FINAL
DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 6953-2

ISO/TC **131**/SC **5**

Secretariat: **AFNOR**

Voting begins on:
2023-08-17

Voting terminates on:
2023-10-12

Pneumatic fluid power — Compressed air pressure regulators and filter-regulators —

Part 2: **Test methods to determine the main characteristics to include in supplier's literature**

Transmissions pneumatiques — Régulateurs de pression et filtres-régulateurs pour air comprimé —

Partie 2: Méthodes d'essai pour déterminer les principales caractéristiques à inclure dans la documentation des fournisseurs

RECIPIENTS OF THIS DRAFT ARE INVITED TO SUBMIT, WITH THEIR COMMENTS, NOTIFICATION OF ANY RELEVANT PATENT RIGHTS OF WHICH THEY ARE AWARE AND TO PROVIDE SUPPORTING DOCUMENTATION.

IN ADDITION TO THEIR EVALUATION AS BEING ACCEPTABLE FOR INDUSTRIAL, TECHNOLOGICAL, COMMERCIAL AND USER PURPOSES, DRAFT INTERNATIONAL STANDARDS MAY ON OCCASION HAVE TO BE CONSIDERED IN THE LIGHT OF THEIR POTENTIAL TO BECOME STANDARDS TO WHICH REFERENCE MAY BE MADE IN NATIONAL REGULATIONS.

Reference number
ISO/FDIS 6953-2:2023(E)

Contents

Page

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 131, *Fluid power systems*, Subcommittee SC 5, *Control products and components*.

This third edition cancels and replaces the second edition (ISO 6953-2:2015), which has been technically revised.

The main changes are as follows:

— addition of new paragraph for an additional test for relief flow rate (7.3.3);

— addition of new paragraph for a test for resolution in case of pressure-pilot air pressure regulator (10.3);

— addition of new detailed test procedure for repeatability test for manual air-pressure regulator and pilot pressure air-pressure regulator (10.5);

— addition of measure of the sensitivity.

A list of all parts in the ISO 6953 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

In pneumatic fluid power systems, power is transmitted and controlled through a gas under pressure within a circuit.

When pressure reduction or pressure regulation is required, regulators and filter-regulators are components designed to maintain the pressure of the gas at an approximately constant level.

It is therefore necessary to know the performance characteristics of these components in order to determine their suitability in an application.

Pneumatic fluid power — Compressed air pressure regulators and filter-regulators —

Part 2: Test methods to determine the main characteristics to include in supplier's literature

1 Scope

This document specifies test procedures and a method of presenting the results concerning the parameters which define the main characteristics to be included in the literature from suppliers of regulators and filter-regulators conforming to ISO 6953-1.

The purpose of this document is to:

— facilitate the comparison of pressure regulators and filter-regulators by standardizing test methods and presentation of test data;

— assist in the proper application of pressure regulators and filter-regulators in compressed air systems.

The tests specified are intended to allow comparison among the different types of regulators and filter-regulators; they are not production tests to be carried out on each pressure regulator or filter-regulator manufactured.

ISO 6953-3 can be used as an alternative dynamic test method for flow-rate characteristics using an isothermal tank instead of a flow meter. However, this method measures only the decreasing flow rate part of the hysteresis curve of forward flow and relief flow characteristics.

NOTE The tests related to electro-pneumatic pressure control valves are specified in ISO 10094–2.

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 3448, *Industrial liquid lubricants — ISO viscosity classification*

ISO 5598, *Fluid power systems and components — Vocabulary*

ISO 6358-1, *Pneumatic fluid power — Determination of flow-rate characteristics of components using compressible fluids — Part 1: General rules and test methods for steady-state flow*

ISO 6953-1:—[1], *Pneumatic fluid power — Compressed air pressure regulators and filter-regulators — Part 1: Main characteristics to be included in literature from suppliers and product-marking requirements*

ISO 10094-1, *Pneumatic fluid power — Electro-pneumatic pressure control valves — Part 1: Main characteristics to include in the supplier's literature*

1) Under preparation. Stage at the time of publication: ISO/FDIS 6953-1:2023.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598, ISO 6358-1, ISO 6953-1 and ISO 10094-1 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/

4 Symbols and units

The symbols and units used in this document are shown in Table 1.

Table 1 — Symbols and units

Description	Symbol	SI unit	Practical unit
Reference atmosphere	p_{atm}	Pa	kPa or bar
Inlet pressure	p_1	Pa	kPa or bar
Regulated pressure	p_2	Pa	kPa or bar
Pilot pressure	w	Pa	kPa or bar
Forward volumetric flow rate at standard reference atmosphere	q_{vf}	m^3/s (ANR)	dm^3/min (ANR)
Relief volumetric flow rate at standard reference atmosphere	q_{vr}	m^3/s (ANR)	dm^3/min (ANR)
Sonic conductance	C_f	kg / (s.Pa) (ANR)	m^3 / (s.Pa)(ANR)
Reference temperature	T_0	K	°C
Inlet temperature	T_1	K	°C
Temperature at the regulated port	T_2	K	°C
Hysteresis	H	-	% FS
Resolution	S	-	% FS
Output resolution	S_o	-	% FS
Sensitivity	m	-	Pa/Pa or Pa/number of turns of control knob
Repeatability	r	-	% FS

Key

ANR standard reference atmosphere (see ISO 8778)

FS full scale

NOTE 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm^2.

5 Test conditions

5.1 Gas supply

Unless otherwise specified, testing shall be conducted with compressed air. If another gas is used, it shall be noted in the test report.

5.2 Temperature

The ambient fluid and the component under test shall be maintained at 23 °C ± 10 °C during all the tests.

5.3 Pressures

The specified pressures shall be maintained within ±2 %.

5.4 Inlet pressure

The inlet pressure used for testing shall be the lower of the following pressures:

— the maximum regulated pressure, $p_{2,\text{max}}$, plus 200 kPa (2 bar);

— the specified maximum inlet pressure, $p_{1,\text{max}}$.

5.5 Test pressures (regulated pressure)

The preferential test pressures are chosen as approximately equal to 20 %, 40 %, 60 %, and 80 % of the upper limit of the recommended adjustable pressure range.

6 Test procedure to verify rated pressure

6.1 Perform this test on three random samples if a single-rated pressure is proposed for the entire product or on six random samples if separate ratings are proposed for the inlet and outlet sections. If the product uses a diaphragm, modify or replace it to withstand the pressure applied (diaphragms are excluded from the test criteria, but not the diaphragm support plates or any piston). Other product sealing means can be modified to prevent leakage and allow structural failure to occur during the test, but modifications shall not increase the structural strength of the pressure-containing envelope. For relieving regulators, the relieving system shall be blocked.

6.2 Prepare the test samples as follows:

a) If a single pressure rating is proposed for the entire product, remove the control spring and replace it with a solid spacer whose length maintains the poppet in its approximately half-open position. Close the gauge ports and the inlet port with plugs, and perform all testing by applying pressure to the outlet port. For relieving regulators, the relieving system shall be blocked.

b) If a separate pressure rating is proposed for the inlet and outlet sections of the regulator, relieve the control spring force on three of the samples. Using a proposed pressure rating for the inlet, perform testing on the inlet port, allowing the poppet to be closed and keeping the outlet port open. Prepare the other three samples as described in 6.2 a) and test them using a proposed pressure rating for the outlet port.

6.3 The test shall be done with a liquid which does not exceed ISO VG 32 according to ISO 3448 or with compressed air. Maintain the temperature given in 5.2. When using a compressible medium, exercise safety precautions to contain an explosive failure.

6.4 After stabilizing the temperature, slowly pressurize to a level of one-half its proposed rated pressure. Hold at this level for 2 min and observe for leakage or failure, as defined in 6.5.

6.4.1 For products constructed of light alloys, brass, and steel, continue raising the pressure until a level of four times the proposed rated pressure has been reached.

6.4.2 For products constructed of zinc, die cast alloys, or plastics:

— with design operating temperatures of up to 50 °C, continue raising the pressure until a level of four times the proposed rated pressure has been reached;

— with design operating temperature between 50 °C to 80 °C, continue raising the pressure until a level of five times the proposed rated pressure has been reached.

6.5 The criteria for a failure are: a fracture, separation of parts, or a crack, or that which can allow enough liquid to pass across the pressure-containing envelope to wet the outer surface. Leakage across the port threads shall not constitute a failure, unless caused by a fracture or a crack.

6.6 The proposed rated pressure is verified if all three samples pass their respective tests.

6.7 Where a unit or sub-assembly in the unit (e.g. reservoir sight glass) is constructed of different materials, the higher appropriate factor should be used. The applied pressure can be restricted to the area of the interface between the different materials.

6.8 Where the pressure-containing envelope design is covered by a pressure vessel code in the market of sale, the requirements of that code take precedence over the requirements stated in this document.

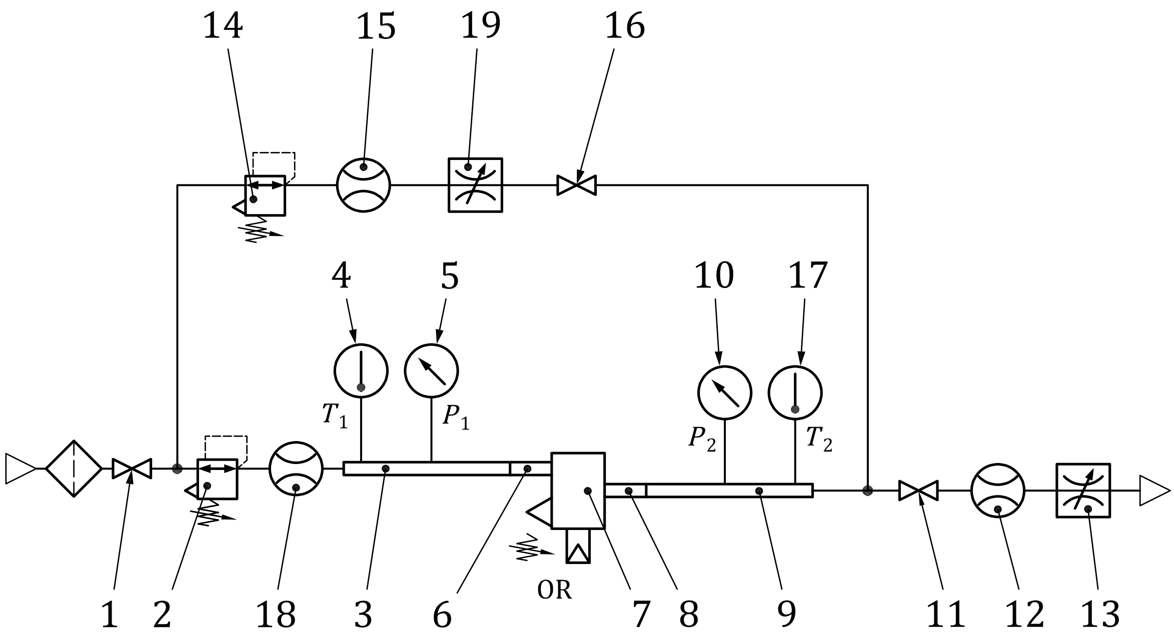
7 Flow characteristics tests

7.1 Test installation

A suitable test circuit as shown in Figure 1 shall be used for measuring forward or relief flow rates. This test circuit combines:

— the constant upstream pressure (in-line) test circuit, as described in ISO 6358-1 for characterizing the components with upstream and downstream pressure-measuring tubes and transition connectors (used for forward flow rate measurements), and

— the variable upstream pressure (exhaust-to-atmosphere) test circuit, as described in ISO 6358-1 (used for relief flow rate measurements).



