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

6.2.1 Normal calculations

Volumetric flow rates should be calculated using the sizing equations of EN 60534-2-1.

6.2.2 Practical calculations

Normally, in the regulators field it is common to use the following equations:

a) sub-critical flow behaviour

A1⟩ $$Q=\frac{13,57}{\sqrt{d\times(t_u+273)}}\times C_g\times\frac{p_u+p_b}{2}\times\sin\left[K_1\times\sqrt{\frac{p_u-p_d}{p_u+p_b}}\right]_{deg} \quad (3)$$ ⟨A1

b) critical flow behaviour (see Equation (9) in 7.7.7.2.2)

A1⟩ $$Q=\frac{13,57}{\sqrt{d\times(t_u+273)}}\times C_g\times\frac{p_u+p_b}{2} \quad (4)$$ ⟨A1

where

C_g is the flow coefficient;

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

K_1 is the body shape factor;

p_b is the ambient atmospheric pressure in bar (absolute value);

t_u is the gas temperature at the inlet of the regulator under test in °C.

6.2.3 Simplified calculations

If $K_1 \leq 130$ and A1⟩ $(p_u - p_d) > 0,1 \times (p_u + p_b)$ ⟨A1 the following simplified equations may be used with an error less than 10 %:

a) sub-critical flow behaviour, where A1⟩ $(p_u - p_d) \leq 0,5 \times (p_u + p_b)$ ⟨A1:

A1⟩ $$Q=\frac{13,57}{\sqrt{d\times(t_u+273)}}\times C_g\times\sqrt{(p_d+p_b)\times(p_u-p_d)} \quad (5)$$ ⟨A1

b) critical flow behaviour, where $(p_u - p_d) > 0,5\,(p_u + p_b)$:

A1⟩ $$Q=\frac{13,57}{\sqrt{d\times(t_u+273)}}\times C_g\times\frac{p_u+p_b}{2} \quad (6)$$ ⟨A1

Conversion of the flow coefficients may be carried out by making reference to EN 60534-2-1.

NOTE The expression Ⓐ1 $\left[\frac{13{,}57}{\sqrt{d\times(t_u+273)}}\times C_g\right]$ Ⓐ1 is also known as K_G.

6.3 Calculation of the maximum accuracy flow rate

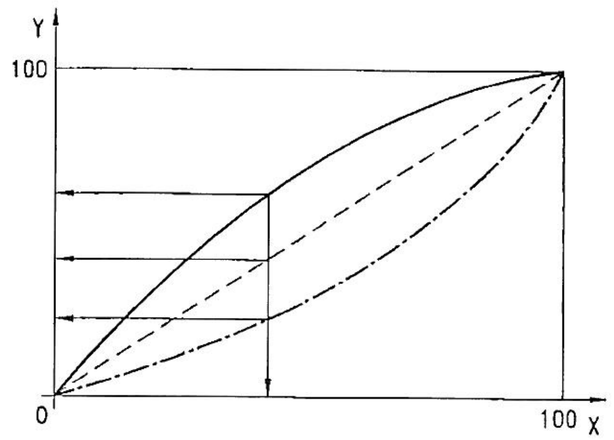
The maximum accuracy flow rate should be calculated from the equations given in 6.2 by using the applicable percentage of the flow coefficient at fully open position. This percentage which is equal to or less than 100, depends on the accuracy class AC and shall always be specified by the manufacturer (see Figures 5 and 9).

6.4 Inherent flow characteristics

The relationship between flow coefficient and the position of the control member is usually represented diagrammatically (see Figure 9). 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 9 gives examples of the inherent flow characteristics of three different types of regulator.

6.5 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 equations given in 6.2, 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 6.4.



Key

X Travel in %

Y C_g in %

Figure 9 — Three examples of inherent flow characteristics

6.6 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 ± 10 %.

7 Testing

7.1 General

Clause 7 provides guidance on the procedure that may be used when a certification of compliance with the requirements of this document is required.

The sub-clauses in Clause 7 may be applied also to the conformity assessment to the PED.

7.2 Tests

Table 13 gives an overview of the different types of tests and correlates them to the requirements and test methods detailed in Clauses 4, 5 and 7.

The requirements in this chapter shall be followed when compliance evaluation with this document is requested.

Where compliance evaluation to this document is finalized with positive result, the regulator can bear as marking the number of this document.

