containing water and H_2S are considered sour) or severely corrosive conditions;
- regulators in service conditions with renewables (e.g. H_2NG with hydrogen more than 10 %) and/or waste gases (e.g. biogas etc.), if additional information is not provided (e. g. contaminant, liquid, etc.).

2 Normative references

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

ISO 23555-1:2022, *Gas pressure safety and control devices for use in gas transmission, distribution and installations for inlet pressures up to and including 10 MPa — Part 1: General requirements*

IEC 60534-1:2005, *Industrial-process control valves — Part 1: Control valve terminology and general considerations*

IEC 60534-2-3, *Industrial-process control valves — Part 2-3: Flow capacity — Test procedures*

IEC 60534-4, *Industrial-process control valves — Part 4: Inspection and routine testing*

3 Terms and definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 23555-1 and the following apply.

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

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

3.1.1 General terms

3.1.1.1

gas pressure regulator

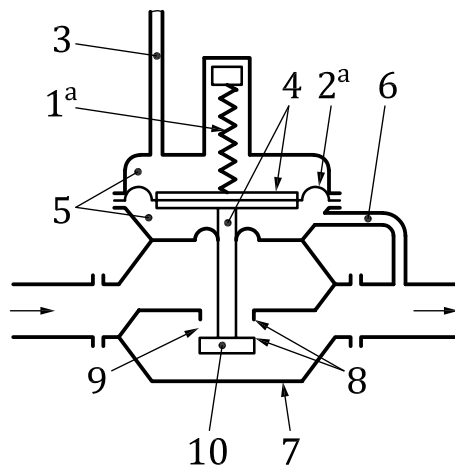
device whose function is to maintain the value of the *controlled variable* (3.1.3.1) within its tolerance field irrespective of disturbance variables

3.1.1.2

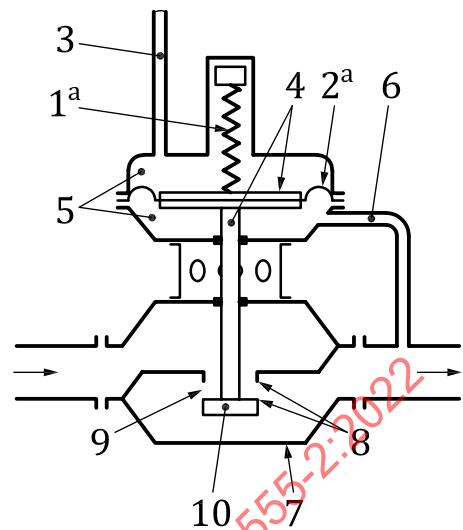
direct acting gas pressure regulator

regulator in which the net force required to move the control member is supplied directly by the controlled variable

Note 1 to entry: See example in [Figure 1](#).



a) Direct acting regulator - type integral strength



b) Direct acting regulator - type differential strength

Key

1 + 2 = Controller

1 setting element

2 pressure detecting element

3 breather/exhaust line

4 actuator

5 casing of actuator

6 sensing line

7 regulator body

8 valve seats

9 seat ring

10 control member

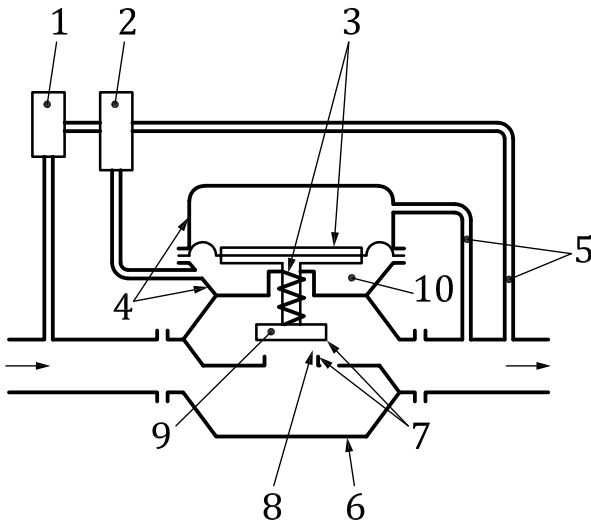
Figure 1 — Examples of a direct acting regulator

3.1.1.3

pilot-controlled gas pressure regulator

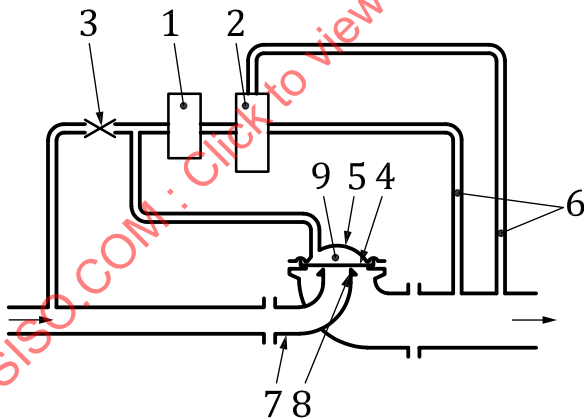
regulator in which the net force required to move the control member is supplied by a pilot

Note 1 to entry: See example in [Figures 2](#) and [3](#).



- Key**
- | | | | |
|---|----------------------|----|----------------------|
| 1 | auxiliary device | 6 | regulator body |
| 2 | pilot | 7 | valve seats |
| 3 | actuator | 8 | seat ring |
| 4 | casing of actuator | 9 | control member |
| 5 | sensing/process line | 10 | motorization chamber |

Figure 2 — Example of a pilot-controlled regulator



- Key**
- | | | | |
|---|--------------------------|---|-----------------------|
| 1 | auxiliary device | 6 | sensing/process lines |
| 2 | pilot | 7 | regulator body |
| 3 | throttle | 8 | valve seat |
| 4 | control member | 9 | motorization chamber |
| 5 | casing of control member | | |

Figure 3 — Example of a pilot-controlled regulator with a diaphragm as control member

**3.1.1.4
monitor**

second regulator installed in series with an active regulator, normally upstream, which has the task of maintaining the controlled variable within allowable limits in the event of its value exceeds pre-established values (e.g. in the event of opening of the active regulator due to a failure, etc.)

3.1.1.5**fail close regulator**

regulator whose control member automatically tends to close or close when failures occur

Note 1 to entry: This definition is based on typical control failure modes.

3.1.1.6**fail open regulator**

regulator whose control member automatically tends to open or open when failures occur

Note 1 to entry: This definition is based on typical control failure modes.

3.1.1.7**regulator size**

nominal size DN of the inlet connection

Note 1 to entry: The preferred DN values are specified in ISO 6708.

3.1.1.8**series of regulators**

regulators with the same design concept but differing only in size

3.1.2 Terms related to flow**3.1.2.1****flow coefficient in critical conditions****C_g**

characteristic value for the flow capacity of regulator in critical conditions

Note 1 to entry: Flow coefficient C_g is a non-SI regulator coefficient.

Note 2 to entry: Numerically, C_g is represented as the number of normal cubic feet per hour of air flowing through a regulator in critical conditions with inlet absolute pressure 1 psia and with a reference inlet temperature $t_{ur} = 15\text{ }^{\circ}\text{C}$ ¹⁾. The numerical value in SI units is equal to the number of m³/h of air flowing through a regulator in critical conditions with inlet absolute pressure 243 kPa (2,43 bar) and inlet temperature of 15 °C.

Note 3 to entry: IEC 60534-2-1:2011, Clause 7 and Appendix B deals with this flow coefficient.

3.1.2.2**flow coefficient in normal conditions****K_G**

characteristic value for the flow capacity of a regulator in normal conditions

Note 1 to entry: The flow coefficient is equal to the volumetric flow rate at normal conditions through the regulator under the following reference conditions:

- reference natural gas at normal conditions with the relative density $d_r = 0,64$ (density $\rho_r = 0,827\text{ 5 kg/m}^3$);
- fully opened control member (mechanical stop);
- reference inlet temperature of $t_{ur} = 15\text{ }^{\circ}\text{C}$;
- reference absolute gas inlet pressure $p_{ur} = 200\text{ kPa}$ (2 bar);
- reference absolute gas outlet pressure $p_{dr} = 100\text{ kPa}$ (1 bar).

Note 2 to entry: The K_G value is specified in (m³/h)/bar.

1) The definition of this flow coefficient is based on IEC 60534-1.

3.1.3 Terms related to variables in the controlling process

3.1.3.1

controlled variable

variable which is monitored by the controlling process

Note 1 to entry: In this document, only the outlet pressure, p_d , is considered as the controlled variable.

3.1.3.2

disturbance variable

variable acting from outside on the controlling process

Note 1 to entry: In the case of regulators with outlet pressure as the controlled variable, the disturbance variables are essentially:

- changes in the inlet pressure;
- changes in the volumetric flow rate.

3.1.3.3

reference inlet temperature

t_{ur}
temperature at the inlet of control in the assessment of its functional performance

Note 1 to entry: This document considers as reference temperature 15 °C.

Note 2 to entry: The use of reference inlet temperature is necessary to obtain homogeneous set of test results when comparing the functional performances of different type of control.

3.1.4 Terms related to the controlled process

3.1.4.1

set point

p_{ds}
nominal value of the controlled variable under specified conditions

Note 1 to entry: The set point is not directly measurable but determined as shown in [Figure 6](#).

3.1.4.2

set range

W_d
whole range of set points which can be obtained from a regulator by adjustment and/or the replacement of some components (i.e. replacement of the valve seat or setting element, e.g. spring)

3.1.4.3

specific set range

W_{ds}
whole range of set points which can be obtained from a regulator by adjustment and with no replacement of its components

3.1.4.4

regulation change

difference between the actual value of the controlled variable and the set point expressed as a percentage of the set point

3.1.5 Terms related to functional performance

3.1.5.1

stable

condition where the controlled variable settles to a stable value after a disturbance has occurred

3.1.5.2
performance curve

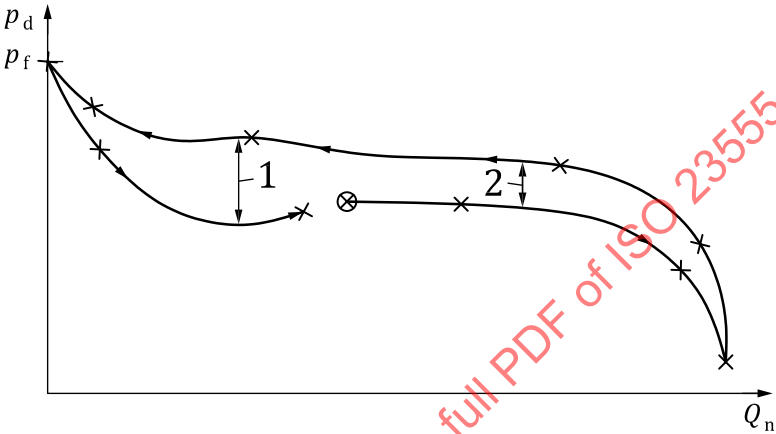
graphic representation of the controlled variable as a function of the volumetric flow rate

Note 1 to entry: This curve is determined by increasing and then decreasing the volumetric flow rate with constant inlet pressure and set point (see [Figure 4](#)).

3.1.5.3
hysteresis band

difference between the two values of outlet pressure for a given volumetric flow rate

Note 1 to entry: See [Figure 4](#).