Key

1	inlet shut-off valve	11	ball valve
2	inlet pressure regulator	12	forward flow meter
3	pressure-measuring tube	13	flow control valve (for forward flow rates)
4	inlet temperature, T_1, measuring-element	14	pressure regulator (for relief flow rates)
5	inlet pressure, p_1, gauge or transducer	15	relief flow meter
6	transition connector	16	ball valve

7 component under test
8 transition connector
9 pressure-measuring tube
10 regulated pressure, p_2, gauge or transducer
17 temperature, T_2, measuring-element (for relief flow rates)
18 flow meter
19 flow control valve (for relief flow rate)

NOTE Item 18 is optional for measuring forward flow rates but only for non-bleeding regulators.

Figure 1 — Test circuit for flow rate-pressure characterization

7.2 General requirements

7.2.1 The component under test (key reference 7 in Figure 1) shall be located in the test circuit so as to connect its inlet port to the upstream transition connector and pressure-measuring tube. Its outlet port is connected to a transition connector and a pressure-measuring tube enabling a measurement of the regulated pressure, p_2. For the relief flow test, air passes through the vent passages to the atmosphere.

7.2.2 Pressure-measuring tubes (key references 3 and 9 in Figure 1) and transition connectors (key references 6 and 8) shall be in accordance with ISO 6358-1.

7.2.3 The components shown as 1, 2, 3, 4, 5, and 6 in Figure 1 correspond to the upstream part of the test circuit used for forward flow measurements. These components shall remain in place for the relief flow rate measurements, and the inlet port of the component under test shall be pressurized from the supply circuit.

7.2.4 Components shown as 8, 9, 10, 11, 12, and 13 in Figure 1 correspond to the downstream part of the test circuit used for forward flow rate measurements.

7.2.5 Components shown as 14, 15, 19, 16, 9, 10, 17, and 8 in Figure 1 correspond to the upstream part of the test circuit used for relief flow rate measurements.

7.2.6 The sonic conductance of the pressure regulator (2), ball valve (11) and maximal sonic conductance of the flow control valve (13) in Figure 1 should each be at least twice the forward sonic conductance of the component under test. The sonic conductance of the pressure regulator (14), maximal sonic conductance of the flow control valve (19) and ball valve (16) should each be at least twice the relief sonic conductance of the component under test.

7.3 Test procedures

7.3.1 Initial test procedure

7.3.1.1 Install the regulator according to Figure 1, with shut-off valve (1), ball valves (11 and 16), and flow control valve (13) closed.

7.3.1.2 Open shut-off valve (1) and adjust pressure regulator (2) to apply an inlet pressure, p_1, chosen according to 5.4. During every measurement concerning the static tests described in 7.3.2, 7.3.3, and 7.3.4, the inlet pressure shall be maintained within the tolerance specified in 5.3 [this can require constant readjustment of regulator (2)].

7.3.1.3 Increase the set pressure on the component under test until it reaches the regulated pressure value, p_2, corresponding to 20 % of the regulated pressure full scale.

7.3.1.4 Follow successively the procedure described in 7.3.2 for forward flow rates and then the procedure described in 7.3.3 for relief flow rates.

7.3.2 Forward flow rate-pressure characteristics test

7.3.2.1 Open the ball valve (11 in Figure 1). Then, slowly open the flow control valve (13) and let a low flow rate of air pass through the component under test.

7.3.2.2 When the flow is steady, measure the forward flow rate using the flow meter (12), the corresponding regulated pressure, p_2, using the pressure transducer (10) and the inlet temperature, T_1.

7.3.2.3 Continue the measurements by gradually increasing the flow rate in steps, recording data after conditions in each step are stable. Continue this process until the maximum flow rate is achieved in the test circuit. Measure additional data for a decreasing forward flow rate, also in steps, until the flow is near zero (item 13 is closed). During the variations of the forward flow (increasing and decreasing), keep the inlet pressure, p_1, within the tolerance specified in 5.3.

7.3.3 Relief flow rate-Pressure characteristics test

7.3.3.1 Open completely the flow control valve (19 in Figure 1). Set the pressure regulator (14) at the same pressure value as the regulated pressure value of the component under test, obtained without flow at the end of the procedure described in 7.3.2.3. Close the ball valve (11) and open the ball valve (16) to apply this pressure on the outlet side of the component under test. Air can begin to flow through the relief outlet of the test regulator.

7.3.3.2 Increase the regulated pressure slightly using the pressure regulator (14 in Figure 1). When the flow is steady, measure the relief flow using the flow meter (15), the corresponding regulated pressure, p_2, using the pressure transducer (10) and temperature, T_2.

7.3.3.3 Continue the measurements by gradually increasing the flow rate in steps [by increasing the pressure using pressure regulator (14)]. Record data after conditions stabilize after each step. Continue this until the pressure reaches a level of the inlet pressure according to 5.4. Measure additional data for a decreasing pressure until the flow rate reaches zero. During variations of the relief flow (increasing and decreasing), keep the inlet pressure, p_1, within the tolerance of 5.3.

7.3.3.4 Close ball valve (16) before continuing to the next step.

7.3.3.5 This test procedure can be substituted by adjusting the flow control valve (19) instead of the pressure regulator (14). In this case, follow points from 7.3.3.6 to 7.3.3.9.

7.3.3.6 Close the ball valve (11) and open the ball valve (16). With flow controller (19) closed, set the pressure regulator (14) at the full-scale value of the component under test while the regulated pressure value of the component under test, p_2, shall be at the same value obtained without flow at the end of the procedure described in 7.3.2.3

7.3.3.7 Slowly open the flow control valve (19) and let a low flow rate of air passes through the component under test. When the flow is steady, measure the relief flow using the flow meter (15), the corresponding regulated pressure, p_2, using the pressure transducer (10) and temperature, T_2.

7.3.3.8 Continue the measurements by gradually increasing the flow rate in steps. Record data after conditions stabilize after each step. Continue this until the pressure reaches the full-scale value. Measure additional data for a decreasing pressure until the flow rate reaches zero. During variations of the relief flow (increasing and decreasing), keep the inlet pressure, p_1, within the tolerance of 5.3.

7.3.3.9 Close ball valve (16) before continuing to the next step.

7.3.4 Procedure for other regulated pressure values

Repeat the procedures for measuring forward flow rate (7.3.2) and relief flow rate (7.3.3) for regulated values corresponding to about 40 %, 60 %, and 80 % of the regulated pressure full scale. Make these settings without flow, gradually adjusting the regulator by increasing values only, until reaching these values. If a pressure setting needs to be adjusted downwards, reduce the pressure well below the desired value and increase the pressure to the desired setting.

7.4 Calculation of characteristics

7.4.1 Flow-pressure characteristic curves

7.4.1.1 For the regulated set pressure which is equal to 20 % of the regulated pressure full scale, for each forward flow rate value, calculate the mean value of the two corresponding regulated pressures, p_2, measured according to the procedure described in 7.3.2 respectively with increasing and decreasing forward flow rates.

Plot a graph of the mean regulated pressure values as a function of the forward flow rate, as shown in the first quadrant of Figure 2.

7.4.1.2 For the regulated set pressure which is equal to 20 % of the regulated pressure full scale, for each relief flow rate value, calculate the mean value of the two corresponding regulated pressures, p_2, measured according to the procedure described in 7.3.3 respectively, with increasing and decreasing relief flow rates.

Plot a graph of the mean regulated pressure values as a function of the relief flow rate, as shown in the second quadrant of Figure 2.

7.4.1.3 Repeat the procedure of calculation and layout for the three other regulated set pressure values: 40 %, 60 %, and 80 % of the full scale.

7.4.2 Flow rate — pressure hysteresis

For each value of forward flow rate until 80 % of $q_{vf,max}$ or relief flow rate, only for the flat part of the curve, calculate the difference between the regulated pressure values measured respectively with increasing and decreasing flow rates. These values are measured according to the procedures described in 7.3.2 and 7.3.3.

Determine the maximal difference, $\Delta p_{2h,max}$.

$$H = \frac{\left|\Delta p_{2h,max}\right|}{p_{2,max}} \times 100 \,. \tag{1}$$

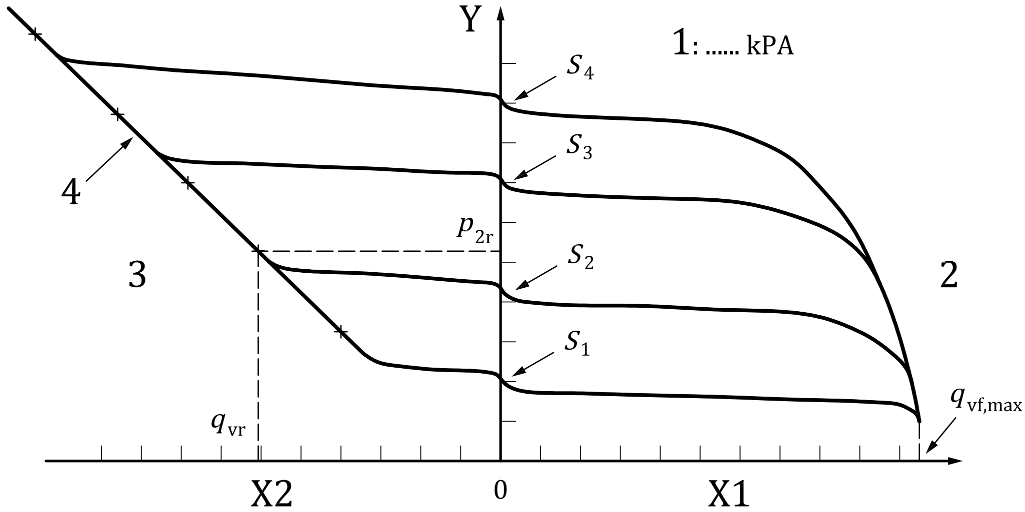
Use Formula (1) to calculate the hysteresis characteristic value expressed as percentage of the regulated pressure full scale.

7.4.3 Maximum forward sonic conductance

7.4.3.1 Graphically determine the maximum forward flow rate, $q_{vf,max}$, as the intersection of an extension line of forward flow rate-pressure characteristic curves obtained in 7.4.1 with the abscissa (regulated pressure is null in relative value), according to Figure 2.

7.4.3.2 Calculate the value of the maximal forward sonic conductance, $C_{f,max}$, by dividing this flow rate value by the inlet pressure according to ISO 6358-1, using Formula (2):

$$C_{f,max} = \frac{q_{vf,max}}{p_1 + p_{atm}} \sqrt{\frac{T_1}{T_0}} \quad (2)$$



Key

X1 forward flow rate, dm³/min (ANR)
X2 relief flow rate, dm³/min (ANR)
Y regulated pressure, p_2, kPa
1 inlet pressure, p_1, kPa
2 first quadrant
3 second quadrant
4 asymptote
S_1, S_2, etc. regulated set pressures

Figure 2 — Graphic determination of the necessary values for calculation of the sonic conductance

7.4.4 Maximum relief sonic conductance

7.4.4.1 Choose graphically five points all over the asymptote of the relief flow rate-pressure curves obtained in 7.4.1.2 according to Figure 2. Each one of them is defined by a relief flow rate value, q_{vr}, and a regulated pressure value, p_{2r}.

7.4.4.2 For each one of these points, calculate the corresponding sonic conductance value, C_r, by dividing the flow rate value by the regulated pressure in accordance with ISO 6358-1 (upstream pressure in this case), using Formula (3):

$$C_r = \frac{q_{vr}}{p_{2r} + p_{atm}} \sqrt{\frac{T_2}{T_0}} . \quad (3)$$

NOTE The squared root is necessary to take into account the test upstream temperature, T_2, deviation from the reference temperature, T_0, according to ISO 6358-1.