Table 13 — Summary of tests and requirements

Test schedule			Requirement	Test method	
T	M	S	Clause	Title	Clause
Constructional tests					
A	A	A	4.1	Dimensional check and visual inspection	7.7.1
A	A	A	4.2	Materials check	7.7.2
A			4.3	Verification of the strength of pressure containing parts and inner metallic partition walls	7.7.3
A	A	A	5.2.1	Shell and inner metallic partition walls strength test	7.7.4
A	A	A	5.2.2	External tightness test	7.7.6
Functional tests					
A			6.6	Determination of the flow coefficients	7.7.7.2
	A [a]	A	5.2.3	Check of internal sealing, setting, lock-up pressure and simplified test method for accuracy class	7.7.7.3
A			5.3.1.1 and 5.3.3	Determination of a performance curve and verification of the hysteresis band	7.7.7.4.2
A			5.2.3	Determination of the lock-up pressure and verification of the internal sealing	7.7.7.4.3
A			5.3	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 given range of inlet pressures	7.7.7.4.4
A			5.3.2.1	Operational check at the limit temperatures of -10 °C or -20 °C and 60 °C	7.7.7.4.5
optional			-	Methods for measuring the sound pressure level	7.7.7.4.6
A			5.4	Final visual inspection after type test	7.7.8.1
	A	A	7.7.8.2	Final visual inspection after routine tests and production surveillance	7.7.8.2

A = Applicable

S = Production surveillance

M = Routine tests

T = Type test

[a] Simplified test method for accuracy class is not required in the routine tests.

7.3 Type test

Those tests (see Table 13) carried out to establish the performance classification of the regulator or the series of regulators. These tests include verification of the documentation listed in 8.1.1.

When changes are made to the design of a regulator or a series of regulators in such a manner as to affect the above tests, the manufacturer shall inform the parties involved, if any, in the compliance evaluation to this document.

7.4 Selection of test samples

The number and types of a series of regulators to be subjected to a type test shall be selected according to the following requirements:

— one regulator for each type of fixture and/or pilot;

— two sizes from a series of up to six sizes and three sizes from series greater than six in number;

— one regulator for each accuracy class AC, if applicable;

— if the series of regulators includes sizes of regulators with more than one valve seat diameter, the test sample shall have the largest valve seat installed.

The check in accordance with 7.7.7.4.5 shall only be carried out on one test sample.

7.5 Routine tests

Those tests (see Table 13) carried out on each regulator by the manufacturer during the production process. The tests verify that materials, dimensions, external conditions and performance remain in compliance with the results of the type test.

Routine tests for integrated safety devices, if any, shall be those detailed in EN 14382.

7.6 Production surveillance

Those tests and verifications (see Table 13) carried out in order to confirm continuing compliance with this document.

The tests and verifications include additionally:

— verification of the routine tests records;

— verification of drawings and material certificates.

7.7 Test and verification methods

7.7.1 Dimensional check and visual inspection

The actions to assess:

— the dimensional compliance of pressure containing parts with the applicable drawings;

— the compliance of the regulator construction with the A1) related (A1 assembly drawing and the construction requirements of this document.

7.7.2 Materials check

The actions to assess the compliance of the materials used or prescribed with the requirements in 4.2.

The verification of the materials used shall be carried out by the review of the material certificates.

The verification of the materials prescribed shall be carried out by the review of the A1) part list (A1.

7.7.3 Verification of the strength of pressure containing parts and inner metallic partition walls

7.7.3.1 Strength calculation method

Verification is made by proving the compliance of the actual safety factors with those specified in 4.3.5 and the compliance of minimum allowable thicknesses shown in drawings with values specified in the strength calculations.

Strength calculation [A1) shall (A1] be carried out according to EN 12516-2 and [A1) EN 12516-4 (A1].

7.7.3.2 Experimental design method

Verification is made by proving the compliance of the actual safety factors with those specified in 4.3.5 taking into account the minimum allowable thicknesses shown in drawings and the minimum proof stress (yielding) for selected material.