Key

- ⊗ start setting
- × measured values

- 1 max hysteresis band
- 2 hysteresis band

Figure 4 — Performance curve (p_{ds} constant, p_u constant)

3.1.5.4
family

<of performance curves> set of the performance curves for each value of inlet pressure determined for a given set point

Note 1 to entry: See [Figure 5](#).

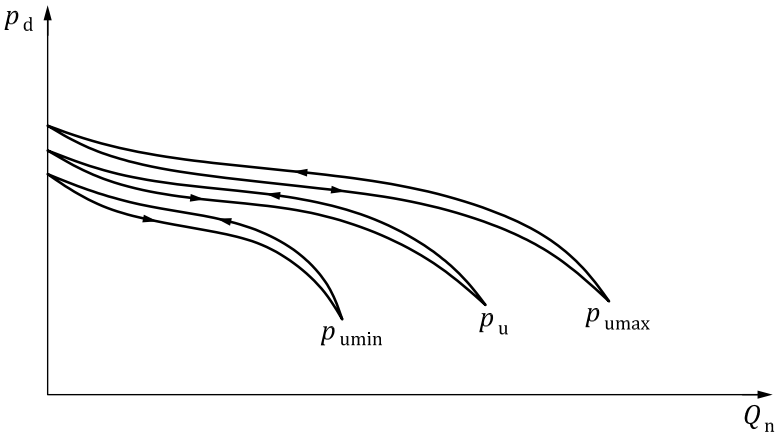


Figure 5 — Family of performance curves (p_{ds} constant)

3.1.6 Feature related to accuracy

3.1.6.1

accuracy

maximum absolute value of regulation change under specified operating range

3.1.6.2

accuracy class

AC

maximum permissible value of the accuracy under specified operating range

3.1.6.3

inlet pressure range

b_{pu}

range of the inlet pressure for which the regulator ensures a given accuracy class

Note 1 to entry: The inlet pressure range is characterized by its limit values $p_{u\max}$ and $p_{u\min}$.

3.1.6.4

maximum accuracy flow rate

lowest value of the maximum volumetric flow rate up to which, for a given set point and within the ambient temperature range specified, a given accuracy class is ensured:

- at the lowest inlet pressure (see Figure 6) $Q_{n,\max,p_{u\min}}$
- at the highest inlet pressure (see Figure 6) $Q_{n,\max,p_{u\max}}$
- at an intermediate inlet pressure between $p_{u\max}$ and $p_{u\min}$ (see Figure 6) $Q_{n,\max,p_u}$

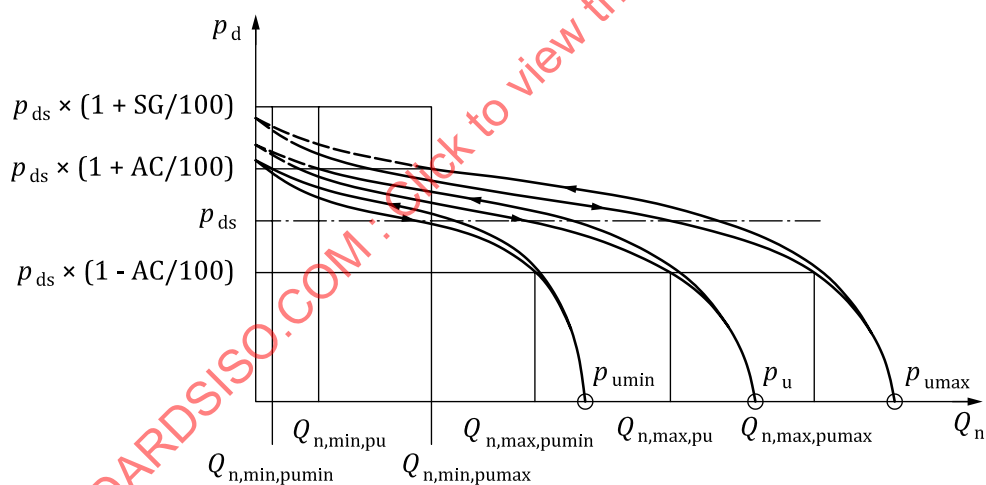


Figure 6 — Family of performance curves indicating maximum accuracy flow rates and minimum flow rates (p_{ds} constant, stable conditions)

3.1.7 Terms related to lock-up behaviour

3.1.7.1

lock-up time

t_f

time taken for the control member to move from an open position to the closed position

3.1.7.2**lock-up pressure** **p_f**

pressure that occurs at the measuring point of the controlled variable when the control member is in the closed position

Note 1 to entry: The lock-up pressure corresponds to the outlet pressure at the volumetric flow rate $Q = 0$ in the performance curve (see [Figure 4](#)). It results when the time taken for a change in volumetric flow rate from Q to zero is greater than the lock-up time of the regulator.

3.1.7.3**lock-up pressure class****SG**

maximum permissible positive difference between the actual lock-up pressure and the set point expressed as a percentage of the set point [see [Formula \(1\)](#)]:

$$SG = \frac{p_f - p_{ds}}{p_{ds}} \cdot 100 \quad (1)$$

Note 1 to entry: For better understanding of $(p_f - p_{ds})_{\max}$, see [Figure 6](#).

3.1.7.4**minimum flow rate**

largest value of the minimum volumetric flow rate down to which, for a given set point and within the ambient temperature range specified, stable conditions are obtained:

- at the lowest inlet pressure (see [Figure 6](#)) $Q_{nmin,pu_{min}}$;
- at the highest inlet pressure (see [Figure 6](#)) $Q_{nmin,pu_{max}}$;
- at an intermediate inlet pressure between $p_{u_{max}}$ and $p_{u_{min}}$ (see [Figure 6](#)) $Q_{nmin,pu}$.

Note 1 to entry: Stable conditions are given in [7.2.8.3](#).

3.1.7.5**lock-up pressure zone**

zone between the volumetric flow rate $Q_n = 0$ and the minimum flow rate $Q_{nmin,pu}$ for each corresponding inlet pressure and set point (see [Figure 7](#))

3.1.7.6**class of lock-up pressure zone****SZ**

maximum permissible lock-up pressure zone for specified:

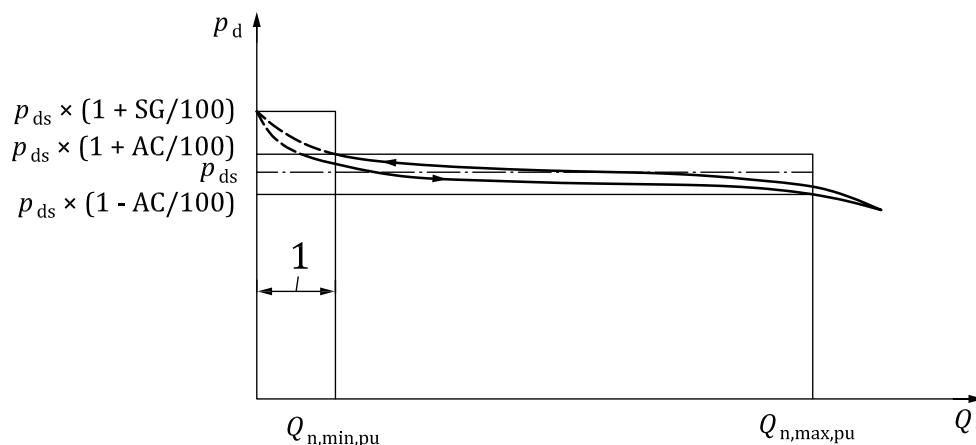
- inlet pressure p_u ;
- set point p_{ds} ;

which is expressed as the percentage of $Q_{nmin,pu}$ to $Q_{nmax,pu}$ [see [Formula \(2\)](#)]:

$$SZ = \frac{Q_{nmin,pu}}{Q_{nmax,pu}} \cdot 100 \quad (2)$$

3.1.7.7**computational fluid dynamics****CFD**

set of numerical methods and algorithms to solve and analyse problems that involve fluid flows

**Key**

1 lock-up pressure zone SZ

Figure 7 — Performance curve indicating lock-up pressure zone (stable condition)**3.1.8 Terms related to design and tests****3.1.8.1****closing force** F_S

force acting on control member of the monitor in full open position in normal operating conditions to bring it to its control position after activation of the monitor itself

3.1.9 Summary of symbols for creep relief valves**3.1.9.1****opening pressure** p_{do}

pressure at which the first internal leak occurs

3.1.9.2**closing pressure** p_{df}

falling pressure at which the relief valve is pressure tight after re-seating

3.2 Symbols

Shall be according to ISO 23555-1:2022, 3.2 with the following addition:

The following prospect summarizes the symbols and relevant descriptions and unit considered in this chapter and/or used in this document. The symbols are listed in alphabetic order.

Symbol	Term	Subclause	Unit
AC	Accuracy class	3.1.6.2	%
b_{pu}	Inlet pressure range	3.1.6.3	kPA
C_g	Flow coefficient in critical conditions	3.1.2.1	See definition
F_S	Closing force	3.1.8.1	N
KG	Flow coefficient in normal conditions	3.1.2.2	See definition
p_{df}	Closing pressure	3.1.9.2	kPA
p_{do}	Opening pressure	3.1.9.1	kPA

Symbol	Term	Subclause	Unit
p_{dr}	Reference absolute outlet pressure	3.1.2.2	kPA abs
p_{ds}	Set point	3.1.4.1	kPA
p_f	Lock-up pressure	3.1.7.2	kPA
p_{ur}	Reference absolute inlet pressure	3.1.2.2	kPA abs
$Q_{nmin,pu}$	Minimum flow rate at inlet pressure p_u	3.1.7.4	m ³ /h at normal conditions
$Q_{nmin,pumax}$	Minimum flow rate at inlet pressure p_{umax}		m ³ /h at normal conditions
$Q_{nmin,pumin}$	Minimum flow rate at inlet pressure p_{umin}		m ³ /h at normal conditions
SG	Lock-up pressure class	3.1.7.3	%
SZ	Class of lock-up pressure zone	3.1.7.6	%
t_f	Lock-up time	3.1.7.1	s
t_{ur}	Reference inlet temperature for KG	3.1.2.1	°C
W_d	Set range	3.1.4.2	kPA
W_{ds}	Specific set range	3.1.4.3	kPA

4 Classification

4.1 General

Shall be according to ISO 23555-1:2022, 4.1 with the following addition.

— Fail condition.

4.2 Temperature classes

Shall be according to ISO 23555-1:2022, 4.2.

4.3 Strength types

Shall be according to ISO 23555-1:2022, 4.2.

4.4 Fail conditions

Subclause specific to this document.

This document considers the following fail conditions.

- Fail close condition: the control member shall tend to close or close.
- Fail open conditions: the control member shall tend to open or open.

5 Materials

Shall be according to ISO 23555-1:2022, Clause 5.

6 Design

6.1 General

Shall be according to ISO 23555-1:2022, 6.1.

6.2 Strength of metallic body and its inner metallic partition walls

Shall be according to ISO 23555-1:2022, 6.2.

6.3 Other pressure metallic containing parts of integral and differential strength controls

Shall be according to ISO 23555-1:2022, 6.3.

6.4 Strength of parts transmitting actuating forces

Shall be according to ISO 23555-1:2022, 6.4.