7.4.4.3 Calculate the maximal relief sonic conductance by determining the average of these five values.

8 Pressure regulation test

8.1 Test circuit

The same test circuit as shown in Figure 1 shall be used for the pressure regulation test. Only the part of the circuit for measuring forward flow rate shall be used.

The general requirements in 7.2.1 to 7.2.4 concerning the test equipment for forward flow rates shall be followed.

8.2 Test procedure

8.2.1 Install the regulator according to Figure 1, with shut-off valve (1), solenoid valves (11 and 16), and flow control valve (13) closed.

8.2.2 Open shut-off valve (1 in Figure 1) and adjust pressure regulator (2) to apply an inlet pressure, p_1, such as specified in 5.4.

8.2.3 Gradually, adjust the test regulator by increasing values only, until reaching a value corresponding to 25 % of the regulated pressure full scale.

8.2.4 Open the solenoid valve (11 in Figure 1). Then, slowly open the flow control valve and set the forward flow rate to q_v = 2 % of $q_{vf,max}$, determined in 7.4.3.1. Readjust the inlet pressure, p_1, once again to reach the initial value determined in 8.2.2.

8.2.5 Reduce the inlet pressure, p_1, of regulator (2 in Figure 1) in steps and after conditions are stable, record the corresponding regulated pressure, p_2, using the pressure transducer (10). Maintain the flow rate constant during this process. Continue these pressure-reducing steps up to the lowest inlet pressure possible for the chosen flow rate (to be maintained).

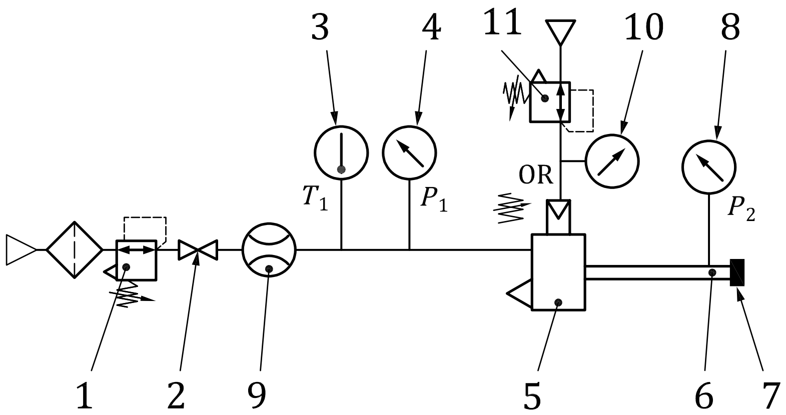
8.2.6 Keeping the same flow rate and regulated pressure setting of the test regulator, increase the inlet pressure, p_1, of regulator (2 in Figure 1) in steps. When conditions have stabilized, record the corresponding regulated pressure, p_2. Continue these pressure-increasing steps until the inlet pressure, p_1, reaches the value determined in 8.2.4. It is necessary to maintain the flow rate constant during this process.

8.2.7 As an option, the procedures of 8.2.4 to 8.2.6 can be repeated with the flow rate at 10 % of $q_{vf,max}$.

9 Maximum air consumption at null forward flow rate or relief flow rate for pilot-operated regulator with air bleed

9.1 Test installation

A suitable test circuit, as shown in Figure 3, shall be used for measuring air consumption at null forward flow or relief flow. The same circuit shall be used to measure pressure control characteristic, linearity, hysteresis, resolution and sensitivity.



Key

1 supply pressure regulator
2 shut-off valve
3 inlet temperature, T_1, measuring-element
4 inlet pressure, p_1, gauge or transducer
5 component under test
6 connector with pressure-measuring tap
7 plug
8 regulated pressure, p_2, gauge or transducer
9 flow meter (only for air consumption test)
10 pilot pressure, w, gauge or transducer
11 piloting precise-pressure regulator

Figure 3 — Typical test circuit for air consumption characterization, pressure control characteristic, linearity, hysteresis, resolution and sensitivity

9.2 Test procedures

Apply the inlet pressure, p_1, chosen according to 5.4.

Measure the air consumption flow rate at the minimum and the maximum of the regulated pressure.

9.3 Calculation of characteristics

For each value of the regulated pressure, calculate the mean value of the two corresponding air consumption flow rates according to the procedure described in 9.2, respectively with an increasing and a decreasing regulated pressure.

Determine the inlet air consumption flow rate maximum value.

10 Special test procedures

10.1 Pilot pressure/regulated pressure characteristics test in the case of external pilot-operated pressure regulators

10.1.1 Test installation

A suitable test circuit, as shown in Figure 3, shall be used for measuring pilot-pressure/regulated pressure characteristic.

10.1.2 Test procedures

Apply the inlet pressure chosen according to 5.4. Increase the pilot pressure in steps (5 % of full-scale per step, with a pause for stability) from zero to full scale, and record this on an x-axis. Record the corresponding regulated pressure on a y-axis. Then reduce the pilot pressure gradually to zero and record the corresponding regulated pressure.

10.1.3 Calculation of characteristics

10.1.3.1 Pressure control characteristics

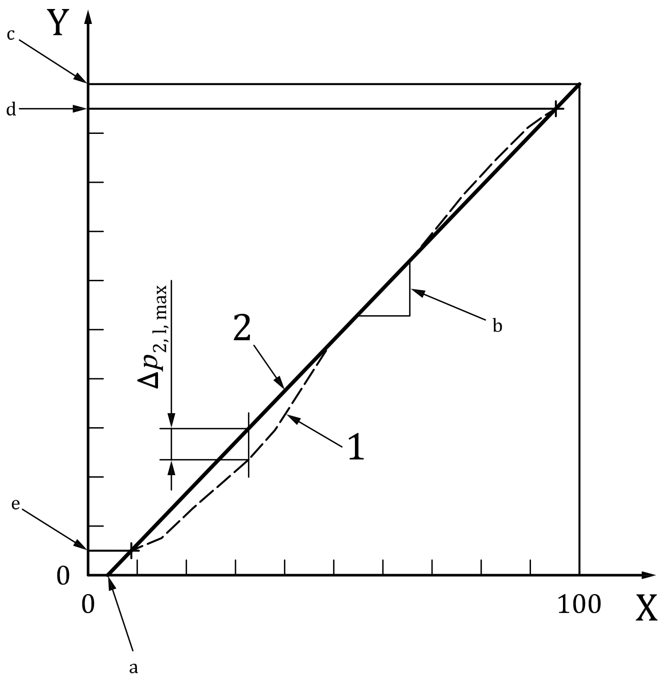
For each step of the pilot pressure, calculate the mean value of the two corresponding regulated pressures, p_2, measured according to the procedure described in 10.1.2, respectively with an increasing and a decreasing pilot pressure.

Plot the mean pressure curve as a function of the pilot pressure as represented in Figure 4.

The characteristic line is the straight line passing by the mean regulated pressure values of 5 % and 95 % of the regulated pressure full-scale according to Figure 4.

The offset of the characteristic line shall be determined by the intersection of the characteristic line with the abscissa axis (regulated pressure, p_2, equal to 0 kPa).

The slope and the offset of the characteristic line shall be indicated on the graph, as represented in Figure 4.



Key

X pilot pressure, in kPa (bar)

Y regulated pressure in kPa (bar)

1 characteristic line

2 mean pressure curve

a Offset.

b Slope.

c $p_{2,max}$.

d 95 % of $p_{2,max}$.

e 5 % of $p_{2,max}$.

Figure 4 — Determination of the pressure control characteristics

10.1.3.2 Linearity

For each pilot pressure value corresponding to regulated pressure value between 5 % and 95 % of the regulated pressure full-scale, calculate, in absolute value, the difference between the mean regulated pressure value calculated in 10.1.3.1 and the corresponding value on the characteristic line plotted in 10.1.3.1.

Determine the maximal difference, $\Delta p_{2,\mathrm{l,max}}$, according to Figure 4, and calculate the linearity value, L, expressed as a percentage of the regulated pressure full-scale using Formula (4):

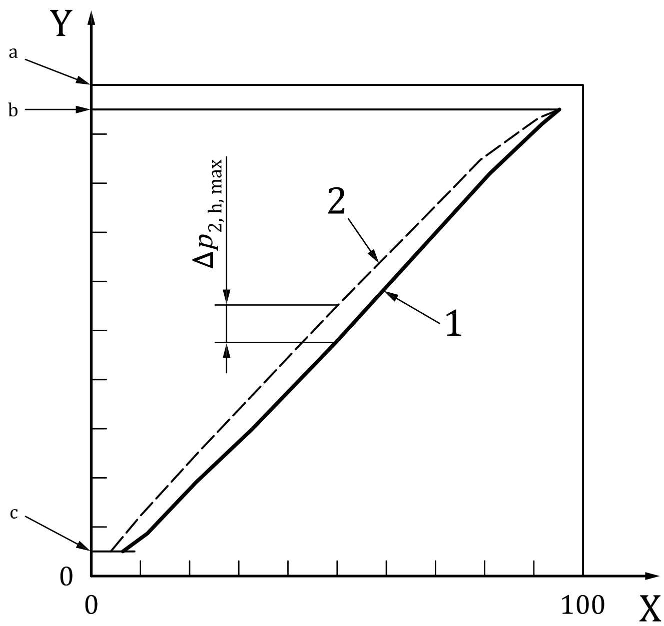
$$L = \frac{\left|\Delta p_{2,\mathrm{l,max}}\right|}{p_{2,\mathrm{max}}} \times 100 \,. \tag{4}$$

10.1.3.3 Pilot pressure/regulated pressure hysteresis

For each pilot pressure value corresponding to a regulated pressure value between 5 % and 95 % of the regulated pressure full-scale, calculate, in absolute value, the difference between the regulated pressure values, p_2, measured respectively with an increasing and a decreasing pilot pressure. These values are obtained according to the procedure described in 10.1.2.

Determine the maximal difference, $\Delta p_{2,\mathrm{h,max}}$, according to Figure 5. Calculate the hysteresis characteristic value, H, evaluating this difference in percentage of the regulated pressure full-scale according to Formula (5):

$$H = \frac{\left|\Delta p_{2,\mathrm{h,max}}\right|}{p_{2,\mathrm{max}}} \times 100 \,. \tag{5}$$



Key

X pilot pressure, in kPa (bar)

Y regulated pressure, p_2, in percentage of $p_{2,\mathrm{max}}$

1 values measured with increasing pilot pressure

2 values measured with decreasing pilot pressure

[a] $p_{2,\mathrm{max}}$.

[b] 95 % of $p_{2,\mathrm{max}}$.

[c] 5 % of $p_{2,\mathrm{max}}$.