Actual safety factors are obtained through one of the following two ways:

— hydrostatic pressure test applied until the first sign of yielding or failure becomes apparent in any component and verification that the limit pressure p_l at which the first sign of yielding or failure becomes apparent is:

[A1) $p_l \geq PS \times S_b \times \frac{s_{ry}}{s_{min}} \times \frac{|R_{p0,2}|_r}{|R_{p0,2}|_{min}}$ (A1] for the body only;

$p_l \geq PS \times S \times \frac{s_{ry}}{s_{min}} \times \frac{|R_{p0,2}|_r}{|R_{p0,2}|_{min}}$ for other components;

— hydrostatic pressure test and verification that permanent deformations do not exceed the values stated in 5.2.1 up to the following test pressures:

$0{,}9 \times PS \times S_b \times \frac{s_{rw}}{s_w} \times \frac{|R_{p0,2}|_r}{|R_{p0,2}|_{min}}$ for the body only;

$0{,}9 \times PS \times S \times \frac{s_{rw}}{s_w} \times \frac{|R_{p0,2}|_r}{|R_{p0,2}|_{min}}$ for other components;

where

s_{min} is the minimum design wall thickness at the point where the first sign of yielding occurs in mm;

s_{ry} is the measured wall thickness of test sample at the point where the first sign of yielding occurs in mm;

$|R_{p0,2}|_{min}$ is the minimum proof stress (yielding) for selected material in N/mm^2;

$|R_{p0,2}|_r$ is the measured proof stress (yielding) for the material of the test sample according to relevant document [A1) *deleted text* (A1] in N/mm^2;

s_w is the minimum design wall thickness for the weakest point in mm;

s_{rw} is the measured wall thickness of test sample at the weakest point in mm.

The weakest point can be located by technical evaluation or A1) by (A1 measurements (strain gauge etc.).

The test is carried out in such a manner that deformations of the test sample in all directions are possible. There shall be no additional stresses due to bending, torque or tension.

Forces from fastening systems shall be similar to those experienced under normal installation conditions.

Regulator bodies and pressure containing parts manufactured from different materials may be pressure tested separately.

A1) Special high strength clamping bolts and nuts and gaskets (between individual pressure containing parts) may be used for hydrostatic testing. (A1

A1) For the components with the specific maximum allowable pressure PSD, in the above two formulae (not in those referred to body) replace the symbol "PS" with the symbol "PSD". (A1

Diaphragms used as pressure containing parts in chambers subjected, or that can be subjected to a maximum differential pressure Δp_{max} shall withstand a test pressure (in bar) of at least:

— 0,3 bar if Δp_{max} < 0,15 bar;

— 2 Δp_{max} if 0,15 bar ≤ Δp_{max} < 5 bar;

— 1,5 Δp_{max} but at least 10 bar if Δp_{max} ≥ 5 bar.

7.7.4 Shell and inner metallic partition walls strength test

Pressure containing parts, A1) including (A1 those that become pressure containing parts in case of a diaphragm or differential pressure seal failure and inner metallic partition walls shall be pressure tested. The test is carried out with water at ambient temperature at a pressure according to the values in Table 14 for 3 min. The criteria of 5.2.1 shall be met.

The test is carried out in such a manner that deformations of the test sample in all directions are possible. There shall be no additional stresses due to bending, torque or tension.

Forces from fastening systems shall be similar to those experienced under normal installation conditions at least during the type test.

The test may be carried out without trim (i.e. the internal parts that are in flowing contact with gas).

The test may also be carried out with air or nitrogen, if the necessary safety measures are taken.

Chambers separated by diaphragms are pressurized on both sides of the diaphragm at equal pressure.

Table 14 — Pressure values for the shell strength test

A1

Chambers with the maximum allowable pressure PS	Chambers with specific maximum allowable pressure PSD
Test pressures	
1,5 PS but at least PS + 2 bar whichever is the greater	1,5 PSD but at least PSD + 2 bar whichever is the greater

A1

7.7.5 Alternative shell and inner metallic partition walls strength test

Hydrostatic pressure tests as detailed in 7.7.4 may be replaced by other tests (e.g. pneumatic test) whose reliability shall be demonstrated. For tests other than the hydrostatic pressure test, additional safety measures, when appropriate, such as non-destructive tests or other methods of equivalent validity, shall be applied before those tests are carried out.

7.7.6 External tightness test

7.7.6.1 External tightness test of metallic housing

The assembled regulator and its fixtures are pneumatically tested to assess compliance with the requirements of 5.2.2. The test is carried out at ambient temperature with air or gas at the test pressure specified in Table 15. This test shall be carried out on a strength-tested regulator for at least:

— 15 min in the type test;

— 1 min in the routine tests and in the production surveillance.