6.5 Strength of diaphragms (elastomeric parts)

Shall be according to ISO 23555-1:2022, 6.5.

6.6 Welding

Shall be according to ISO 23555-1:2022, 6.6.

6.7 Main function of a regulator

6.7.1 General

Subclause specific to this document.

The main function of a regulator is to maintain the value of the controlled variable within its tolerance field irrespective of the disturbance variables.

Regulators shall not have any continuous discharge of gas into the atmosphere. However, temporary discharges from auxiliary devices can occur.

Regulators shall be so designed that the external tightness and internal sealing meet the requirements of 7.2.4 and 7.2.5. If in the event of failure of the regulator (e.g. failure of a diaphragm) leakage to atmosphere is possible, the breather shall be provided with a threaded connection of at least DN 10 to enable an exhaust line to be connected. This connection may be used for a specific device (e.g. a dumping device). For proper operation of the regulator, any exhaust line shall be designed in such a way to prevent the ingress of foreign materials.

Pressure bearing parts including measuring and test points, which may be dismantled for servicing, adjustment or conversion shall be made pressure tight by mechanical means (e.g. metal to metal joints, o-rings, gaskets, etc.). Jointing compounds, such as liquids and pastes, shall not be used.

Jointing compounds, however, may be used for permanent assemblies and shall remain effective under normal operating conditions.

Pressure bearing parts not intended to be dismantled during servicing, adjustment or conversion shall be sealed by means which show evidence of interference or tampering (e.g. lacquer).

When external protrusions or other external parts need special care to cover the hazards during transport and handling, the manual shall include the provisions to cover these risks.

The motorization energy in a pilot-controlled regulator shall be provided by the gas upstream of the regulator.

For regulators used as stand-by monitor, it shall be possible to check whether the control member is in fully open or in controlling position by a visual inspection.

6.7.2 Gas pressure regulators with associated safety devices

6.7.2.1 Gas pressure regulators with integrated safety devices

Additional integrated (same body) safety devices, i.e. gas safety shut-off devices (SSD) and/or a monitor shall be functionally independent from the regulator.

This requirement is met if:

- a) the function of the regulator is not affected in the event of the failure and/or loss of functionality of one or more of the following safety shut-off device/monitor components:
 - closure / control member;
 - seat ring;
 - actuator;
 - casing of actuator;
 - controller;
 - pilot (in case of pilot-controlled monitor type);
 - sensing and process lines;
- b) the function of the safety shut-off device/monitor is not affected in the event of the failure and/or loss of functionality of one or more of the following regulator components:
 - control member;
 - seat ring;
 - actuator;
 - casing of actuator;
 - controller;
 - pilot (in case of pilot-controlled regulator type);
 - sensing and process lines.

When the regulator incorporates more than one safety devices (e.g. a monitor and an SSD or two SSDs), the functional independence shall be met by each device from the other ones in similar way as detailed in this subclause.

When the integrated safety device is a slam-shut device or a cut-off device or a monitor, the motorization energy for the regulator, when it is a pilot-controlled type, shall be provided by the gas downstream of the safety device.

6.7.2.2 Gas pressure regulators with in-line monitor

The system includes a regulator with the function of active regulator and a second (in series) regulator with the function of monitor. The monitor shall be installed normally upstream of the active regulator and both equipment shall control the pressure at the same location.

The associated in-line monitor shall be functionally independent from the active regulator.

This requirement is met if:

- a) the function of the active regulator is not affected in the event of the failure and/or loss of functionality of one or more of the following monitor components:
 - pilot (in case of pilot-controlled monitor type);
 - sensing and process lines; and
- b) the function of the monitor is not affected in the event of the failure and/or loss of functionality of one or more of the following active regulator components:
 - pilot (in case of pilot-controlled regulator type);
 - sensing and process lines.

The motorization energy for active regulator in case of pilot-controlled type shall be taken downstream of the monitor.

For monitor in fully open position in normal operating conditions, it is necessary to adopt appropriate design measures to avoid the possible effect of static friction (break away friction) at the first movement between movable and fixed parts.

6.7.2.3 Gas pressure regulator with in-line safety shut off device

The system includes a regulator with the function of active regulator and an in-line SSD (in series).

The SSD shall be installed directly upstream of active regulator and both devices shall control the pressure at the same location.

The associated in-line SSD shall be functionally independent from the active regulator.

The requirement is met if:

- a) the function of active regulator is not affected in the event of the failure and/or loss of functionality of one or more of the following SSD components:
 - controller;
 - sensing and process lines; and
- b) the function of SSD is not affected in the event of the failure and/or loss of functionality of one or more of the following active regulator components:
 - pilot (in case of pilot-controlled regulator type);
 - sensing and process lines.

The motorization energy for active regulator, in case of pilot-controlled type, shall be taken downstream of the SSD.

7 Performance and testing requirements

7.1 General

7.1.1 Approach to stable product phase

Shall be according to ISO 23555-1:2022, 7.1.1.

7.1.2 Test conditions

Shall be according to ISO 23555-1:2022, 7.1.2.

7.1.3 Test tolerances

Shall be according to ISO 23555-1:2022, 7.1.3.

7.1.4 Overview table

Shall be according to ISO 23555-1:2022, 7.1.4 with the replacement of Table 11 by [Table 1](#):

Table 1 — Summary of test methods and requirements

Test schedule			Requirement	Test method	
T	M	S	Clause	Title	Clause
Constructional tests					
A	A	A	6.1	Dimensional check and visual inspection	7.3.3
A	A	A	6.1	Materials check	ISO 23555-1
A			6.3	Verification of the strength of pressure bearing parts and inner metallic partition walls	ISO 23555-1
A			6.4	Verification of the strength of parts transmitting actuating forces	ISO 23555-1:2022, 6.4.3
A	A	A	6.2	Shell and inner metallic partition walls strength test	7.3.5
A	A	A	7.2.5	External tightness test	7.3.6
A			7.2.9	Method to prove the compliance with requirements detailed in 7.2.9 or 7.2.10	7.3.10.5
A			7.2.10		
A			7.2.11	Verification of closing force for monitor in fully open position under normal operating conditions	7.3.12
A		A	7.2.6	Test method and acceptance criteria to verify the antistatic characteristics	7.3.8
Functional tests					
A			7.2.12.6	Determination of the flow coefficients	7.3.10.2
	A (a)	A	7.2.8.2	Check of internal sealing and lock-up pressure	7.3.7
A			7.2.8.1.1 and 7.2.8.3	Determination of a performance curve and verification of the hysteresis band	7.3.10.4.2
A			7.2.8.2	Determination of the lock-up pressure and verification of the internal sealing	7.3.10.4.3
A			7.2.8	Performance classification of pressure regulators	7.3.10.4.4
A = Applicable S = Batch surveillance M = Routine tests T = Type test ^a Simplified test method for accuracy class is not required in the routine tests. The procedures of 7.3.10.3 can be used to check the set point.					

Table 1 (continued)

Test schedule			Requirement	Test method	
T	M	S	Clause	Title	Clause
A			7.2.8.2.1	Operational check at the limit temperatures of -10 °C or -20 °C and 60 °C	7.3.10.4.5
optional			—	Methods for measuring the sound pressure level	ISO 23555-1:2022, Annex E
A			7.2.3	Final visual inspection after type test	7.3.11.1
	A	A	7.2.3	Final visual inspection after routine tests and batch surveillance	7.3.11.2
A = Applicable S = Batch surveillance M = Routine tests T = Type test ^a Simplified test method for accuracy class is not required in the routine tests. The procedures of 7.3.10.3 can be used to check the set point.					

7.2 Requirements

7.2.1 Test rig

Shall be according to ISO 23555-1:2022, 7.2.1.

7.2.2 Classification of stable production tests

Shall be according to ISO 23555-1:2022, 7.2.2.

7.2.3 Dimensional check and visual inspection

Shall be according to ISO 23555-1:2022, 7.2.3.

7.2.4 Shell strength

Shall be according to ISO 23555-1:2022, 7.2.4.

7.2.5 External/Internal tightness

Shall be according to ISO 23555-1:2022, 7.2.5 with the following modification.

Internal sealing is tested according to [7.3.10.4.3](#).

7.2.6 Antistatic characteristics

Shall be according to ISO 23555-1:2022, 7.2.6.

7.2.7 Sound emission

Shall be according to ISO 23555-1:2022, 7.2.7.

7.2.8 Control classifications

7.2.8.1 General

7.2.8.1.1 Accuracy classes

Subclause specific to this document.

Accuracy under stable conditions.

Regulators shall conform to accuracy requirements relevant to the declared accuracy class(es) chosen from [Table 2](#).

Table 2 — Accuracy classes

Accuracy class	Permissible positive and negative regulation change
AC 1	$\pm 1\%$ ^a
AC 2,5	$\pm 2,5\%$ ^a
AC 5	$\pm 5\%$ ^a
AC 10	$\pm 10\%$
AC 20	$\pm 20\%$
AC 30	$\pm 30\%$
^a But not lower than $\pm 0,1$ kPa (1 mbar).	

The same type of regulator may have different accuracy classes depending on the set range, W_d , and/or the inlet pressure range, b_{pu} .

7.2.8.1.2 Hysteresis

The hysteresis is included in the accuracy class and shall be declared by the manufacturer if requested in the order specification.

7.2.8.2 Lock-up behaviour

7.2.8.2.1 Lock-up pressure classes

Regulators shall conform to lock-up pressure requirements relevant to the declared class(es) chosen from [Table 3](#).

Table 3 — Lock-up pressure classes

Lock-up pressure class	Permissible positive regulation change within the lock-up pressure zone
SG 2,5	$2,5\%$ ^a
SG 5	5% ^a
SG 10	10%
SG 20	20%
SG 30	30%
SG 50	50%
^a But not lower than $0,1$ kPa (1 mbar).	

The same type of regulator may have different lock-up pressure classes depending on the specified set range, W_d , and/or the inlet pressure range, b_{pu} .

At the lowest limit temperature, the permissible deviation for the declared lock-up pressure classes may move to a less stringent class as detailed in [7.3.10.4](#).

7.2.8.2.2 Classes of lock-up pressure zone

Regulators shall conform to lock-up pressure zone requirements relevant to the declared class(es) chosen from [Table 4](#).

Table 4 — Lock-up pressure zone classes

Class of lock-up pressure zone	Limit value of the lock-up pressure zone as a percentage of $Q_{\min,pu}$ to $Q_{\max,pu}$
SZ 2,5	2,5 %
SZ 5	5 %
SZ 10	10 %
SZ 20	20 %

Within the lock-up pressure zone, the regulator shall be in accordance with [7.2.8.3](#).

The same type of regulator can have different classes of lock-up pressure zone depending on the set range, W_d , and/or the inlet range, b_{pu} .

7.2.8.3 Stable conditions

For the permissible positive and negative regulation change specified in [7.2.8.2.1](#), the amplitude of any oscillations occurring in steady state shall not exceed 20 % of the accuracy class or 0,1 kPa (1 mbar) whichever is the higher value.

7.2.9 Fail close conditions

For fail close regulators the control member shall tend to close or close in the following cases:

- failure of any main diaphragm;
- failure of continuous supply of energy from gas system to move the control member.