Figure 5 — Representation of the maximal scattering of hysteresis difference

10.2 Output resolution in the case of manual air pressure regulator

10.2.1 Test installation

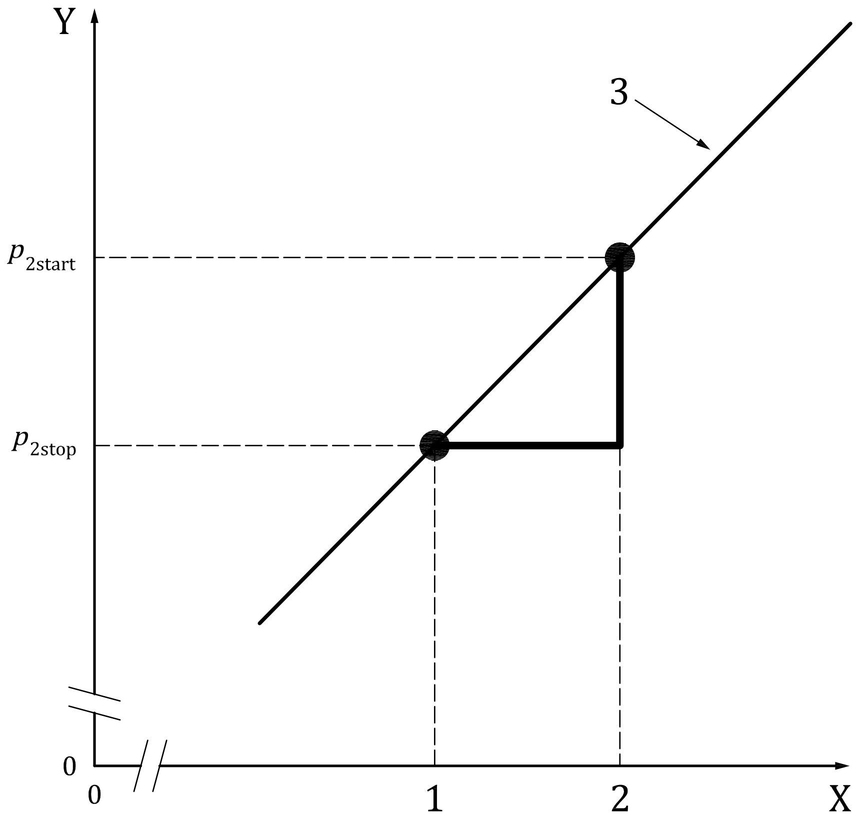
A suitable test circuit, as shown in Figure 3, shall be used for measuring resolution.

10.2.2 Test procedures

10.2.2.1 From the fully released position of the adjustable control knob, gradually modify the control knob by increasing values only, until reaching the value corresponding to 15 % of the regulated pressure full-scale.

10.2.2.2 Maintain this state for more than 10 s and note this regulated pressure, $p_{2,stop}$.

10.2.2.3 Then gradually re-increase the rotating position of the control knob and stop increasing when the regulated pressure starts re-increasing as shown in Figure 6. Note the increased regulated pressure, $p_{2,start}$.



Key

X control knob rotation (turns)

Y regulated pressure (MPa or bar)

1 condition 1: increasing start

2 condition 2: increasing stop

3 idealized pressure curve

Figure 6 — Output resolution test procedure

10.2.2.4 Repeat the operations described in 10.2.2.2 and 10.2.2.3 for 50 % and 85 % of the regulated pressure full-scale. Gradually modify the control knob, by increasing values only, until reaching these values.

10.2.3 Calculation of characteristics

10.2.3.1 For each of the three tests done according to 10.2.2, for 15 %, 50 %, and 85 % of the regulated pressure full-scale, calculate the corresponding output resolution, expressed as a percentage of the regulated pressure full-scale, using Formula (6):

$$S_0 = \frac{p_{2\text{start}} - p_{2\text{stop}}}{p_{2,\text{max}}} \times 100 \quad (6)$$

10.2.3.2 Calculate the output resolution by taking the maximal value of the three values obtained in 10.2.3.1.

10.3 Resolution in case of pressure-pilot air pressure regulator

10.3.1 Test procedures

10.3.1.1 A suitable test circuit, as shown in Figure 3, shall be used for measuring output resolution.

10.3.1.2 From the minimal pilot pressure control signal (0 %), gradually modify the pilot pressure value by increasing values only, until reaching the value corresponding to 15 % of the regulated pressure full-scale.

10.3.1.3 Maintain this state for more than 10 s, note this control pilot pressure value, w_{stop}.

10.3.1.4 Then gradually re-increase the pilot pressure noting the pilot pressure, w_{start}, for which the regulated pressure, p_2, starts re-increasing.

10.3.1.5 Repeat the operations described in 10.3.1.2 to 10.3.1.4 for the pilot pressure values corresponding to 50 % and 85 % of the regulated pressure full-scale. Gradually modify the control signal, by increasing values only, until reaching these values.

10.3.2 Calculation of characteristic

10.3.2.1 For each of the three tests done according to 10.3.1, for 15 %, 50 %, and 85 % of the regulated pressure full-scale, calculate the corresponding resolution, expressed in percentage of the control signal full-scale, using Formula (7):

$$S = \frac{w_{\text{start}} - w_{\text{stop}}}{w_{\text{max}} - w_{\text{min}}} \times 100 \quad (7)$$

10.3.2.2 Calculate the resolution by taking the maximal value of the three values obtained in 10.3.2.1.

10.4 Sensitivity

10.4.1 Test procedures

10.4.1.1 A suitable test circuit, as shown in Figure 3, shall be used for measuring sensitivity.

10.4.1.2 From the fully released position of the adjustable control knob or the minimal pilot pressure (0 %), gradually modify the control knob or pilot pressure by increasing values only, until reaching the value corresponding to 5 % of the regulated pressure full-scale. This condition is noted as w ($p_{2,5\ \%}$) for pressure-pilot regulator and as the starting point to count the number of turns of the control knob for manual regulator.

10.4.1.3 Maintain this state for more than 10 s and note this regulated pressure, ($p_{2,5\ \%}$).

10.4.1.4 Then gradually re-increase the rotating position of the control knob (counting the number of turns) or pilot pressure until reaching the value corresponding to 95 % of the regulated pressure full-scale. This condition is noted as w ($p_{2,95\ \%}$) for pressure-pilot regulator and $n_{95\ \%}$ (number of turns of the control knob completed) for manual regulator.

10.4.1.5 Maintain this state for more than 10 s and note this regulated pressure, ($p_{2,95\ \%}$).

10.4.2 Calculation of characteristic

10.4.2.1 With the values measured in 10.4.1.2 to 10.4.1.5, calculate sensitivity for pressure-pilot pressure regulator, expressed as Pa/Pa by using Formula (8), and sensitivity for manual pressure regulator, expressed as Pa/number of turns of the control knob by using Formula (9):

$$m = \frac{p_{2,95\,\%} - p_{2,5\,\%}}{w_{2,95\,\%} - w_{2,5\,\%}} \tag{8}$$

$$m = \frac{p_{2,95\,\%} - p_{2,5\,\%}}{n_{95\,\%}}\,. \tag{9}$$

10.5 Repeatability test

10.5.1 General

The repeatability, r, corresponds to the maximal dispersion in regulated pressure, for a given set pressure.

For the manual air pressure regulator, the test shall be performed in accordance with 10.5.4.1.

For the pressure-pilot air pressure regulator, the test shall be performed in accordance with 10.5.4.2.

The repeatability, r, expressed as a percentage of the regulated pressure full-scale, shall be determined in accordance with 10.5.5.

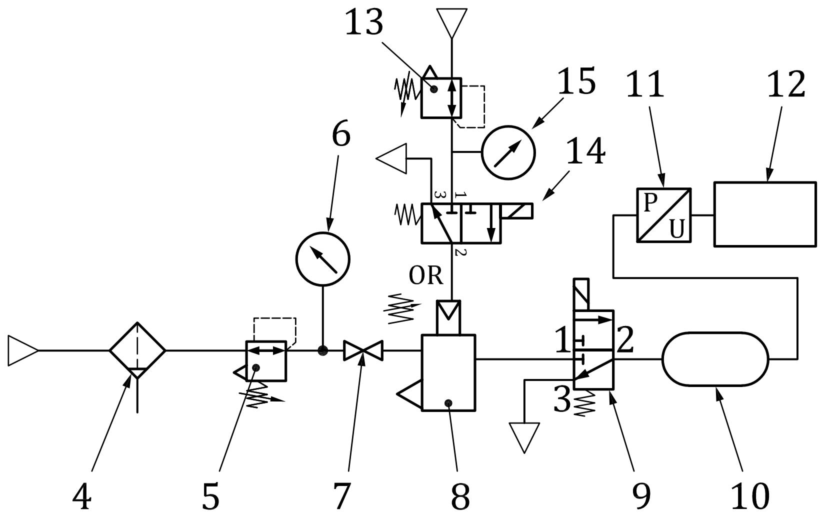
A comparison of the reliability test method for manual air pressure regulators in given in Annex A.

10.5.2 Test installation

A suitable test circuit, as shown in Figure 7, shall be used for measuring repeatability. The directional control valve (9 in Figure 7) shall have a sonic conductance greater than that of the regulator under test, and the test volume, V, in m^3 shall be determined using Formula (10):

$$V = 1{,}0 \times 10^4\, C \tag{10}$$

where C is the forward sonic conductance of the regulator under test in $m^3/(s\cdot Pa)$(ANR).



Key

1 to 3	ports of valves		
4	filter	10	test volume
5	supply pressure regulator	11	regulated pressure, p_2, sensor
6	inlet pressure, p_1, gauge or transducer	12	time-based pressure recorder
7	shut-off valve	13	piloting precise-pressure regulator
8	component under test	14	directional control valve
9	directional control valve	15	pilot pressure gauge or transducer

Figure 7 — Typical charging test circuit for repeatability

10.5.3 General test method

The component under test is set to a fixed pressure level, and the output is directed to a volume that is charged to the adjusted set pressure. The deviation of the regulated pressure is evaluated from repeated trials of pressurizing and exhausting the test volume.

Set the regulated pressure of the component (5 in Figure 7) to the inlet pressure defined in 5.4, open shut-off valve (7 in Figure 7).

Activate the directional valve (9 in Figure 7) and adjust the regulated pressure, p_2, of the component under test to 50 % of the specified maximum regulated pressure, $p_{2,\text{max}}$. This is the set pressure. Depressurize the volume completely by switching off the directional valve (9).

10.5.4 Test execution

10.5.4.1 Manual air-pressure regulator

Activate the directional valve (9 in Figure 7) and observe that pressure builds up in the volume. The measured value, p_2, shall be recorded after a sufficiently stabilization time to have a good stabilization of the regulated pressure. Then the directional valve is switched off to depressurize the volume completely.

Repeat this testing procedure at least 23 times and record the stabilized pressure values, $p_{2,j}$, (j = 1...23) for each cycle.

10.5.4.2 Pressure-pilot air pressure regulator

Activate, in sequence, the directional valves (9 and 14 in Figure 7) and observe that pressure builds up in the volume. The measured value, p_2, shall be recorded after a sufficient stabilization time, so as to ensure a good stabilization of the regulated pressure. Then, in sequence, switch off the directional valves (11 and 6) to depressurize the volume completely.

Repeat this testing procedure at least 23 times and record the stabilized pressure values, $p_{2,j}$, (j = 1...23) for each cycle.

10.5.5 Calculation of the repeatability value

Using the stabilized regulated pressure values, $p_{2,j}$, obtained from data points 4 to 23 (discarding the first three data points), calculate the repeatability value, r, expressed as a percentage of the regulated pressure full-scale, using Formula (11):

$$r = \frac{p_{2,j,\max} - p_{2,j,\min}}{p_{2,\max}} \times 100 . \qquad (11)$$

11 Presentation of data

11.1 General

Data from which the performances of the pressure regulator can be compared shall be presented as show in 11.2 to 11.6.

11.2 Flow-pressure characteristics

The flow-pressure characteristics, determined according to Clause 7, shall be presented as follows:

— a data graph in accordance with ISO 6953-1:—,[1)] Figure 2;

— the hysteresis value obtained according to 7.4.2;

— the value of the maximum forward sonic conductance according to Formula (2);

— the value of the maximum relief sonic conductance according to 7.4.4.

11.3 Pressure regulation characteristics

A data graph shall be presented in accordance with ISO 6953-1:—,[1)], Figure 3.

11.4 Maximum air consumption for pilot operated regulators with air bleed

The maximum air consumption at null forward flow rate, or relief flow rate, determined according to Clause 9, shall be presented as the maximal value of the air consumption, according to 9.2.