The result of the test is satisfactory if one of the following conditions is met:

— bubble tight for a time of 5 s. This test may be carried out by covering the regulator with a foaming liquid, by immersing the regulator in a tank of water or by other equivalent methods;

— external leakage not higher than the values listed in Table 16.

The test pressures in Table 15 do not apply to any chambers bounded on at least one side by a diaphragm even if they are subjected to gas pressure under normal operating conditions.

The test is carried out in such a manner that deformations of the A1 regulator A1 in all directions are possible. There shall be no additional stresses due to bending, torque or tension.

Forces from fastening systems shall be similar to those experienced under normal installation conditions at least during the type test.

Recognized alternative detection methods may be used for checking leakage (e.g. electronic device). For such methods the equivalence to the above requirements shall be demonstrated.

Table 15 — Pressure values in the external tightness test

Chambers subjected, or that can be subjected to gas pressures		A1 Chambers safeguarded in accordance with 4.3.3 with specific maximum allowable pressure PSD A1
$> p_d$	$\leq p_d$ [a]	
Test pressures		
1,1 PS	1,2 p_{ds} max but at least 0,5 PS whichever is the greater	A1 1,1 PSD A1

[a] Only if PS ≤ 20 bar. For PS > 20 bar the test pressure shall be 1,1 PS.

Table 16 — Maximum external and internal leakage rates

Nominal size DN	Air leakage rate in cm^3/h [a]	
	external	internal [b]
25	40	15
40 to 80	60	25
100 to 150	100	40
200 to 250	150	60
300 to 350	200	100
400	400	300

[a] At normal conditions.

[b] In case of specific requirement in the order specification, see Annex E.

7.7.6.2 External tightness test of chambers bounded on at least one side by a diaphragm

Such chambers shall be pneumatically tested at a test pressure (in bar) equal to at least:

— 0,2 bar if Δp_{max} < 0,15 bar;

— 1,33 Δp_{max} if 0,15 bar ≤ Δp_{max} < 5 bar;

— 1,1 Δp_{max} but at least 6,65 bar if Δp_{max} ≥ 5 bar.

Test method and acceptance criteria in accordance with 7.7.6.1.

7.7.7 Functional tests

7.7.7.1 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 will 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 7.7.7.4, 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.

7.7.7.2 Determination of the flow coefficients

7.7.7.2.1 Normal method

If the volumetric flow rates are calculated using the sizing equations of EN 60534-2-1, the tests shall be carried out in accordance with EN 60534-2-3.

7.7.7.2.2 Practical method

If in the flow calculation the equations given in 6.2 are being used then the following equations shall be used to calculate flow coefficient C_g and the body shape factor K_1.

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 8 of 6.1. The C_g shall be determined for at least three different operating conditions in the critical flow behaviour with:

A1⟩ $$C_g = \frac{2 \times Q \times \sqrt{d \times (t_u + 273)}}{13{,}57 \times (p_u + p_b)}$$ ⟨A1 (7)

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 6.2.2) shall be determined for at least three different operating conditions in the sub-critical flow behaviour with:

A1⟩ $$K_1 = \frac{\arcsin\left[\frac{Q \times \sqrt{d \times (t_u + 273)}}{13{,}57 \times C_g} \times \frac{2}{p_u + p_b}\right]_{deg}}{\sqrt{\frac{p_u - p_d}{p_u + p_b}}}$$ ⟨A1 (8)

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

For C_g and K_1 shape values a tolerance of ± 10 % is permitted.

The behaviour shall be assumed to be critical when:

$$\frac{p_u + p_b}{p_d + p_b} \geq \frac{1}{1 - \left(\frac{90}{K_1}\right)^2} = \frac{K_1^2}{K_1^2 - 8100}$$ (9)

In the equations (7) and (8) Q is the volumetric flow rate at normal conditions of the test fluid as measured by the flow meter 9 in Figure 14. The measured values shall be converted into values related to the normal conditions specified in A1⟩ 3.3.2.1 ⟨A1. The calculation of Q shall be carried out using the following equation:

$$\text{A}_1\rangle\ Q = \frac{p_M + p_b}{p_n} \times \frac{T_n}{t_M + T_n} \times Q_M = 269{,}64 \times \frac{p_M + p_b}{t_M + 273} \times Q_M\ \langle\text{A}_1 \qquad (10)$$

where

for p_n and T_n see A1⟩ 3.3.2.1 ⟨A1;

p_M is the gas pressure at the flow meter;

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

t_M is the gas temperature at the flow meter in °C.