7.2.10 Fail open conditions

For fail open regulators the control member shall tend to open or open in at least one of the following cases:

- failure of any main diaphragm;
- failure of continuous supply of energy from gas system to move the control member.

7.2.11 Closing force for monitor at full open position

At the activation of the monitor, the closing force shall ensure the reaching of the controlling position of control member by a sufficient safety factor under all operating conditions. In the case of closing springs, appropriate measures against the breakage of springs shall be considered as those detailed in [6.1](#).

The closing force, when the monitor is activated at its fully open position, shall conform with [Formulae \(3\)](#) and [\(4\)](#):

$$F_s \geq 5 \times R \pm f_o \times S \pm f_o \times W + f_o \times D \quad (3)$$

$$F_s \geq 5 \times R \pm f_a \times S \pm f_a \times W + f_o \times D \quad (4)$$

where

- F_s is the closing force;
- R is the friction force (non-static friction) in N;
- S is the unbalanced load from static pressure in N;
- W is the weight of the moving parts in N;
- D is the dynamic force on the closing member from the flowing gas through the regulator in N;
- f_o is where the force opposes the closing of the control member, $f_o = 1, 1$;
- f_a is where the force assists the closing of the control member, $f_a = 0, 9$;

The addition (+) is applied when the force opposes the closing of the control member and the subtraction (-) when the force assists the closing of the control member.

NOTE 1 In [Formulae \(3\)](#) and [\(4\)](#) the forces S and W depend on control design and they can oppose (f_o) or assist (f_a) the closing of the control member.

NOTE 2 The dynamic force, D , is considered zero if it assists the closing of the control member.

When there is any torque developed in moving parts by the flowing gas it shall be considered when calculating F_s .

The value of closing force shall be verified at the most critical operating conditions in the most critical mounting position.

This requirement is not applicable to:

- direct acting regulators (e.g. [Figure 1](#));
- pilot-controlled regulators using a diaphragm as control member (e.g. [Figure 3](#)).

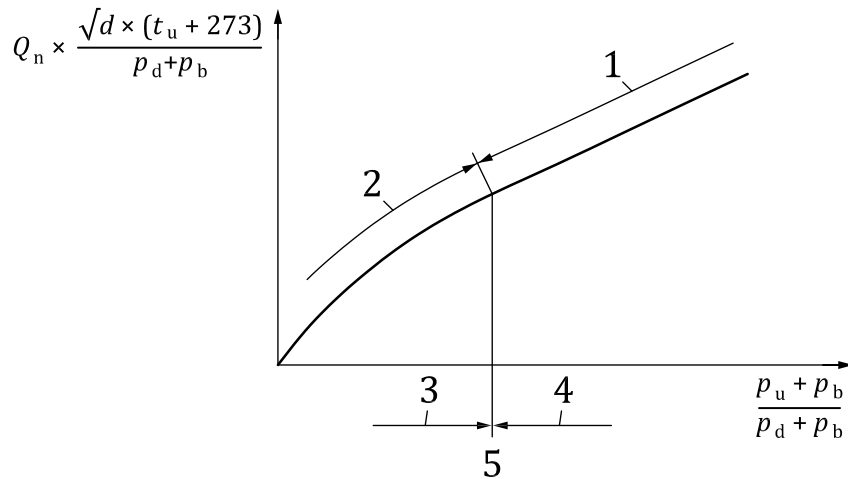
7.2.12 Gas pressure regulator sizing

7.2.12.1 Flow behaviour

The flow behaviour of a regulator is said to be critical if, at constant inlet temperature, the volumetric flow rate varies proportionally only with the absolute inlet pressure.

The flow behaviour of a regulator is said to be sub-critical if, at constant inlet temperature, the volumetric flow rate varies with both the absolute inlet and outlet pressures.

The boundaries of the critical and sub-critical flow behaviour [see [Formula \(11\)](#)] are shown in the system of Cartesian coordinates of [Figure 9](#) and coincide with the two different sections of the plotted curve. For the definition of the symbols, see [7.2.12.2](#).



Key

- 1 linear section
- 2 non-linear section
- 3 sub-critical behaviour
- 4 critical behaviour
- 5 border point between sub-critical and critical behaviour

Figure 8 — Flow behaviour of a regulator with the control member in a fixed position

7.2.12.2 Sizing formulae for the calculation of volumetric flow rates of a gas pressure regulator with its control member in its mechanically fully open position

7.2.12.2.1 Normal calculations

Volumetric flow rates should be calculated using the sizing formulae of IEC 60534-2-1:2011, Formula 7.

7.2.12.2.2 Practical calculations

Normally, in the regulators field it is common to use [Formulae \(5\)](#) and [\(6\)](#):

a) sub-critical flow behaviour:

$$Q_n = \frac{13,58}{\sqrt{d \times (t_u + 273,15)}} \times C_g \times \frac{P_u + P_b}{2} \times \sin \left[K_1 \times \sqrt{\frac{P_u - P_d}{P_u + P_b}} \right]_{\text{deg}} \quad (5)$$

b) critical flow behaviour [see [Formula \(11\)](#) in [7.3.10.2.2](#)]:

$$Q_n = \frac{13,58}{\sqrt{d \times (t_u + 273,15)}} \times C_g \times \frac{P_u + P_b}{2} \quad (6)$$

where

K_1 is the body shape factor;

C_g is the flow coefficient in critical conditions;

d is the relative density of the gas (air = 1, non-dimensional value);

t_u is the gas temperature at the inlet of the regulator in °C;

p_u is the pressure at the inlet of the regulator, in Pa;

p_d is the pressure at the outlet of the regulator, in Pa;

p_b is the local static atmospheric pressure, in Pa (absolute pressure).

NOTE These Formulae can be found in References [8] or [9].

7.2.12.2.3 Simplified calculations

Formulae (7) and (8) can be used with an adequate accuracy for use in practice to make a simplified calculation of the flow rates. The relative density, d , and the temperature, t_u , of the gas for which the flow is calculated, are used:

- a) flow at sub-critical pressure ratio $(p_u - p_d) \leq 0,5 \times (p_u + p_b)$

$$Q_n = \frac{13,58}{\sqrt{d \times (t_u + 273,15)}} \times K_G \times \sqrt{(p_d + p_b) \times (p_u - p_d)} \quad (7)$$

- b) flow at critical pressure ratio $(p_u - p_d) > 0,5 \times (p_u + p_b)$:

$$Q_n = \frac{13,58}{\sqrt{d \times (t_u + 273,15)}} \times K_G \times \frac{p_u + p_b}{2} \quad (8)$$

where

K_G is the flow coefficient in normal conditions;

d is the relative density of the gas (air = 1, non-dimensional value);

t_u is the gas temperature at the inlet of the regulator in °C;

p_u is the pressure at the inlet of the regulator, in Pa;

p_d is the pressure at the outlet of the regulator, in Pa;

p_b is the local static atmospheric pressure, in Pa (absolute pressure).

The manufacturer shall detail in the relevant document supplementary information on the appropriated use of the flow coefficient K_G for high pressure-recovery body [9] focused to meet the expected accuracy in the volumetric flow rate calculation.

7.2.12.3 Calculation of the maximum accuracy flow rate

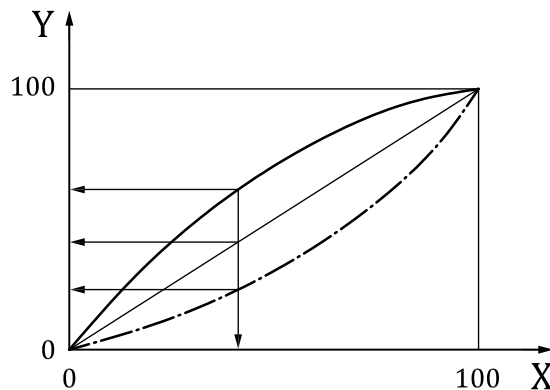
The maximum accuracy flow rate shall be calculated according to Formulae (5) and (6) or Formulae (7) and (8) by using the applicable percentage of the flow coefficient at fully open position. This percentage which is equal to or less than 100, depends on the accuracy class AC and shall always be specified by the manufacturer (see Figure 6).

7.2.12.4 Inherent flow characteristics

The relationship between flow coefficient and the position of the control member is usually represented diagrammatically (see Figure 10). Flow coefficients are usually expressed as a percentage of the flow coefficient at fully open position and the position of the control member as a percentage of the maximum travel (limit imposed by a mechanical stop). Figure 10 gives examples of the inherent flow characteristics of three different types of regulator.

7.2.12.5 Calculation of volumetric flow rates for partially open gas pressure regulators

Volumetric flow rates for regulator positions between closed and fully open shall be calculated using the formulae given in 7.2.12.2, but by using the percentage of the flow coefficient at fully open position associated with a given percentage of the valve travel as detailed in 7.2.12.4.



Key

X travel in %

Y Cg, KG in %

Figure 9 — Three examples of inherent flow characteristics (stable condition)

7.2.12.6 Flow coefficient

For all flow coefficients, the tolerance between the value declared by the manufacturer and the actual value verified during the type test shall be within $\pm 10\%$.

7.3 Tests

7.3.1 General

Shall be according to ISO 23555-1, with the following additions.

7.3.2 Materials check at stable production phase

Shall be according to ISO 23555-1:2022, 7.3.1.

7.3.3 Dimensional check and visual inspection

Shall be according to ISO 23555-1:2022, 7.3.2.

7.3.4 Mounting position

Shall be according to ISO 23555-1:2022, 7.3.3.

7.3.5 Shell strength

Shall be according to ISO 23555-1:2022, 7.3.4.

7.3.6 External tightness

Shall be according to ISO 23555-1:2022, 7.3.5.

7.3.7 Internal tightness

Shall be according to ISO 23555-1:2022, 7.3.6, with the following modification: [7.3.10.4.3](#).

7.3.8 Antistatic characteristics

Shall be according to ISO 23555-1:2022, 7.3.7.

7.3.9 Methods for calculating and measuring the sound pressure level

Shall be according to ISO 23555-1:2022, 7.3.8.

7.3.10 Control classifications

Subclause specific to this document.

7.3.10.1 General conditions

If the regulator has built-in safety device(s), it shall be tested with the safety device(s) in its (their) normal operating position.

The tests may be carried out either with air or with gas. Where necessary, measured volumetric flow rates shall be converted into values that are related to air at normal conditions. Due to the need to obtain a homogeneous set of test results that permit different types of regulators to be compared with each other, or to assess in the laboratory the requested performance of a regulator in the field, or make the assessments specified in [7.3.10.4](#), the measured values shall be converted into volumetric flow rates related to an inlet reference temperature of 15 °C. Pressure gauges shall have an accuracy of at least AC/4 across the scale range according to the applicable document and a full scale not greater than twice the value of the variable to be measured. Tests shall be carried out at ambient temperature. Regulators shall be tested in the mounting position specified by the manufacturer.

The external sensing/process lines shall be located on the downstream pipework according to the recommendations of the manufacturer.

7.3.10.2 Determination of the flow coefficients**7.3.10.2.1 Normal method**

If the volumetric flow rates are calculated using the sizing formulae of IEC 60534-2-1:2011, Formula 6 and 7, the tests shall be carried out in accordance with IEC 60534-2-3.