11.5 Additional characteristics for pressure-pilot air pressure regulators

The characteristics, determined according to 10.1, shall be presented as follows:

— a data graph in accordance with ISO 6953-1:—,[1)], Figure 4;

— the value of the linearity obtained according to Formula (4);

— the hysteresis value obtained according to Formula (5);

— the resolution value obtained according to Formula (7);

— the sensitivity value obtained according to Formula (8);

— the repeatability value obtained according to Formula (11).

11.6 Additional characteristics for manual air pressure regulators

— the output resolution value obtained according to Formula (6);

— the sensitivity value obtained according to Formula (9);

— the repeatability value obtained according to Formula (11).

Annex A
(informative)

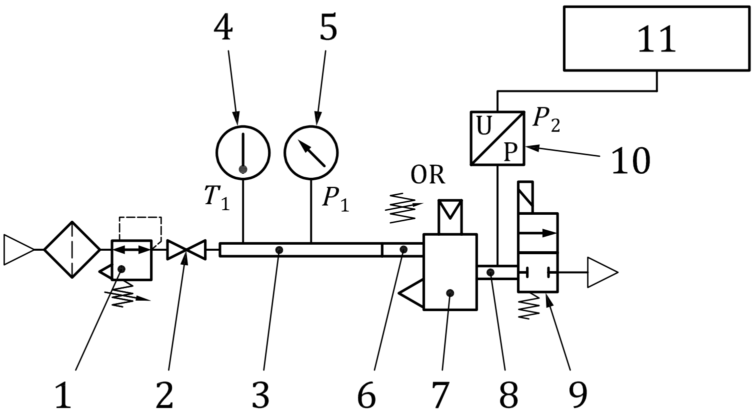
Comparison of repeatability test methods for manual air pressure regulators

A.1 General

A blowing test method was considered for this document and was tested for comparison with the charging test method specified in 10.5. Results of the testing are described in this annex.

A.2 Test circuit

The test circuit for the blowing test method is shown in Figure A.1 (the charging test method is shown in Figure 7).



Key

1	supply pressure regulator	7	component under test
2	shut-off valve	8	connector with pressure-measuring tap
3	pressure-measuring tube	9	directional control valve
4	inlet temperature, T_1, measuring-element	10	outlet pressure, p_2, sensor
5	inlet pressure, p_1, gauge or transducer	11	X-Y recorder
6	upstream transition connector		

NOTE Flow control valve is connected downstream from the directional control valve (9).

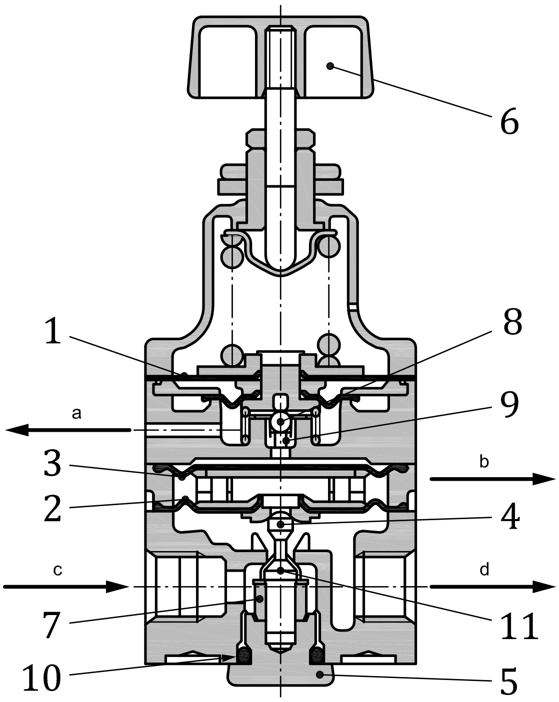
Figure A.1 — "Blowing test" circuit for repeatability

A.3 Test components and test conditions

The specifications of the components tested and the test conditions are shown in Table A.1. Figure A.2 shows the structure of PB1-REG (pilot-type regulator with air bleeding). Figure A.3 shows the structure of DO-REG (direct operated regulator). The main component for comparing the two test methods was PB1-REG, but DO-REG was also tested for information.

Table A.1 — Specifications of components under test and test conditions

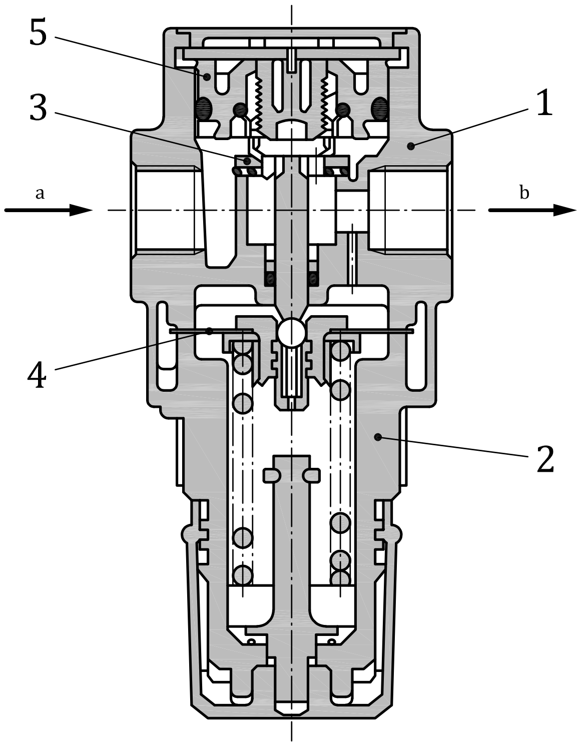
Model	PB1 – REG Pilot-type regulator with air bleeding (see Figure A.2)	DO – REG Direct operated regulator (see Figure A.3)
Max. inlet pressure	1,0 MPa	1,0 MPa
Regulated pressure range	0,01 MPa to 0,8 MPa	0,01 MPa to 0,85 MPa
Port size	Rc 1/8	Rc 1/4
Forward sonic conductance	1,8 $dm^3/(s·bar)$ (ANR)	4 $dm^3/(s·bar)$ (ANR)
Resolution	Within 0,2 % of full span	-
Repeatability	Within ±0,5 % of full span	-
Air consumption	4,4 dm^3/min (ANR) or less at inlet pressure of 1,0 MPa	-
Inlet pressure	630 kPa	630 kPa
Set regulated pressure	400 kPa	425 kPa
Volume for charging test	985 cm^3; 590 cm^3; 10 cm^3	985 cm^3; 590 cm^3; 25 cm^3
Volume between CUT and control valve	19 cm^3	19 cm^3
Sonic conductance of directional control valve	6,5 $dm^3/(s·bar)$ (ANR)	12 $dm^3/(s·bar)$ (ANR)
Pressure gauge	Digital pressure gauge Measurement pressure range: −80 kPa to 3 000 kPa Accuracy: ±0,02 % of reading	



Key

1 diaphragm (A)
2 diaphragm (B)
3 diaphragm (C)
4 exhaust valve
5 valve guide
6 knob for pressure setting
7 spring
8 steel ball
9 nozzle
10 o-ring seal
11 main valve
a Bleed.
b Exhaust.
c Supply.
d Regulated pressure.

Figure A.2 — PB1-REG: Pilot-type regulator with air bleeding



Key

1 main body
2 bonnet
3 poppet
4 diaphragm
5 valve guide
[a] Supply.
[b] Regulated pressure.

Figure A.3 — DO-REG: Direct operated regulator

A.4 Measurement results of repeatability test

A.4.1 Measurement results

A.4.1.1 Measurement results of both repeatability tests, for 25 trials, are shown in Table A.2 and Table A.3. The regulated pressures are measured between the component under test (5) and directional control valve (6) in Figure 7.

Table A.2 — Regulated pressures for PB1-REG

Trial	Blowing test[a] kPa				Charging test[b] kPa					
	Full opened[c]		Restricted[d]		Volume 985 cm^3		Volume 590 cm^3		Volume 10 cm^3	
	After 5 s	After 10 s	After 5 s	After 10 s	After 5 s	After 10 s	After 5 s	After 10 s	After 5 s	After 10 s
Initial	400,30		400,45		400,32		400,28		400,26	
1	400,31	400,32	400,47	400,47	399,86	399,77	399,78	399,70	400,25	400,25
2	400,35	400,36	400,42	400,42	399,81	399,71	399,87	399,96	400,26	400,27
3	400,35	400,33	400,42	400,42	399,83	399,51	399,75	399,94	400,27	400,26
4	400,32	400,31	400,44	400,43	399,71	399,77	399,80	400,12	400,26	400,26
5	400,33	400,32	400,41	400,39	399,82	399,73	399,80	399,84	400,25	400,27
6	400,32	400,29	400,40	400,39	399,86	399,73	399,80	399,84	400,26	400,27
7	400,33	400,34	400,43	400,43	399,83	399,66	399,86	400,10	400,27	400,27
8	400,35	400,33	400,41	400,39	399,87	399,76	399,88	399,98	400,24	400,27
9	400,32	400,32	400,38	400,38	399,87	399,73	399,82	400,03	400,26	400,27
10	400,31	400,29	400,39	400,40	399,81	399,88	399,90	400,01	400,26	400,27
11	400,36	400,34	400,39	400,38	399,85	399,77	399,85	400,14	400,26	400,27
12	400,32	400,32	400,40	400,38	399,88	399,74	399,84	399,93	400,24	400,26
13	400,35	400,33	400,42	400,40	399,89	399,85	399,85	400,09	400,26	400,27
14	400,36	400,35	400,43	400,43	399,91	399,72	399,81	400,10	400,26	400,26
15	400,34	400,32	400,39	400,38	399,90	399,89	399,87	400,14	400,25	400,26
16	400,34	400,34	400,43	400,43	399,80	399,80	399,88	399,99	400,26	400,26
17	400,33	400,31	400,38	400,36	399,91	399,74	399,91	399,95	400,25	400,27
18	400,35	400,33	400,43	400,42	399,84	399,80	399,85	399,95	400,25	400,26
19	400,35	400,35	400,38	400,38	399,91	399,91	399,89	400,12	400,26	400,27
20	400,33	400,32	400,40	400,38	399,93	399,82	399,87	399,98	400,27	400,27
21	400,35	400,33	400,38	400,37	399,90	399,87	399,86	400,13	400,26	400,26
22	400,35	400,33	400,40	400,38	399,80	399,71	399,88	400,10	400,26	400,27
23	400,35	400,32	400,35	400,35	399,84	399,81	399,86	400,09	400,25	400,27
24	400,38	400,36	400,39	400,38	399,76	399,63	399,85	400,13	400,27	400,26
25	400,35	400,34	400,38	400,35	399,85	399,66	399,87	400,09	400,26	400,26
Average	400,34	-	400,40	-	399,85	-	399,85	-	400,26	-
Max.	400,38	400,36	400,47	400,47	399,93	399,91	399,91	400,14	400,27	400,27
Min.	400,31	400,29	400,35	400,35	399,71	399,51	399,75	399,70	400,24	400,25
Repeatability, *r* %	0,01	0,01	0,02	0,02	0,03	0,05	0,02	0,05	0,00	0,00

[a] Blowing time is 1,0 s. Cycle time is 30 s.

[b] Charging time is 15 s. Cycle time is 30 s.

[c] Sonic conductance of flow control valve is 8,22 $dm^3/(s·bar)$ (ANR). Flow rate is 1 150 dm^3/min (ANR). Air consumption is 19,0 dm^3 (ANR).

[d] Sonic conductance of flow control valve is 1,46 $dm^3/(s·bar)$ (ANR). Flow rate is 435 dm^3/min (ANR). Air consumption is 7,2 dm^3 (ANR).