The tests shall be carried out where technical possible and economically justified on a test rig in accordance with 7.7.7.4.7. Where this is not the case, alternative test and calculation methods e.g. that detailed in A.3 may be used for the determination of flow coefficient C_g.

7.7.7.3 Check of internal sealing, set point, lock-up pressure class and simplified test method for accuracy class

These tests shall be carried out with volumetric flow rates greater than $Q_{min,pu}$ 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;

e) measure the value of outlet pressure p_d;

f) repeat the above steps from a) to c) without any further adjustment of the setting;

g) reduce the volumetric flow rate until complete lock-up takes place within a period not less than the response time of the regulator;

h) increase the inlet pressure up to 1,1 PS;

i) 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 7.7.7.4.7 is not mandatory.

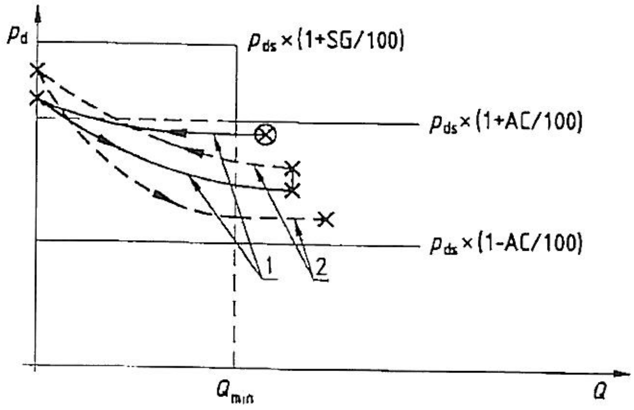
If a detection method is available to verify compliance with the required internal leakage rates given in Table 16, an alternative procedure may be followed to check the internal sealing and to measure the lock-up pressure at p_{umin} and p_{umax}.

In this case the determined leakage rates shall comply with:

— the requirements of Table 16 or

— the requirements of EN 1349 if specified in the order specification (see Annexes E and G).

[A1)



(A1]

Key

1 p_{umin}

2 p_{umax}

⊗ Setting

× Measured value

[A1)

⋈ p_u = 1,1 PS (A1]

Figure 10 — Graphical representation of the tests detailed in 7.7.7.3

7.7.7.4 Functional tests under stable conditions

7.7.7.4.1 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;

— maximum hysteresis band, if specified in the order specification;

— lock-up pressure class;

— class of lock-up pressure zone;

— 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 7.7.7.4.7.

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

a) 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 7.7.7.4.7;

b) 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;

c) 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 can not be tested using a test rig in accordance with 7.7.7.4.7, the test method as detailed in Annex A 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.

7.7.7.4.2 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 (Figure 14) 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 (Figure 14) shall be recalculated to refer to:

— normal conditions (see A1) 3.3.2.1 (A1);

— air at the reference temperature of 15 °C at the inlet of the regulator under test.

To this end the following equation shall be used:

A1)

$$Q = Q_M \times \frac{p_M + p_b}{p_n} \times \frac{T_n}{t_M + T_n} \times \frac{\sqrt{d \times (t_u + T_n)}}{\sqrt{1 \times (15 + T_n)}} = 15{,}88 \times \frac{p_M + p_b}{t_M + 273} \times Q_M \times \sqrt{d \times (t_u + 273)} \quad (11)$$ ⟨A1]

where

for p_n and T_n see [A1⟩ 3.3.2.1 ⟨A1];

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

p_M is the gas pressure at the flow meter;

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

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

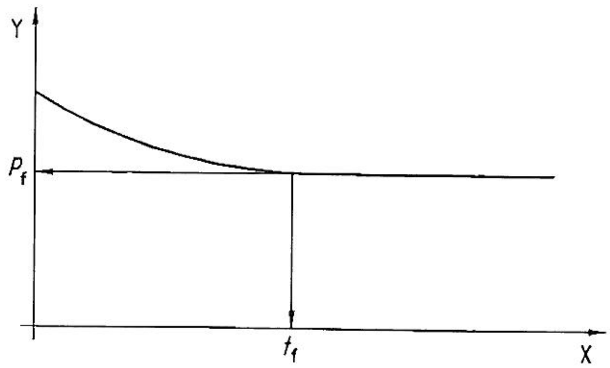
t_u is the gas temperature in °C at the inlet of regulator under test.