7.3.10.2.2 Practical method for C_g flow coefficient and K₁ body shape factor

If in the flow calculation the formulae given in [7.2.12.2](#) are being used, then [Formulae \(9\)](#) to [\(10\)](#) shall be used to calculate flow coefficient C_g and the body shape factor K₁.

To determine C_g of a regulator with the control member in the mechanically fully open position it is necessary to plot a diagram as shown in [Figure 9](#). The C_g shall be determined for at least three different operating conditions in the critical flow behaviour with:

$$C_g = \frac{2 \times Q_n \times \sqrt{d \times (t_u + 273,15)}}{13,58 \times (P_u + P_b)} \quad (9)$$

[Formula \(9\)](#) derives from [Formula \(6\)](#).

The C_g flow coefficient shall be assumed to be equal to the arithmetic mean of the three values.

The shape factor K_1 (see 7.2.12.2.2) shall be determined for at least two different operating conditions in the sub-critical flow behaviour with Formula (10):

$$K_1 = \frac{\arcsin \left[\frac{Q_n \times \sqrt{d \times (t_u + 273,15)}}{13,58 \times C_g} \times \frac{2}{P_u + P_b} \right]_{\text{deg}}}{\sqrt{\frac{P_u - P_d}{P_u + P_b}}} \quad (10)$$

Formula (10) derives from Formula (5)

The two different sub-critical operating conditions shall be chosen within following two values (1,15/1,25) and (1,40/1,50) of the ratio $(p_u + p_b)/(p_d + p_b)$.

The shape factor K_1 shall be assumed to be equal to the arithmetic mean of the two values.

For C_g and K_1 shape values a tolerance of $\pm 10\%$ is permitted.

The behaviour shall be assumed to be critical when:

$$\frac{p_u + p_b}{p_u + p_b} \geq \frac{K_1^2}{K_1^2 - 8 \cdot 100} \quad (11)$$

i.e. under the operating conditions at which the $\sin=1$ for the first time versus the increasing of the ratio $\frac{p_u + p_b}{p_d + p_b}$.

In Formulae (9) and (10), Q is the volumetric flow rate at normal conditions of the test fluid as measured by the flow meter 9 in ISO 23555-1:2022, Figure 2. The measured values shall be converted into values related to the normal conditions specified in ISO 23555-1:2022, 3.1.3.5. Q shall be calculated with Formula (12):

$$Q_n = 269,58 \times \frac{p_M + p_b}{t_M + 273,15} \times Q_M \quad (12)$$

where

C_g is the flow coefficient in critical conditions;

d is the relative density of the test fluid (air = 1, non-dimensional value);

t_u is the temperature of the test fluid in °C at the inlet of the regulator;

p_M is the fluid pressure at the flow meter;

p_d is the pressure at the outlet of the regulator in bar abs;

p_u is the pressure at the inlet of the regulator in bar abs;

p_b is the local static atmospheric pressure in bar (absolute pressure);

Q_n is the volumetric flow rate in m³/h at normal conditions;

Q_M is the volumetric flow rate measured at the flow meter at operating conditions;

t_M is the fluid temperature at the flow meter in °C;

K_1 is the body shape factor.

The tests shall be carried out where technically possible and economically justified on a test rig in accordance with 7.2.1. Where this is not the case, alternative test and calculation methods, e.g. that detailed in E.3 and E.4, may be used for the determination of flow coefficient C_g .

7.3.10.2.3 Test method for flow coefficient in normal conditions, K_G

For the determination of the flow coefficient the regulator with the control member in the mechanically fully open position shall install in a test rig according to 7.2.1.

The volumetric flow rate Q is measured at an absolute inlet pressure $p_u = 200$ kPa (2 bar) and absolute outlet pressure $p_d = 100$ kPa (1 bar).

The flow coefficient is related to conditions specified in 3.1.4.2 and calculated with Formula (13):

$$K_G = 2 \times Q_n \times \frac{\sqrt{d \times (t_u + 273,15)}}{13,58 \times (p_u + p_b)} \quad (13)$$

This formula derives from Formula (8).

For larger regulators or insufficient capacity of the test facility the value of the volumetric flow rate Q shall be measured at sub-critical flow behaviour $(p_u - p_d) \leq 0,5 \times (p_u + p_b)$ for three different Δp between inlet pressure p_u and outlet pressures p_d .

For every measured value the associated flow coefficient is calculated with Formula (14):

$$K_G = \frac{Q_n}{\sqrt{(p_d + p_b) \times (p_u - p_d)}} \times \frac{\sqrt{d \times (t_u + 273,15)}}{13,58} \quad (14)$$

Formula (14) derives from Formula (7).

The volumetric flow rate Q_n is calculated by the Formula (12).

The flow coefficient of the regulator is the arithmetic average value from the three calculated values.

The manufacturer shall consider further measures on the suitability of the above test methods for high pressure-recovery bodies^[9] focused to meet the expected accuracy in the volumetric flow calculation.

where

K_G is the flow coefficient in normal conditions;

d is the relative density of the test fluid (air = 1, non-dimensional value);

t_u is the temperature of the test fluid in °C at the inlet of the regulator;

p_d is the pressure at the outlet of the regulator, in Pa;

p_b local static atmospheric pressure, in Pa;

p_u is the pressure at the inlet of the regulator, in Pa;

Q_n is the volumetric flow rate in m³/h at normal conditions.

7.3.10.2.4 Calculation method

The calculation of the flow coefficient C_g by the computational fluid dynamics (CFD) can be an alternative method to the aforesaid practical methods. ASME V&V 20-2009 [R2016] can be a reference for verification and validation of C_g result, calculated by CFD.

7.3.10.3 Check of internal tightness and lock-up pressure class

These tests shall be carried out with volumetric flow rates greater than $Q_{n,min,pu}$ at the extreme values of the inlet pressure range, b_{pu} , for the setting of the controlled pressure or for the extreme values of specific set range, W_{ds} , or for the extreme values of set range, W_d , according to the order specification.

Initial conditions to be set as follows:

- inlet pressure to be equal to p_{umin} and the volumetric flow rate to be zero;
- increase the volumetric flow rate to the level specified above;
- adjust the controlled pressure to the required set point.

The test for each setting shall comprise the following steps (see [Figure 10](#)):

- a) reduce the volumetric flow rate until complete lock-up takes place within a period not less than the response time of the regulator;
- b) record the lock-up pressure:
 - after 5 s;
 - after 30 s

from the closure of the regulator;

NOTE 1 These values are not appropriate for pilot-controlled regulators.

- c) increase the volumetric flow rate close to the above value and determine the corresponding outlet pressure p_d ;
- d) increase the inlet pressure until p_{umax} is reached and determine the corresponding outlet pressure p_d ;
- e) repeat the above steps from a) to c) without any further adjustment of the setting;
- f) reduce the volumetric flow rate until complete lock-up takes place within a period not less than the response time of the regulator;
- g) record the lock-up pressure:
 - after 5 s;
 - after 30 s

from the closure of the regulator;

NOTE 2 These values are not appropriate for pilot-controlled regulators.

Provided the values of lock-up pressure at 5 s and 30 s are comparable, taking account of the accuracy of the measuring system, it shall be assumed that the regulator has passed the internal leakage test.

The values of lock-up pressure, the outlet pressures resulting from the two increases in the volumetric flow rate and the setting shall be within the applicable range.

If the manufacturer is unable to provide the required test volumetric flow rate, an alternative test procedure may be used to cover these checks.

In these verifications, a test rig in accordance with [7.2.1](#) is not mandatory.

If a detection method is available to verify compliance with the required internal leakage rates given in ISO 23555-1:2022, Table 12 an alternative procedure may be followed to check the internal sealing and to measure the lock-up pressure at p_{umin} and p_{umax} .

In this case the determined leakage rates shall comply with:

- the requirements of ISO 23555-1:2022, Table 12; or
- the leakage class in accordance with IEC 60534-4 if specified in the order specification (see [Annexe I](#)).

After the completion of above verifications, it shall be verified that the regulator meets the internal sealing performance also for momentary inlet pressure surge up to 1,1 PS.

NOTE 3 Above procedures can be used to check the set point.

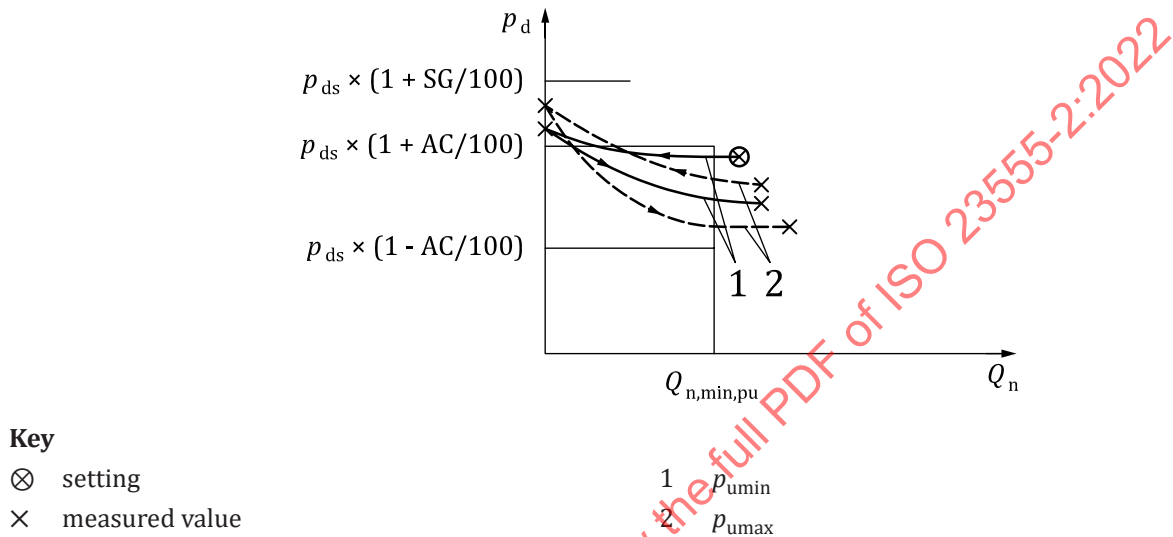


Figure 10 — Graphical representation of the tests detailed in [7.3.10.3](#)

7.3.10.4 Functional tests under stable conditions

7.3.10.4.1 General conditions

These tests shall be carried out at ambient temperature. The purpose is to verify the values stated by the manufacturer for:

- the accuracy class;
- the maximum hysteresis band, if specified in the order specification;
- the lock-up pressure class;
- the class of lock-up pressure zone;
- the maximum accuracy flow rate and minimum flow rate.

The tests shall be carried out where technically possible and economically justified on a test rig in accordance with [7.2.1](#).

Where this is not the case, alternative test and calculation methods may be used for the determination of $Q_{nmax,pumin}$, $Q_{nmax,pumax}$, AC, SG and hysteresis band (e.g. those explained in [Annex E](#) or the modelling tests on test specimens to a smaller scale as described in IEC 60534-2-3) if specified in the order specification under the following pre-conditions:

- c) the maximum possible size and at least the minimum size of a series of regulators shall be tested using a test rig in accordance with [7.2.1](#);

- d) to prove that the alternative method chosen is reliable by comparing the results with those from a test at full operating conditions in a particular regulator size;
- e) to use the alternative method for larger sizes of regulators of the same series.