Table A.3 — Regulated pressures for DO-REG

Trial	Blowing test[a] kPa				Charging test[b] kPa					
	Full opened[c]		Restricted[d]		Volume 985 cm³		Volume 590 cm³		Volume 25 cm³	
	After 5 s	After 10 s	After 5 s	After 10 s	After 5 s	After 10 s	After 5 s	After 10 s	After 5 s	After 10 s
Initial	426,05 kPa		425,30 kPa		425,05 kPa		425,50 kPa		425,89 kPa	
1	430,11	430,49	429,26	429,40	428,09	430,43	428,30	429,84	431,19	431,82
2	430,28	430,52	429,43	429,65	428,11	430,20	427,38	429,25	431,46	432,31
3	430,41	430,53	429,47	429,72	427,82	430,17	427,81	429,50	431,57	432,52
4	430,49	430,85	429,46	429,72	428,10	430,17	427,77	429,62	431,66	432,58
5	430,66	431,02	429,51	429,72	428,01	430,13	427,88	429,67	431,73	432,61
6	430,80	431,07	429,50	429,80	428,25	430,22	428,01	429,66	431,81	432,68
7	430,84	431,36	429,70	429,90	428,59	430,37	428,13	429,74	431,79	432,74
8	431,00	431,23	429,74	429,96	428,00	430,21	428,01	429,78	431,70	432,73
9	431,12	431,55	429,75	430,00	427,86	430,25	428,00	429,74	431,83	432,72
10	431,01	431,15	429,75	430,03	428,13	430,34	428,02	429,73	431,79	432,80
11	431,32	431,59	429,87	430,02	427,84	430,41	428,04	429,81	431,86	432,77
12	431,43	431,85	429,89	430,09	428,33	430,36	428,03	429,79	431,82	432,77
13	431,45	431,95	429,93	430,07	428,15	430,38	427,89	429,75	431,79	432,80
14	431,37	431,93	429,94	430,15	428,12	430,34	427,99	429,77	431,78	432,76
15	431,56	432,07	429,92	430,13	428,33	430,62	428,06	429,77	431,84	432,83
16	431,55	432,11	429,93	430,11	428,25	430,38	428,07	429,78	431,94	432,81
17	431,58	432,09	430,09	430,31	428,09	430,38	427,93	429,73	431,87	432,90
18	431,77	431,89	429,91	430,32	428,26	430,42	428,02	429,81	432,05	432,96
19	431,55	431,76	430,01	430,23	428,17	430,44	427,99	429,74	431,89	432,84
20	431,74	431,90	430,11	430,32	427,92	430,38	427,90	429,76	431,89	432,93
21	431,80	432,26	430,00	430,32	428,16	430,35	427,97	429,74	431,95	433,04
22	431,84	432,30	430,01	430,27	428,02	430,44	427,90	429,73	432,05	432,94
23	431,78	432,31	429,92	430,24	428,23	430,49	427,90	429,67	431,92	432,87
24	431,62	432,11	430,01	430,26	428,19	430,46	427,83	429,65	432,01	432,93
25	431,89	432,16	430,08	430,36	428,30	430,41	427,73	429,66	431,97	432,95
Average	431,24	-	429,81	-	428,13	-	427,94	-	431,81	-
Max.	431,89	432,31	430,11	430,36	428,59	430,62	428,30	429,84	432,05	433,04
Min.	430,11	430,49	429,26	429,40	427,82	430,13	427,38	429,25	431,19	431,82
Repeatability, *r* %	0,21	0,21	0,10	0,11	0,09	0,06	0,11	0,07	0,10	0,14

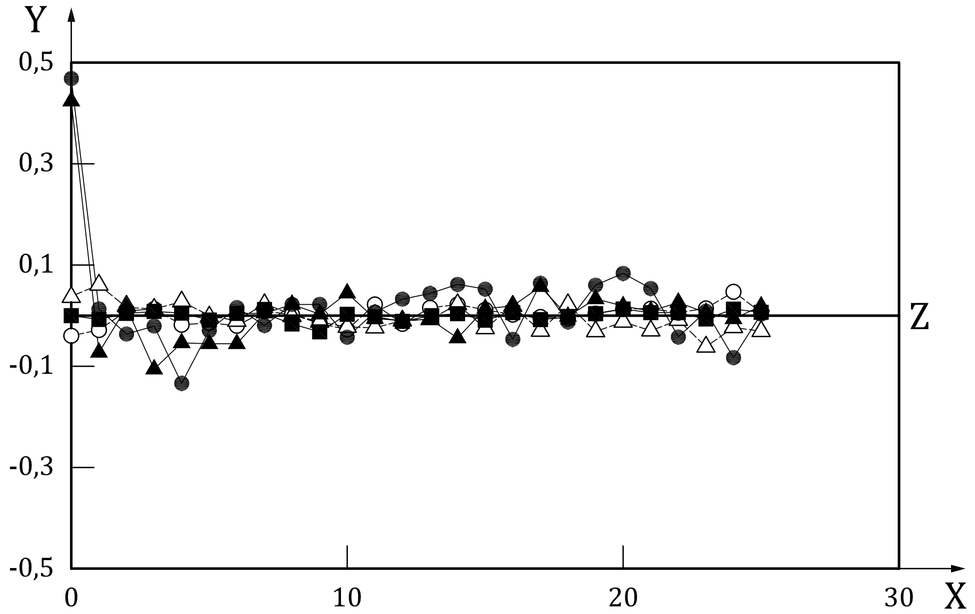
[a] Blowing time is 1,0 s. Cycle time is 30 s.

[b] Charging time is 15 s. Cycle time is 30 s.

[c] Sonic conductance of flow control valve is 8,22 $dm^3/(s{\cdot}bar)$ (ANR). Flow rate is 1 530 dm^3/min (ANR). Air consumption is 25,5 dm^3 (ANR).

[d] Sonic conductance of flow control valve is 5,34 $dm^3/(s{\cdot}bar)$ (ANR). Flow rate is 1 140 dm^3/min (ANR). Air consumption is 18,8 dm^3 (ANR).

A.4.1.2 The pressure deviations are shown in Figures A.4, A.5, A.6 and A.7.



Key

X pressure deviation kPa

Y trials

Z average after 5 s

---○--- full opened

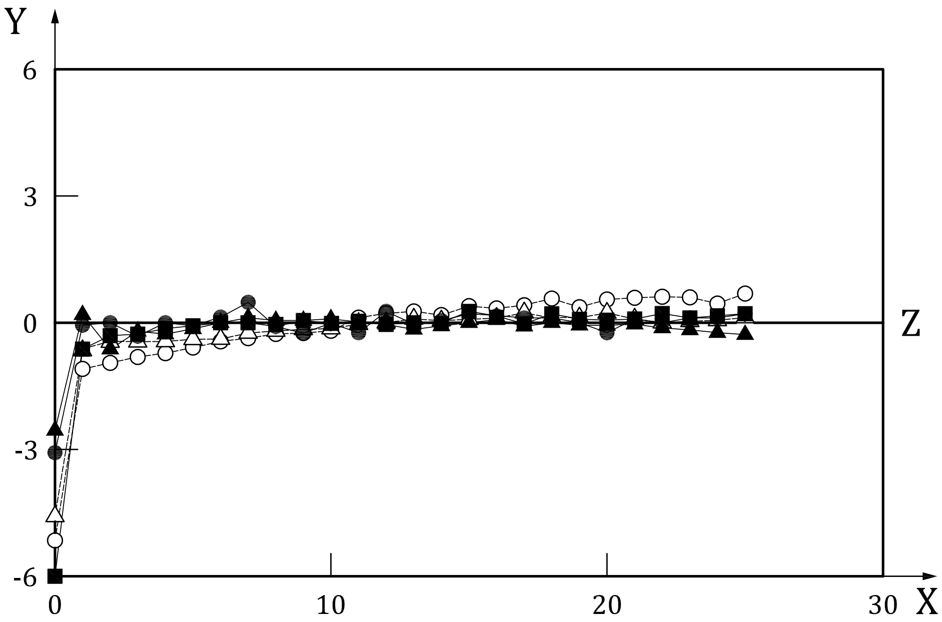
---△--- restricted

—●— volume 985 cm^3

—▲— volume 590 cm^3

—■— volume 10 cm^3

Figure A.4 — Pressure deviations after 5 s — PB1-REG



Key

X pressure deviation kPa

Y trials

Z average after 5 s

- - -○- - - full opened

- - -△- - - restricted

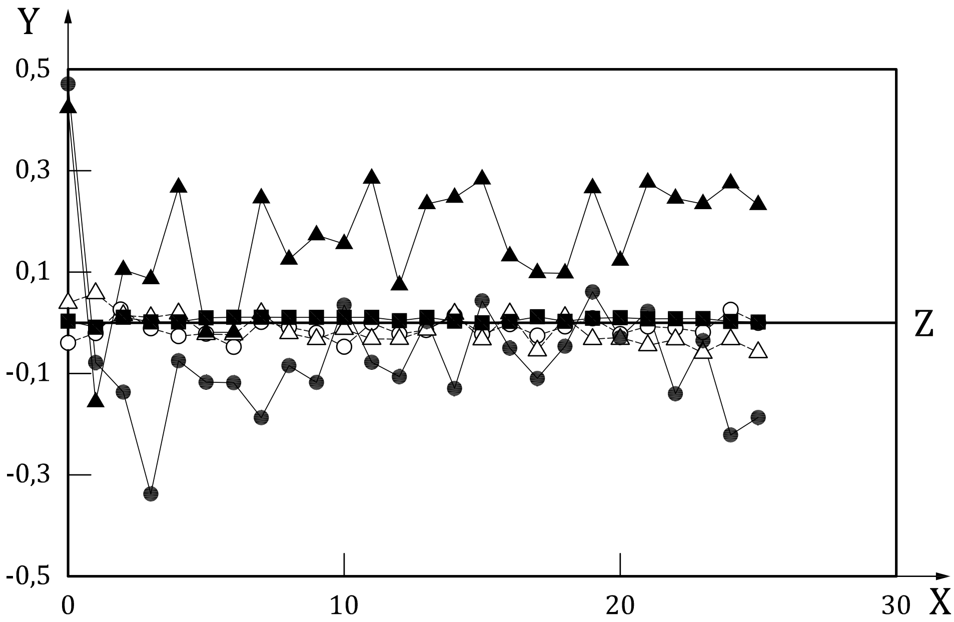
—●— volume 985 cm^3

—▲— volume 590 cm^3

—■— volume 25 cm^3

NOTE Pressure deviation = measurement value − average value after 5 s.