At least 11 different measurements conveniently distributed over the full range of values between Q_{min} and Q_{max} (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 3 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.

7.7.7.4.3 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).



X Time to reduce the volumetric flow rate to zero

Y Pressure with control member at closing position

Figure 11 — Graphical representation of 7.7.7.4.3

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 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 the following equation:

A1 $$p_f = \frac{t + 273}{t_i + 273} \times (p_{fi} + p_b) - p_b$$ A1 (12)

where

p_b is the absolute ambient pressure;

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

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

t_i is the gas 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:

— Table 16 or

— EN 1349 if specified in the order specification (see Annexes E and G).

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 Figure 14.

The internal sealing of regulator shall also be verified at:

— inlet pressure of 1,1 PS;

— outlet pressure of zero.

7.7.7.4.4 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 given range of inlet pressures

The determination is based on optimal enveloping of each family of performance curves with the vertical and horizontal limit lines as shown in Figure 5. 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;

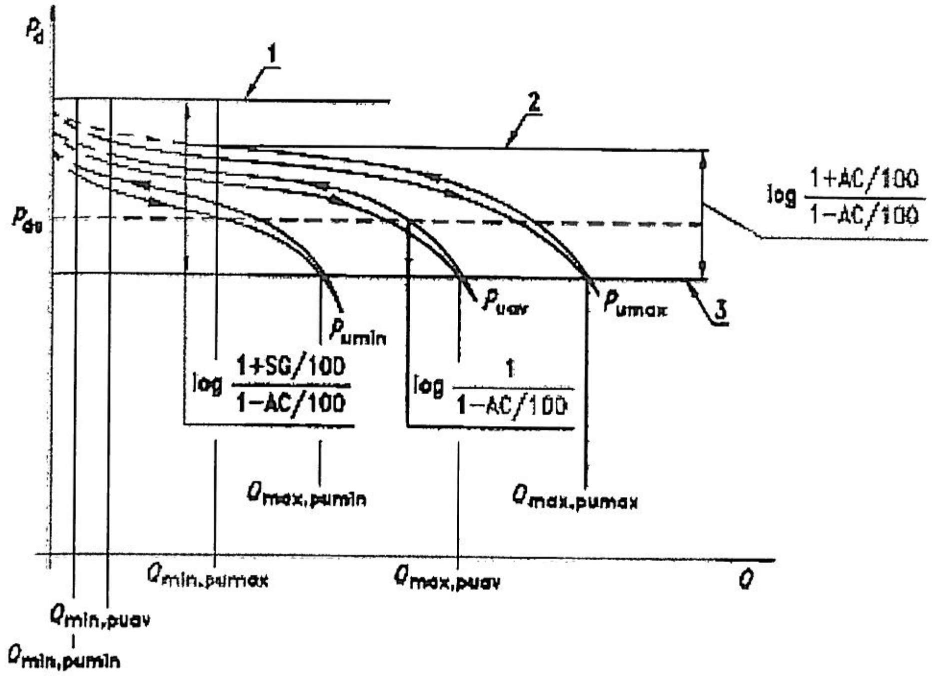
— locate on this diagram, in an optimized manner, three horizontal lines spaced as shown in Figure 12; the optimization of the location of these lines is reached when the greatest possible number of performance requirements are met;

— identify the actual set point where the dashed horizontal line intersects the ordinate;

— ensure that $Q_{max,puav}$, $Q_{max,pumin}$, $Q_{max,pumax}$, $Q_{min,pumax}$, $Q_{min,puav}$, $Q_{min,pumin}$, 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.



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 example of 7.7.7.4.4

7.7.7.4.5 Operational check at the limit temperatures of –20 °C or –10 °C and 60 °C

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

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 7.7.7.4.3 under the following conditions:

— max inlet pressure/min outlet pressure;

— min inlet pressure/min outlet pressure;

at the relevant temperatures.