However, if the regulator or even the smallest regulator of a series cannot be tested using a test rig in accordance with 7.2.1, the test method as detailed in Annex E may be used without other pre-conditions.

The compliance with performance requirements shall be checked against only three families of performance curves for three different values of outlet pressure chosen within the set range, W_d , in accordance with the following criteria:

- p_{dmin} ;
- p_{dmax} ;
- $p_{dint} = p_{dmin} + \frac{p_{dmax} - p_{dmin}}{3}$.

For each family of performance curves three values of inlet pressure shall be chosen within the inlet pressure range, b_{pu} , in accordance with the following criteria:

- p_{umin} ;
- p_{umax} ;
- $p_{uav} = \frac{p_{umin} + p_{umax}}{2}$ (rounded to the nearest whole number).

The regulator shall be kept pressurized throughout the whole process with no interruption of this condition until the determination of the families of performance curves is completed.

7.3.10.4.2 Determination of a performance curve and verification of the hysteresis band

With the understanding that the "actual set point" cannot be determined at the outset of this process, the setting of the regulator shall be adjusted at:

- an inlet pressure equal to p_{uav} ;
- the volumetric flow rate recommended by the manufacturer.

Changes to the setting prior to the completion of the whole process for the determination of a single performance curve, or families of performance curves, are not permitted. The flow rate regulating valve 8 (ISO 23555-1:2022, Figure 2) shall be used to vary the volumetric flow rates. The operating time of the valve shall not be less than the response time of the regulator as specified by the manufacturer. Volumetric flow rates measured by the flow meter 9 (ISO 23555-1:2022, Figure 2) shall be recalculated to refer to:

- normal conditions (see ISO 23555-1:2022, 3.3.5);
- test fluid at the reference temperature of 15 °C at the inlet of the regulator under test.

To this end, Formula (15) shall be used:

$$Q_n = 16,75 \frac{P_M + P_b}{t_M + 273} Q_M \sqrt{d (t_u + 273)} \quad (15)$$

where

Q_n is the volumetric flow rate in m³/h of the test fluid with relative density d and inlet temperature t_u for p_n and T_n see 3.3.5;

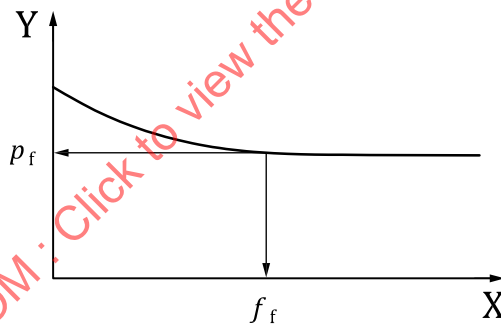
- d is the relative density of the test fluid (air = 1 non-dimensional value);
- p_M is the fluid pressure at the flow meter;
- Q_M is the volumetric flow rate measured at the flow meter at operating conditions;
- t_M is the fluid temperature at the flow meter in °C;
- t_u is the fluid temperature in °C at the inlet of regulator under test.

At least 11 different measurements conveniently distributed over the full range of values between Q_{nmin} and Q_{nmax} (5 with volumetric flow rates increasing, 4 with volumetric flow rates decreasing, an additional measurement at zero volumetric flow rate and one at the start setting) shall be taken for each pair of p_u and p_{ds} values.

Figure 4 is an example of a chart showing the relevant details such as the start setting, the measured results and the performance curve for the controlled variable related to a single pair of p_u and p_{ds} values.

7.3.10.4.3 Determination of the lock-up pressure and verification of the internal sealing

The lock-up pressure shall be determined in connection with tests carried out to determine the performance curve of the controlled variable. The time required to reduce the volumetric flow rate to zero shall not be less than the lock-up time of the regulator. This condition is deemed to be satisfied when the lock-up pressure is found to be independent of the time needed to reduce the volumetric flow rate to zero (see Figure 11).



Key

- X time to reduce the volumetric flow rate to zero
- Y pressure with control member at closing position

Figure 11 — Graphical representation of tests detailed in 7.3.10.4.3

The lock-up pressure p_f shall be measured twice, after 1 min and after 2 min from the regulator closure. When the inlet pressure is greater than 1,6 MPa (16 bar) the second measurement shall be taken after 5 min.

Any lock-up pressure value that can be affected by temperature variation in the fluid contained in the volume between the regulator under test and the flow rate regulating valve, shall be recalculated and related to the initial temperature by using Formula (16):

$$p_f = \frac{t + 273}{t_i + 273} (p_{fi} + p_b) - p_b \quad (16)$$

where

p_{fi} is the lock-up pressure related to the second measurement;

t is the test fluid temperature in °C related to the first measurement;

t_i is the test fluid temperature in °C related to the second measurement.

The regulator shall be deemed leak-tight if the last two lock-up pressures, corrected for the initial temperature, are comparable (taking account of the accuracy of the measuring system) or comply with the internal leakage rate requirements given in:

- ISO 23555-1:2022, Table 12; or
- the leakage class in accordance with IEC 60534-4 if specified in the order specification (see [Annexe I](#)).

The lock-up pressures of the regulator shall be within the applicable range. For lock-up pressure measurements the outlet pipework of the test rig shall have a minimum length as specified in ISO 23555-1:2022, Figure 2.

The internal sealing of regulator shall also be verified at:

- outlet pressure of zero;
- after the completion of above verifications, it shall be verified that the regulator meets the internal sealing performance also for momentary inlet pressure surge up to 1,1 PS.

7.3.10.4.4 Performance classification of pressure regulators

7.3.10.4.4.1 Determination of the accuracy class, the lock-up pressure class, the class of lock-up pressure zone, the maximum accuracy flow rate and the minimum flow rate related to a specified inlet pressures range (family of performance curves)

The determination is based on optimal enveloping of each family of performance curves with the vertical and horizontal limit lines as shown in [Figure 6](#). An example of an optimal enveloping procedure is shown in [Figure 12](#) and is described as follows:

- plot the performance curves of a family in a semilog diagram with volumetric flow rates on the decimal scale of the abscissa and outlet pressure on the logarithmic scale of the ordinate;
- locate on this diagram, in an optimized manner, three horizontal lines spaced as shown in [Figure 12](#); the optimization of the location of these lines is reached when the greatest possible number of performance requirements are met;
- identify the actual set point where the dashed horizontal line intersects the ordinate;
- ensure that $Q_{nmax,puav}$, $Q_{nmax,pumin}$, $Q_{nmax,pumax}$, $Q_{nmin,pumax}$, $Q_{nmin,puav}$, $Q_{nmin,pumin}$, AC and p_f are within the established limits.

Other equivalent optimal enveloping methods may be used.

If the performance data listed by the manufacturer are not met, the test report shall detail the actual performance data taken from the type tests.

7.3.10.4.4.2 Determination of the accuracy class, the lock-up pressure class, the class of lock-up pressure zone, the maximum accuracy flow rate and the minimum flow rate related to a specified inlet pressure range and set range (more than one family of performance curves)

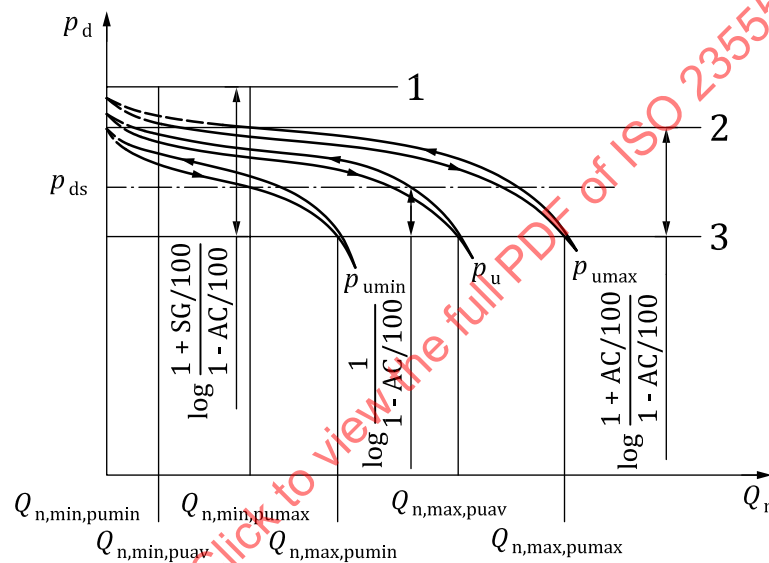
The determination is based on the output data as in the previous sub-clause deduced from the three families of performance curves specified in [7.3.10.4.4.1](#).

The regulator is classified for a specified inlet pressure range, b_{pu} , and set range, W_d , in accordance with following procedure:

- accuracy class (AC);
- lock up pressure class (SG); and
- lock up pressure zone (SZ);

shall be the less performance data verified for above three families of performance curves while:

- the maximum accuracy flow rate is the lowest maximum accuracy flow rate of the three above families of performance curves and
- the minimum flow rate is largest minimum flow rate of the three above families of performance curves.



Key

- 1 max limit for p_f
- 2 max limit for p_d with Q outside the lock-up zone
- 3 min limit for p_d

Figure 12 — Graphical representation of tests detailed in [7.3.10.4.4](#)

7.3.10.4.5 Operational check at the limit temperatures of -10 °C or -20 °C and 60 °C

The regulator shall be installed in a suitable thermostatically controlled enclosure.

The operational check shall include in the listing order a test at lowest limit temperature and subsequently a test at highest limit temperature.

To start the check the test medium shall be brought to the relevant temperature.

The check shall verify the internal sealing and determine the lock-up pressure in accordance with [7.3.10.4.3](#) under the following conditions:

- maximum inlet pressure/minimum outlet pressure;
- at the two relevant limit temperatures.

The lock-up pressure at the -10 °C and at the -20 °C limit temperatures shall be as per [Formula \(17\)](#) except when at ambient temperature:

- lock-up pressure SG = 30. In this case, the SG = 30 may be multiplied by 1,5;
- lock-up pressure SG = 50.

$$P_f \leq P_{ds} \times \left(1 + \frac{2 \text{ SG}}{100} \right) \quad (17)$$

EXAMPLE At ambient temperature, SG 5 can change to SG 10 both at -20 °C and at -10 °C. At ambient temperature, SG 30 can change to SG 45 both at -20 °C and at -10 °C.

The lock-up pressure at upper limit temperature shall be as per [Formula \(18\)](#):

$$P_f \leq P_{ds} \left(1 + \frac{\text{SG}}{100} \right) \quad (18)$$

where p_{ds} and SG are those determined at ambient temperature.

Further, the check shall include the verification of opening start.

- At lowest limit temperatures a check to determine the control member movement shall also be carried out at the following conditions: minimum value of set point (p_{dsmin}).
- Minimum operating differential pressure Δp_{min} .

After above checks, the external tightness test in accordance with [7.3.6](#) is repeated at the lower limit temperatures.

7.3.10.5 Method to prove the compliance with requirements detailed in [7.2.9](#) or [7.2.10](#)

The reaction of regulators detailed in [7.2.9](#) and [7.2.10](#) shall either be proved by appropriate failure analysis or in case of doubt by the relevant test(s).

The failure analysis shall consider:

- only the failures listed in [7.2.9](#) or [7.2.10](#); and
- only one of the failure at same time and its consequences, if any.