Figure A.5 — Pressure deviations after 5 s — DO-REG



Key

X pressure deviation kPa

Y trials

Z average after 10 s

---○--- full opened

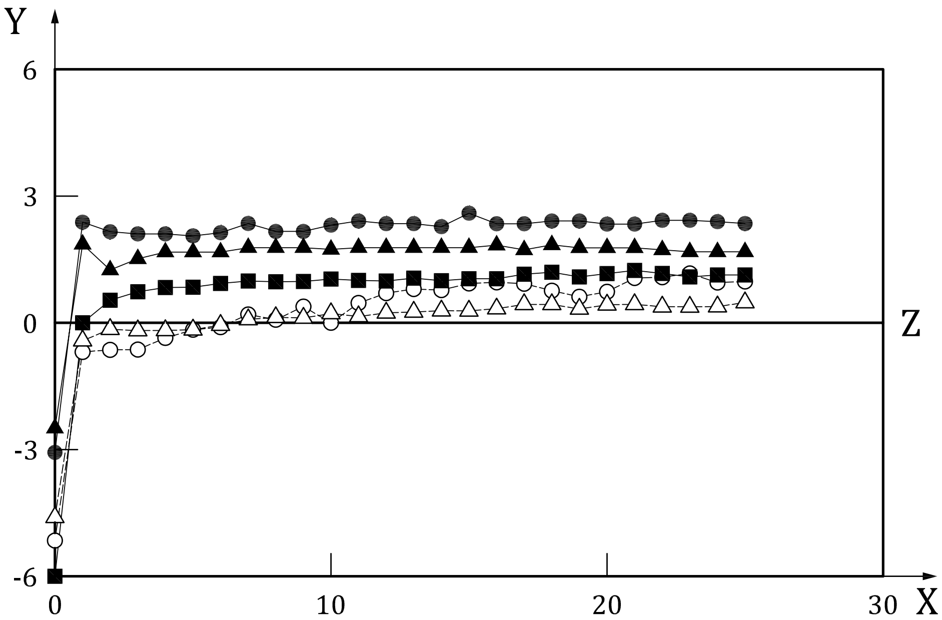
---△--- restricted

—●— volume 985 cm^3

—▲— volume 590 cm^3

—■— volume 10 cm^3

Figure A.6 — Pressure deviations after 10 s — PB1-REG



Key

X pressure deviation kPa

Y trials

Z average after 10 s

- - -○- - - full opened

- - -△- - - restricted

—●— volume 985 cm^3

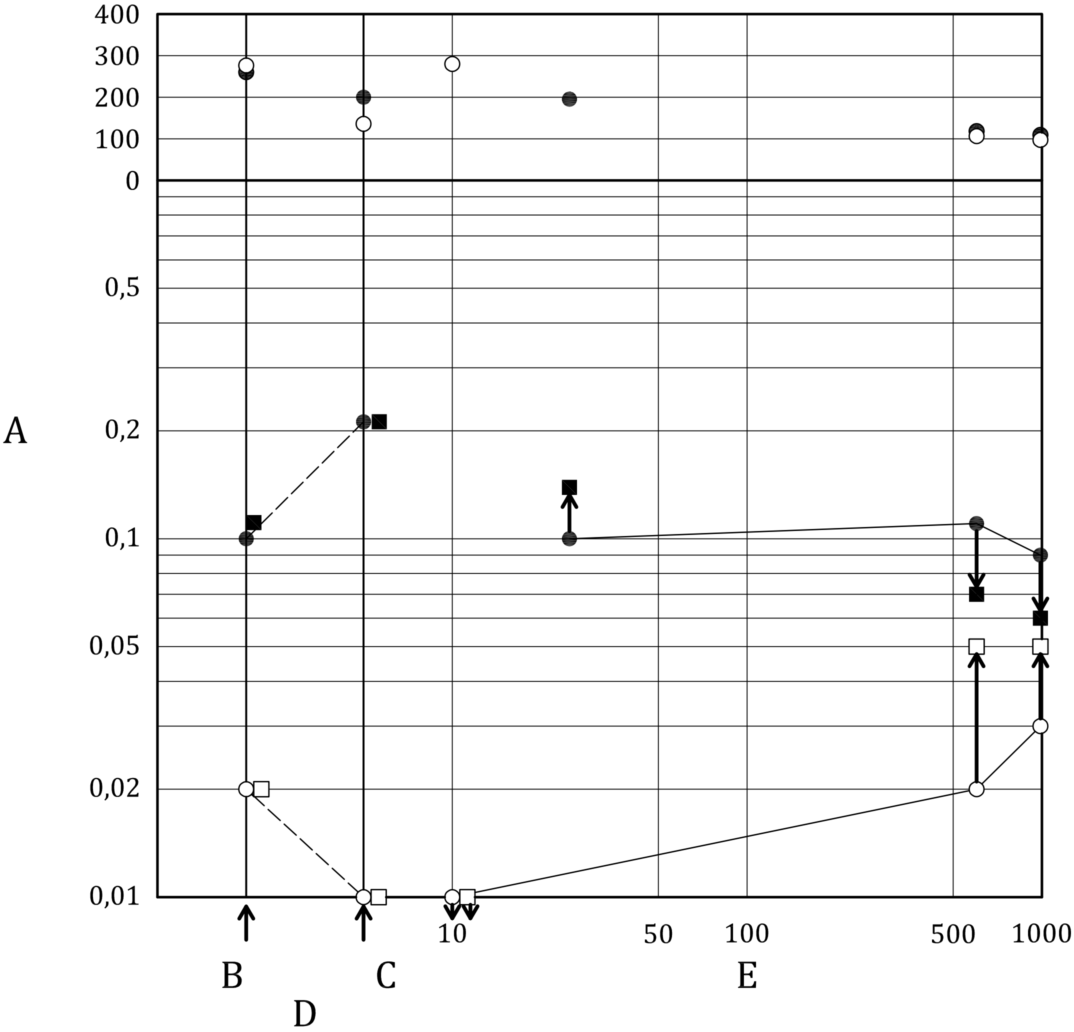
—▲— volume 590 cm^3

—■— volume 25 cm^3

NOTE Pressure deviation = measurement value − average value after 10 s.

Figure A.7 — Pressure deviations after 10 s — DO-REG

A.4.1.3 Calculation results of the repeatability are shown in Figure A.8.



Key

A repeatability, *r* %

B restricted

C full opened

D blowing test

E volume for charging test cm^3

	After 5 s	After 10 s
DO-REG	●	■
PB1-REG	○	□

NOTE Repeatability, *r* = (max. value − min. value)/(regulated pressure full scale) × 100.

Figure A.8 — Repeatability

A.4.2 Observations

A.4.2.1 The first three data points frequently caused outliers.

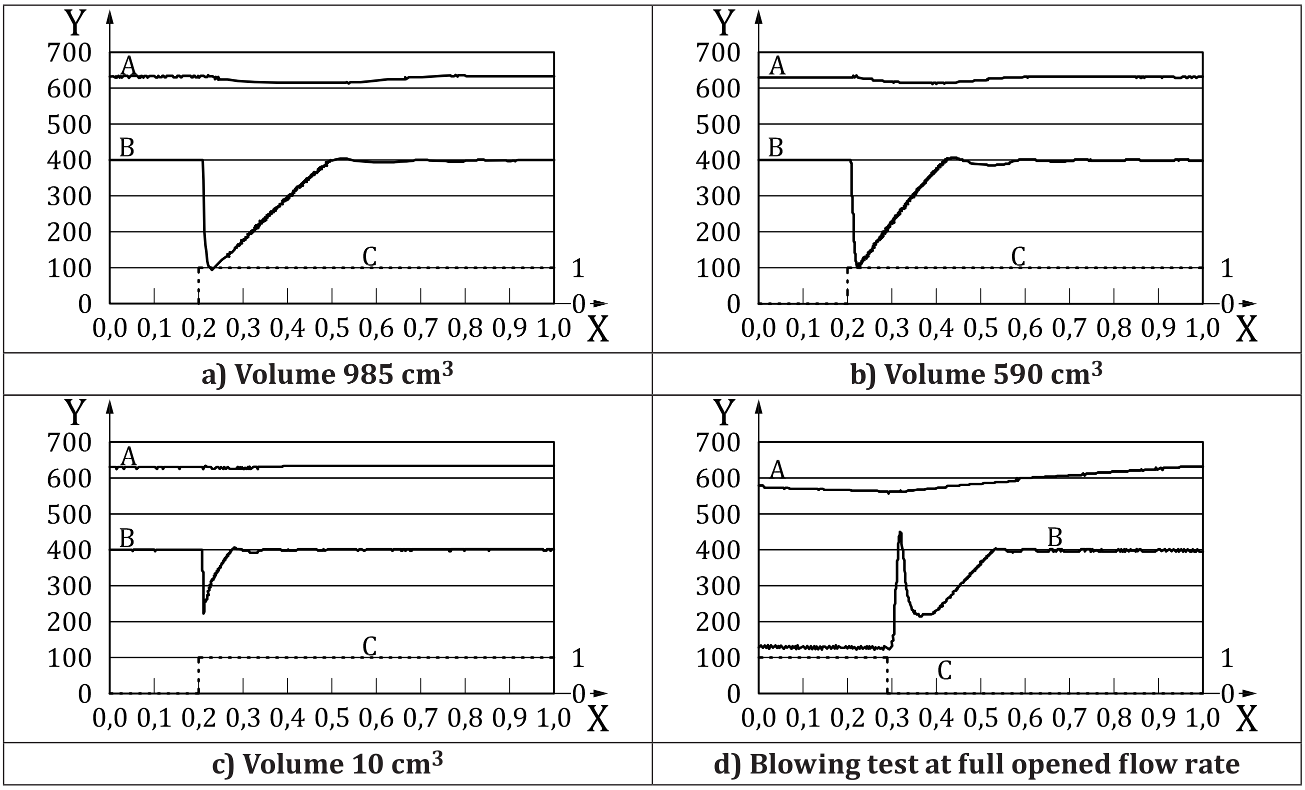
A.4.2.2 Measurement values after 10 s are approximately the same level as the values after 5 s on the blowing test, but there is a large difference in the measurement values after 10 s and 5 s on the charging test.

A.4.2.3 The repeatability of PB1-REG is 0,05 % or less. This value shows 1/20 of the specification in Table A.1. The larger the volume, the larger the repeatability of the charging test.

A.4.2.4 The repeatability of DO-REG is 10 times larger than that of PB1-REG.

A.5 Measurement results of pressure response

A.5.1 Measurement results of the charging waveform are shown in Figure A.9 and Figure A.10.



a) Volume 985 cm^3

b) Volume 590 cm^3

c) Volume 10 cm^3

d) Blowing test at full opened flow rate

Key

X time [s]

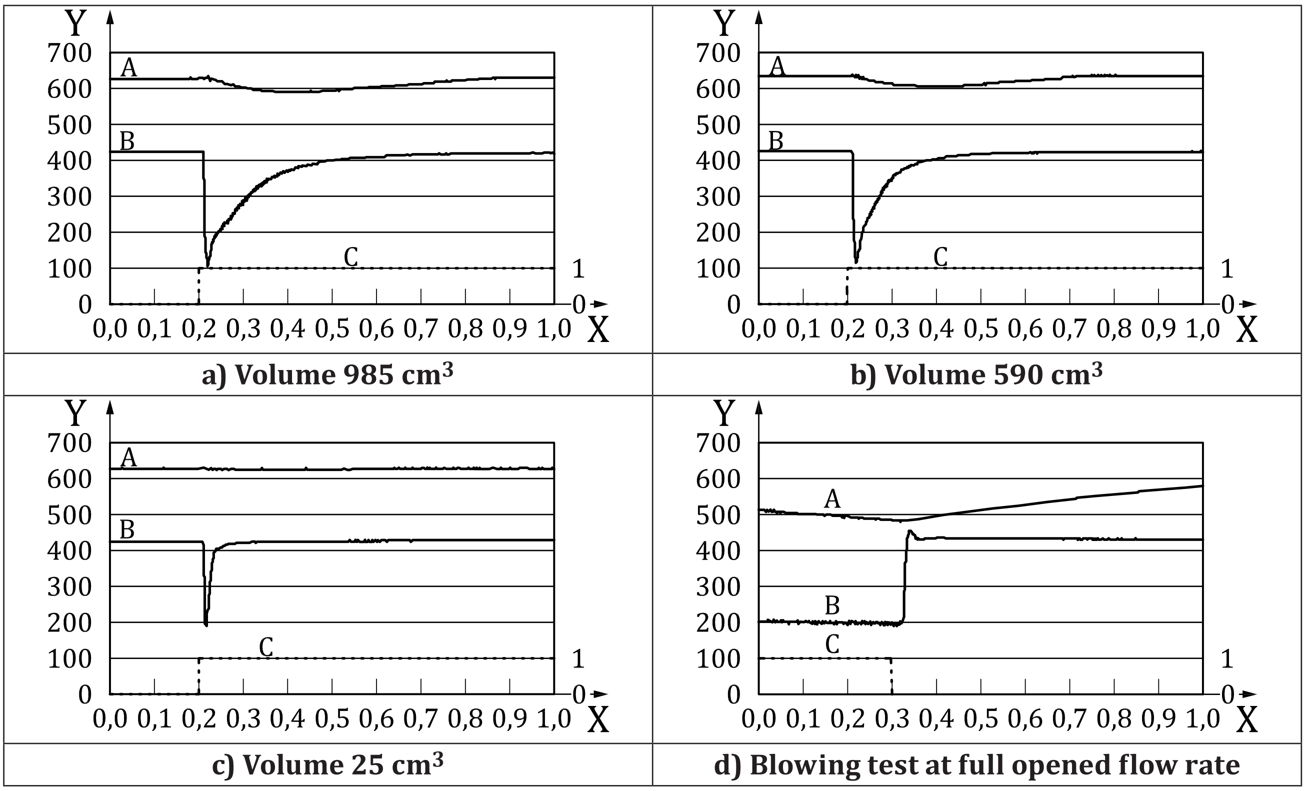
Y pressure [kPa]