[A1) The lock-up pressure at the -10 °C and at the -20 °C limit temperatures shall be: (A1]

[A1) $$p_f \leq p_{ds} \times \left(1 + \frac{2\,SG}{100}\right)$$ (A1]

[A1) except when, at ambient temperature, SG = 30. In this case the SG = 30 may be multiplied by 1,5.

EXAMPLES At ambient temperature SG 5 may change to SG 10 both at –20 °C and at –10 °C. At ambient temperature SG 30 may change to SG 45 both at –20 °C and at –10 °C. (A1]

[A1) The lock-up pressure at upper limit temperature shall be: (A1]

[A1) $$p_f \leq p_{ds} \times \left(1 + \frac{SG}{100}\right)$$ (A1]

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

A check to determine the control member travel of the regulator shall also be carried out at no flow condition in order to demonstrate that the regulator can fully open.

If specified in the order specification, alternative methods in accordance with Annex A may be used.

After this check, the test in accordance with 7.7.6 is repeated at the lower limit temperatures.

7.7.7.4.6 Methods for measuring the sound pressure level

The fully assembled regulator with all its fixtures shall be installed:

— at between 0,8 m and 1,2 m above floor level;

— in accordance with the requirements specified in 7.7.7.4.7 with regard to the velocities of the gas in the test rig.

The floor shall be one of normal concrete or similar construction. Care shall be taken to ensure that any possible effects of sound emissions other than the noise generated by the regulator are excluded (for example noise generated by the flow rate regulating valve or the external environment). The points of measurement of sound emission shall be in accordance with Figure 7.

The sound pressure level measurement may be carried out on a test rig built in accordance with Figure 14 if the above requirements are met.

The results of the measurements shall be expressed in such a way as to conform with relevant regulations and the requirements of this document.

The test report shall include the following data:

— test procedure;

— thickness and nominal diameter of inlet and outlet pipes;

— indication of the point at which the measured sound level is the highest;

— the units of measurement used to express the results.

7.7.7.4.7 Test rig requirements

The requirements detailed in this sub-clause are mandatory only for type testing.

The tests shall be carried out on a test rig built as specified in Figure 14 or in accordance with EN 60534-2-3 as appropriate. The nominal diameter of the pipework connecting the full bore valves and the flow rate regulating valves with the regulator shall not be smaller than the nominal diameter of the regulator and so chosen as to ensure that in all operating conditions during the tests the velocity of the gas does not exceed:

— 50 m/s for pressure ≥ 0,5 bar;

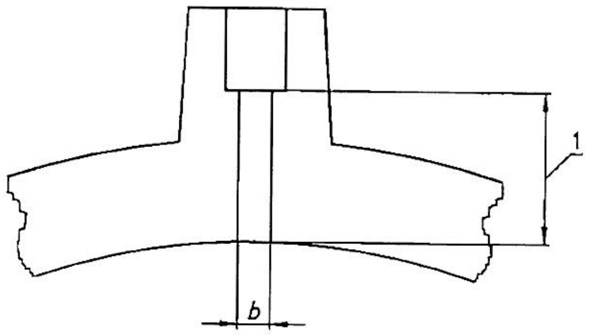
— 25 m/s for pressures < 0,5 bar.

The connections between the regulator and the test rig pipework shall be made using concentric reducers according to ISO 3419 or equivalent. The pressure tapping diameter *b* shown in Figure 13 shall be at least 3 mm and shall be no larger than 12 mm or one-tenth of the nominal pipe diameter, whichever is the lesser. The tapping shall be circular and its edge shall be clean and sharp or slightly rounded and free from burrs or other irregularities. Any suitable method of making a physical connection is acceptable provided the above recommendations are followed. However, fittings shall not protrude inside the pipework.

In the event of unstable conditions due to volumetric flow rate variations consequent to the operation of the flow regulating valve 8 (see Figure 14), it is permissible to increase the length of the pipework connecting the flow regulating valve 8 (see Figure 14) to the regulator, or to provide for an additional volume by installing a parallel line or reservoir.

The lock-up pressure tests shall always be carried out on a test rig in which the downstream pipework has the minimum specified length; for these tests an additional downstream volume is not permitted. The flow meter shall be installed in accordance with the instructions of the manufacturer.

NOTE For alternative test methods under the conditions of 7.7.7.4.1 see also Annex A.



Key

1 Minimum 2,5 *b*, recommended 5 *b*

Figure 13 — Recommended pressure tapping