Regulators whose reaction to all the specified failures in [7.2.9](#), comply with the requirements detailed in the same sub-clause, are classified as “fail close” type.

Regulators whose reaction to any specified failures in [7.2.10](#), comply with the requirements detailed in the same subclause, are classified as “fail open” type.

Failure analysis can identify a differentiation in the reaction of “fail open” regulators to the failures listed in [7.2.10](#). For example, it is necessary to consider that damages on other diaphragms can bring the regulator to tend to open or to open or to tend to close or close (see [Figure 3](#)). Details shall be specified in the installation, operation and maintenance manual.

7.3.11 Final visual inspections

7.3.11.1 Final visual inspection after type test

Upon completion of the tests in [7.3.5](#), up to and including [7.3.10.4.5](#), and the test [7.2.1](#) when applicable, the test samples shall be dismantled and inspected to verify the compliance with the requirements detailed in [7.2.3](#). Test in [7.3.7](#) is excluded.

7.3.11.2 Final visual inspection after routine tests and batch surveillance

Upon completion of the routine tests, the regulator shall be externally inspected to verify the compliance with the requirements detailed in [7.2.3](#).

7.3.12 Verification of closing force for monitor in fully open position under normal operating conditions

The data specified by the manufacturer for all relevant loads are checked by testing the monitor at ambient temperature. The test shall be carried out at the most unfavourable operating conditions, to be specified by the manufacturer.

For this purpose, the friction (R) is determined as the arithmetic mean of 3 tests. The friction to be considered is that measured with motion (not static friction).

The loads (S) and (W) are calculated or determined by any other method.

The dynamic force (D) shall be considered only if in the fully open position it opposes the closing of the control member. It may be either measured at the most unfavourable operating conditions or calculated. [Annex H](#) details one method of calculation.

NOTE For meaning of the symbols, refer to [7.2.11](#).

8 Documentation

8.1 General

Shall be according to ISO 23555-1:2022, 8.1.

8.2 Documentation related to type test

Shall be according to ISO 23555-1:2022, 8.2.

8.3 Documentation related to batch surveillance

Shall be according to ISO 23555-1:2022, 8.3.

8.4 Documentation related to the routine tests

8.4.1 Documentation provided at the request of the customer

Shall be according to ISO 23555-1:2022, 8.4.1.

8.4.2 Documentation provided with the regulator

Shall be according to ISO 23555-1:2022, 8.4.2 with the following addition:

- details of fail reaction of regulators;
- regulator response time or range shall be on the documentation for the regulator along with the max. flow for the lockup pressure rating.

9 Marking

9.1 General

Shall be according to ISO 23555-1:2022, 9.1.

9.2 Basic requirements

Shall be according to ISO 23555-1:2022, 9.2.

9.3 Markings for the various connections

Shall be according to ISO 23555-1:2022, 9.3.

9.4 Marking of integrated safety devices

Shall be according to ISO 23555-1:2022, 9.4.

9.5 Other additional requirements

Subclause specific to this document.

The following further information shall be included in the marking:

- a reference to this document (i.e. ISO 23555-2);
- end connection type (flanged, threaded, etc.);
- specific set range, W_{ds} ;
- type of regulator (IS or DS);
- failure mode type (fail close regulator or fail open regulator);
- valve seat diameter (only where different sizes are provided) or valve trim (for this term, see IEC 60534-1) or the flow coefficient if the previous data are not representative of the regulator flow rate;
- maximum component operating pressure, p_{max} , and the specific maximum allowable pressure DPD of safeguarded chambers (for differential strength regulators only);
- leakage class in accordance with IEC 60534-4, when specified in the order specification;
- where necessary, warning drawing attention to dangerous misuses;
- additional marking in accordance with order specification.

10 Packaging and transportation of finished product

Shall be according to ISO 23555-1:2022, Clause 10.

Annex A
(normative)

List of materials

Shall be according to ISO 23555-1:2022, Annex A.

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Annex B
(normative)

Elastomeric material

Shall be according to ISO 23555-1:2022, Annex B.

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Annex C
(normative)

High pressure vent limiter

Shall be according to ISO 23555-1:2022, Annex C.

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Annex D
(normative)

Compliance evaluation

Shall be according to ISO 23555-1:2022, Annex D.

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Annex E (informative)

Alternative methods for the determination of the accuracy class, the lock-up pressure class, the maximum accuracy flow rate, the flow coefficients and the verification of the hysteresis band

E.1 General

Annex specific to this document.

The following alternative test methods may be used to establish the performance classification of a regulator or a series of regulators. The detailed procedure shall be agreed with the manufacturer.

E.2 Test methods

E.2.1 Direct acting gas pressure regulator

In this type of regulator, it is necessary to vary the pressure on one side of the pressure detecting element in order to move the control member from the open position to the closed position.

The test method comprises the following steps:

- set the regulator at the minimum value of the set range, W_d , following the manufacturer's instructions;
- increase the pressure in the casing of the actuator from an external source until the control member reaches its closed position and verify the internal sealing at the minimum and maximum inlet pressures (internally impulsed regulators may have to be modified);
- vent the pressure from the body;
- slowly reduce the pressure in the casing of the actuator until the control member reaches the required open position (i.e. the one relevant to the expected maximum accuracy flow rate) and measure the pressure corresponding to each 10 % increase in the valve travel;
- slowly increase the pressure in the casing of the actuator until the control member reaches the lock-up position and measure the pressure corresponding to each 10 % decrease in the valve travel;
- establish the closed position by the verification of internal sealing;
- calculate for each position of the control member the volumetric flow rate, Q , using the method detailed in [7.2.12.5](#).

With balanced moving parts (i.e. no variation in the thrust on the moving parts against changes in inlet pressure, p_u) all measured values of the pressure, except that for the closed position, shall be within the expected accuracy class AC.

The measured value of the lock-up pressure p_f shall be within the expected lock-up pressure class SG. The hysteresis can be verified by measuring the maximum difference in pressure for the same position of the control member.

The calculated value of flow rate giving maximum accuracy shall be greater than or equal to that specified by the manufacturer (see [Figure E.1](#)).

With unbalanced moving parts the same method shall be used, with account taken of the unbalanced thrust (see [Figure E.2](#)).

E.2.2 Pilot-controlled gas pressure regulators

With this type of regulator, it is necessary to vary the motorization pressure in the motorization chamber in order to move the control member from the closed position to an open position and vice versa. The thrust created by the motorization pressure is normally balanced by the load of a spring. The motorization pressure is supplied by the pilot. The pilot controls the supply of the motorization fluid according to the value of the difference between the value of the controlled variable and the set point in such a way as to keep the outlet pressure as close as possible to its set point.

Therefore, in both a regulator and pilot with moving parts balanced (i.e. no variation in the thrust on the moving parts with changes in inlet pressure), it is possible to classify the performance of the system i.e. the regulator with its pilot, by measuring the variation in outlet pressure against the position of the control member from the closed position to a specific valve travel. The test method shall be established in detail according to the specific design of the regulator.

In the following test method, reference shall be made to the functional diagram given in [Figure E.3](#).

[Figure E.4](#) shows the relationship between the valve travel, motorization pressure p_m and the flow through the process line, Q_f , and the outlet pressure of the system p_d including the regulator and its pilot.

The test method comprises the following steps:

- a) set the pilot at the minimum value of the set range, W_d , following the manufacturer's instructions;
- b) feed the pilot from an external source using the applicable auxiliary device at minimum inlet pressure $p_{u\min}$ and exhaust the fluid from the chamber where both process and sensing lines are connected;
- c) keep the regulator in the closed position using upstream inlet pressure. The inlet and outlet end connections may be sealed by using blind flanges;
- d) verify internal sealing of the regulator with $Q_f = 0$ at minimum and maximum inlet pressure p_u ;
- e) regulate the inlet pressure at $p_{u\min}$;
- f) increase the flow, Q_f , until the first internal flow occurs in the regulator and measure the outlet pressure p_d in the chamber where both process and sensing lines are connected (at this stage the inlet and outlet pressures in the regulator body are balanced, because there is zero flow through the regulator);
- g) increase the flow, Q_f , to open the regulator until 100 % of the valve travel relevant to the maximum accuracy flow rate, $Q_{n\max, p_{u\min}}$, has occurred and measure the outlet pressure p_d corresponding to each 10 % increase in the valve travel;
- h) decrease the flow, Q_f , to bring the regulator to the closed position and measure the outlet pressure p_d corresponding to each 10 % decrease in the valve travel. The closed position is verified by an internal sealing test;
- i) regulate the inlet pressure at $p_{u\max}$;
- j) repeat the tests a) to c);
- k) calculate, for each position of the control member, the volumetric flow rate, Q , using the method detailed in [7.2.12.5](#).

With balanced moving parts (i.e. no variation in the thrust on the moving parts with changes in the inlet pressure, p_u), all measured values of:

- outlet pressure p_d shall be within the expected accuracy class AC. The hysteresis can be verified by measuring the maximum difference in outlet pressures p_d for the same position of the control member;
- lock-up pressure p_f shall be within the lock-up pressure class SG and the calculated value of the maximum accuracy flow rate shall be greater than or equal to that specified by the manufacturer (see [Figure E.4](#)).

With unbalanced moving parts the same method shall be used, with account taken of the unbalanced thrust (see [Figure E.5](#)).

E.3 Determination of flow coefficients for larger capacity regulators

For larger capacity regulators if the available volumetric flow rates do not permit the use of the method detailed in [7.3.10.2](#), the following procedure may be followed:

- firstly, determine the flow coefficient for a partially open position that is compatible with the available volumetric flow rate by using [Formula \(9\)](#);
- determine the shape factor K_1 applicable to the same partially open position by using [Formula \(10\)](#);
- determine the function shown in [Figure E.6](#) at sub-critical conditions calculating $C_{g,x}$ by using [Formula \(E.1\)](#):

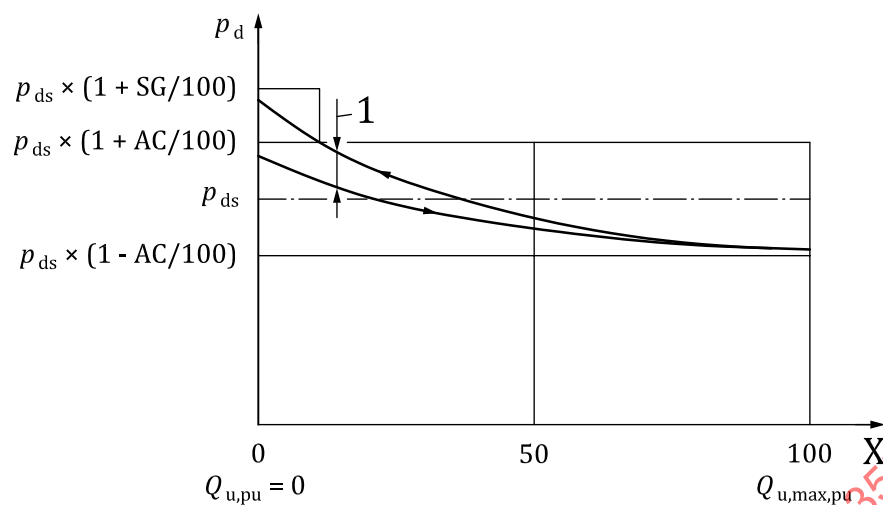
$$C_{g,x} = \frac{Q_n \times \sqrt{d \times (t_u + 273,15)}}{13,58 \times \frac{p_u + p_b}{2} \times \sin \left[K_1 \times \sqrt{\frac{p_u - p_d}{p_u + p_b}} \right]_{\text{deg}}} \quad (\text{E.1})$$

- these calculations shall be made for three different opening positions of the control member;
- extrapolate the value of C_g taken from the graph given in [Figure E.6](#) by starting from the point in the x co-ordinate for 100 % control member travel.

Where there is sufficient flow, the previous extrapolation can be avoided by carrying out the test detailed in the third indent with the control member at full open position.

To convert the measured flow rate to the volumetric flow rate, Q , to normal conditions see [7.3.10.2.2](#).

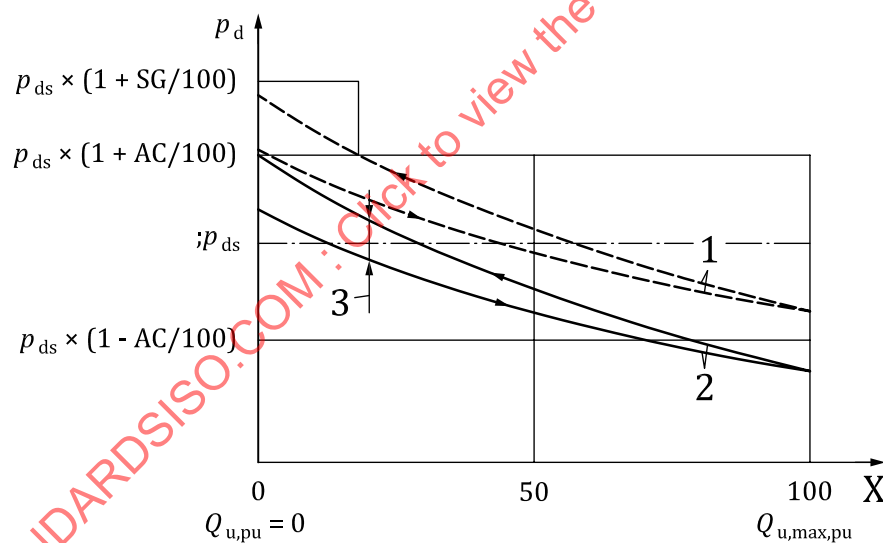
For C_g and K_1 values limit deviations of ± 10 % are permitted.



Key

- X travel in %
- 1 hysteresis band

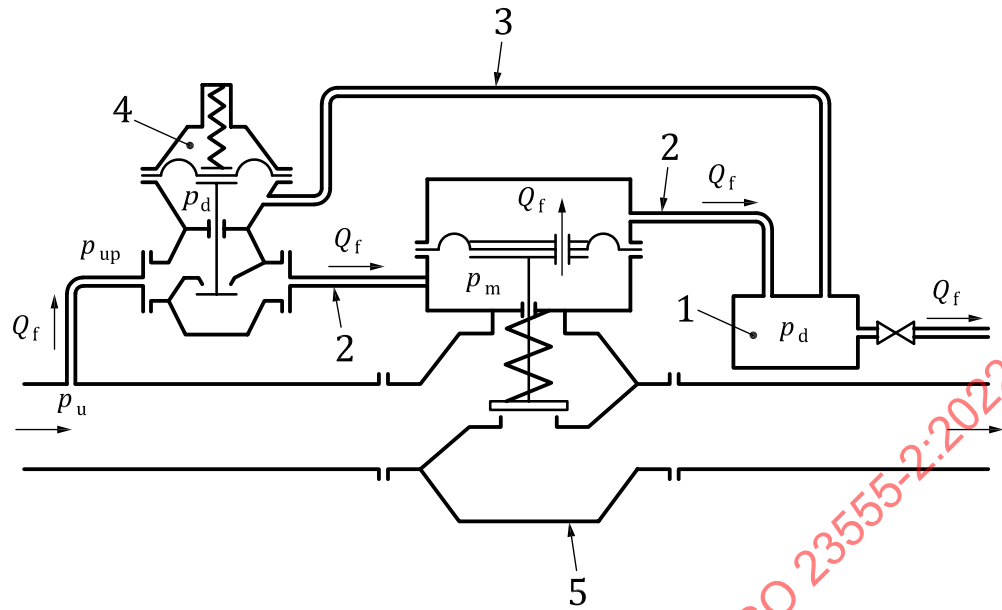
Figure E.1 — Outlet pressure plotted against different positions of the control member in a balanced direct acting regulator



Key

- X travel in %
- 1 corrected measured values to take account of unbalanced thrust
- 2 measured values
- 3 hysteresis band

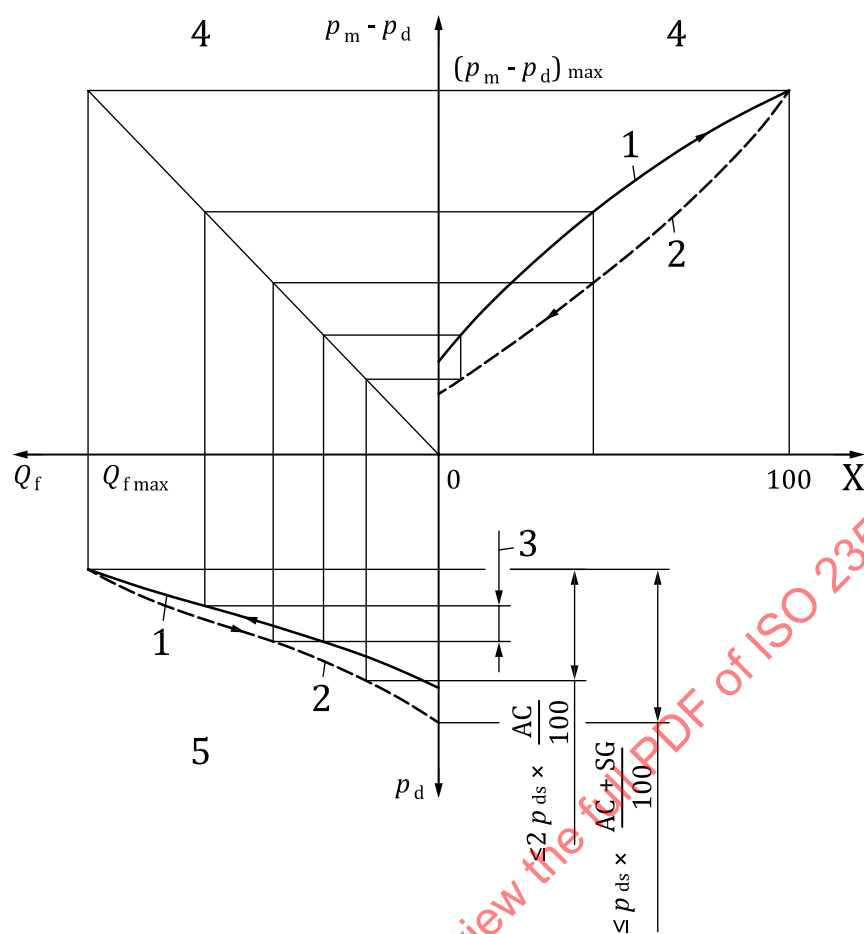
Figure E.2 — Outlet pressure plotted against different positions of the control member in an unbalanced direct acting regulator



Key

- 1 chamber for test purposes
- 2 process line
- 3 sensing line
- 4 pilot
- 5 regulator

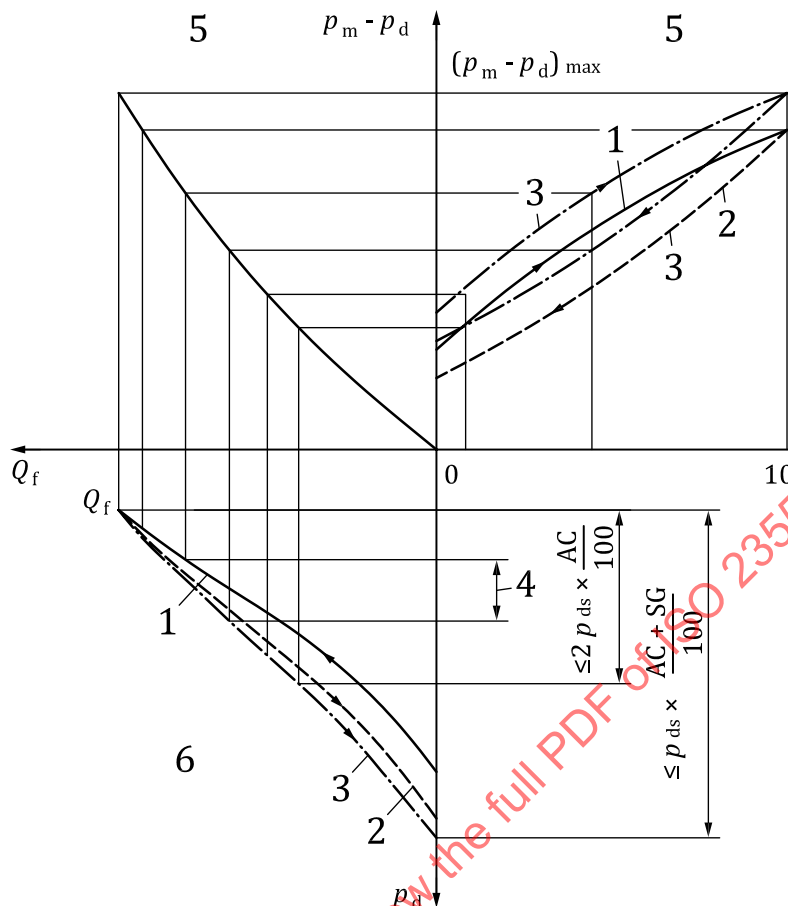
Figure E.3 — Functional diagram of a pilot-controlled regulator



Key

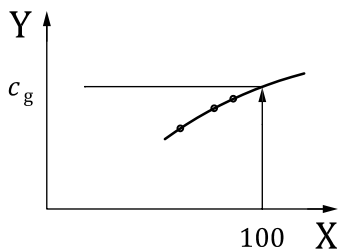
- | | |
|---|-----------------------|
| X | regulator travel in % |
| 1 | opening |
| 2 | closing |
| 3 | hysteresis band |
| 4 | regulator |
| 5 | pilot |

Figure E.4 — Graphs relating to the tests detailed in [E.2](#) for a balanced pilot-controlled regulator



- Key**
- X regulator travel in %
 - 1 opening
 - 2 closing
 - 3 corrected measured values to take account of unbalanced thrust
 - 4 hysteresis band
 - 5 regulator
 - 6 pilot

Figure E.5 — Graphs relating to the tests detailed in E.2 for an unbalanced pilot-controlled regulator



- Key**
- X travel in %
 - Y cgx
 - measured values

Figure E.6 — Graph of Cg values plotted against different positions of the control member

E.4 Determination of flow coefficients by calculation

The flow coefficients (C_g and K_G) are calculated by the computational fluid dynamics (CFD), after verification and validation of calculated values proofed to be equally suitable.

NOTE ASME V&V 20-2009 [R2016] can be used as a reference for verification and validation of calculation method by CFD.

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