A inlet pressure

B regulated pressure

C signal

Figure A.9 — Charging waveforms for PB1-REG



a) Volume 985 cm³

b) Volume 590 cm³

c) Volume 25 cm³

d) Blowing test at full opened flow rate

Key

X time [s]

Y pressure [kPa]

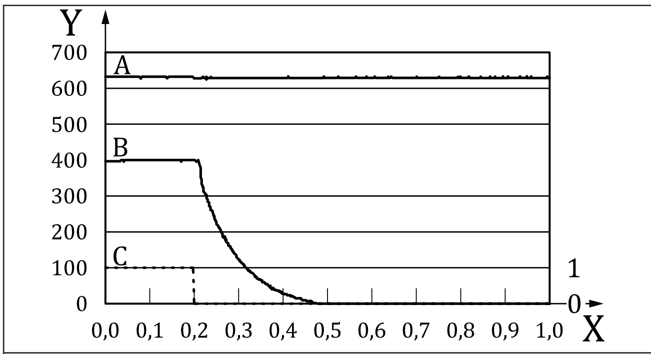
A inlet pressure

B regulated pressure

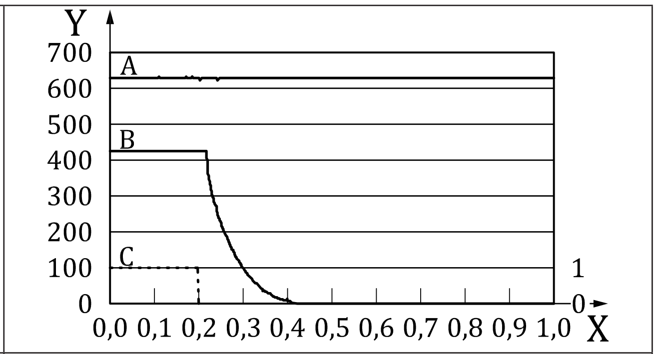
C signal

Figure A.10 — Charging waveforms for DO-REG

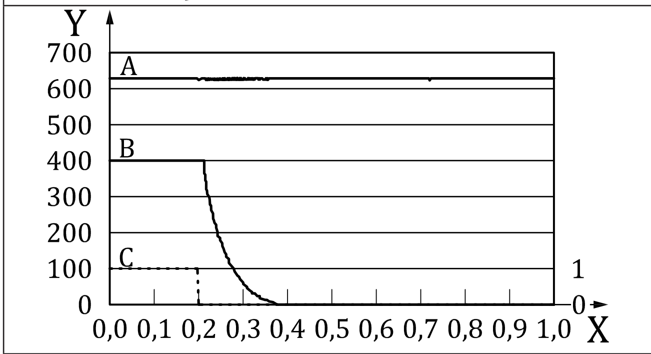
A.5.2 The discharging waveforms are shown in Figure A.11.



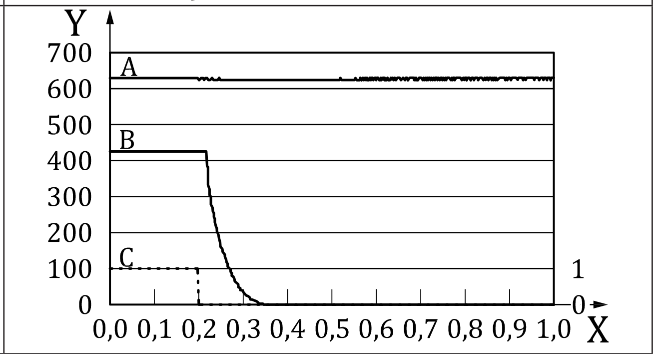
a) 985 cm³ for PB1-REG



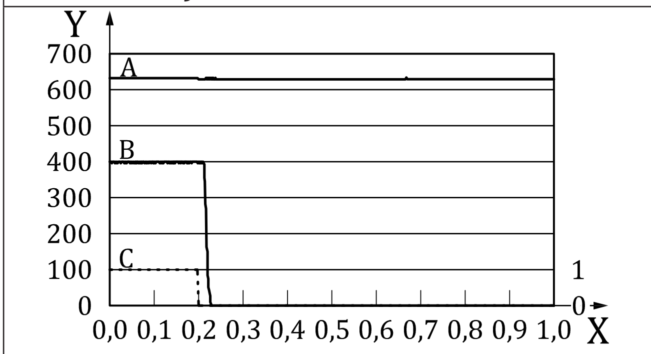
b) 985 cm³ for DO-REG



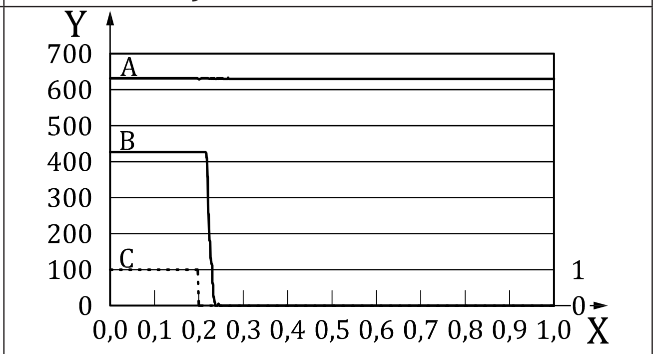
c) 590 cm³ for PB1-REG



d) 590 cm³ for DO-REG



e) 10 cm³ for PB1-REG



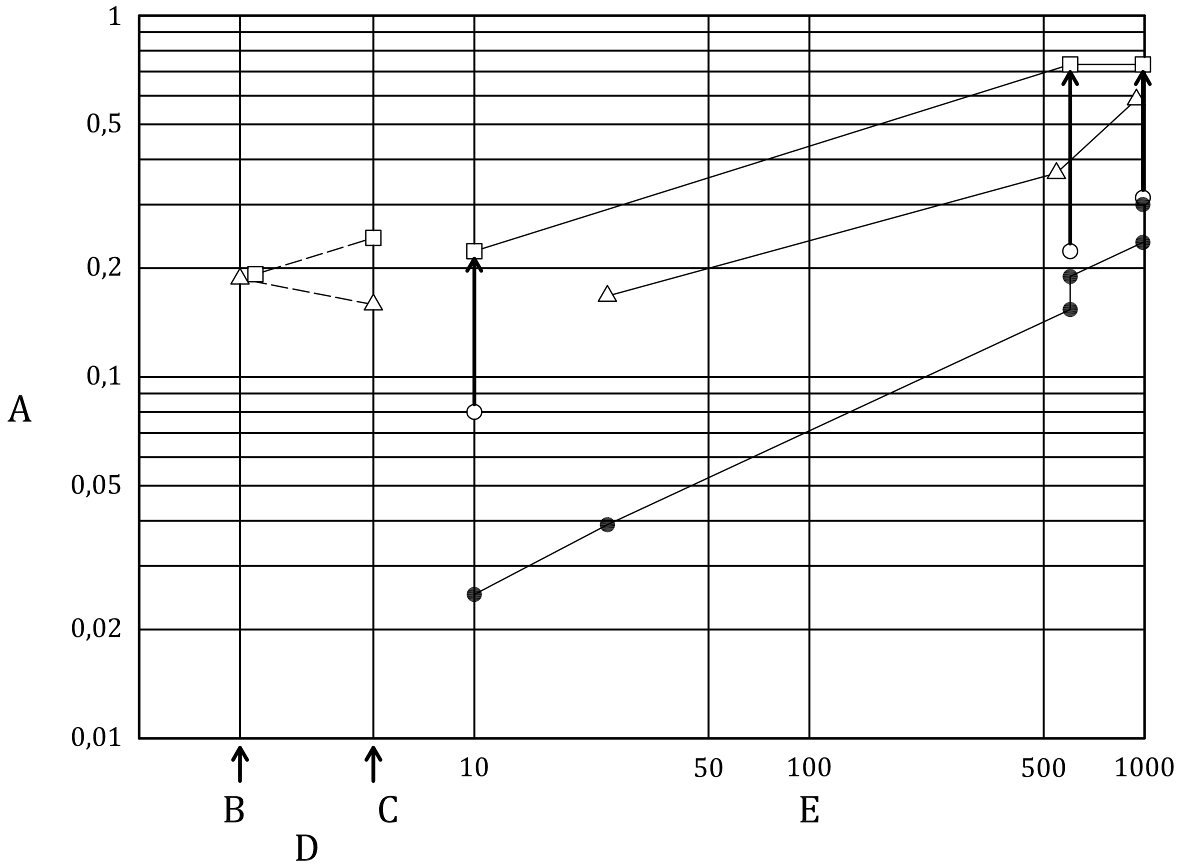
f) 25 cm³ for DO-REG

Key

X time [s]
Y pressure [kPa]
A inlet pressure
B regulated pressure
C signal

Figure A.11 — Discharge waveforms

A.5.3 The pressure response times are shown in Figure A.12.



Key

A pressure response time [s]

B restricted

C full opened

D blowing test

E volume for charging test [cm^3]

		PB1-REG	Do-REG
Charging	Settling time	□	△
	Reach time	○	
Discharging from volume		●	

Figure A.12 — Pressure response time

A.5.4 Observations

A.5.4.1 The regulated pressure of PB1-REG settled after repeating overshoot and undershoot.

A.5.4.2 The regulated pressure of DO-REG settled after increasing gradually.

A.5.4.3 The pressure settling time is considered to be 1 s or less.

A.5.4.4 The discharging time from volume is 0,3 s or less on the charging test.

A.5.4.5 The volume smaller than 50 cm^3 is considered unsuitable because the minimum outlet pressures are not sufficiently low and maximum openings of the regulator will not be enough.

A.6 Air consumption

The amount of air consumption for the various combinations are shown in Table A.4.

Table A.4 — Air consumption (ANR)/trial

	Blowing test by measurement dm^3		**Charging test by calculation** dm^3			
	Full opened	**Restricted**	**985 cm^3**	**590 cm^3**	**25 cm^3**	**10 cm^3**
PB1-REG	19,0	7,2	4,0	2,0	-	0,04
DO-REG	25,5	18,8	4,3	2,1	0,11	-

NOTE The air consumption of the charging test is significantly lower than that of the blowing test.

A.7 Testing time

The charging time can be set to 10 s because measurement values after 5 s can be recorded for 5 s on the charging test. 5 s is enough for the discharging time. Therefore, the cycle time is 15 s/cycle.

The blowing test can be repeated at a higher frequency than the charging test because the blowing time is 1 s.

A.8 Verification test

A.8.1 The charging test as described in 10.5.2 was verified using two test units of different size, PB1-REG and PB2-REG. Measurement results of the repeatability test are shown in Table A.5 and Figure A.13.

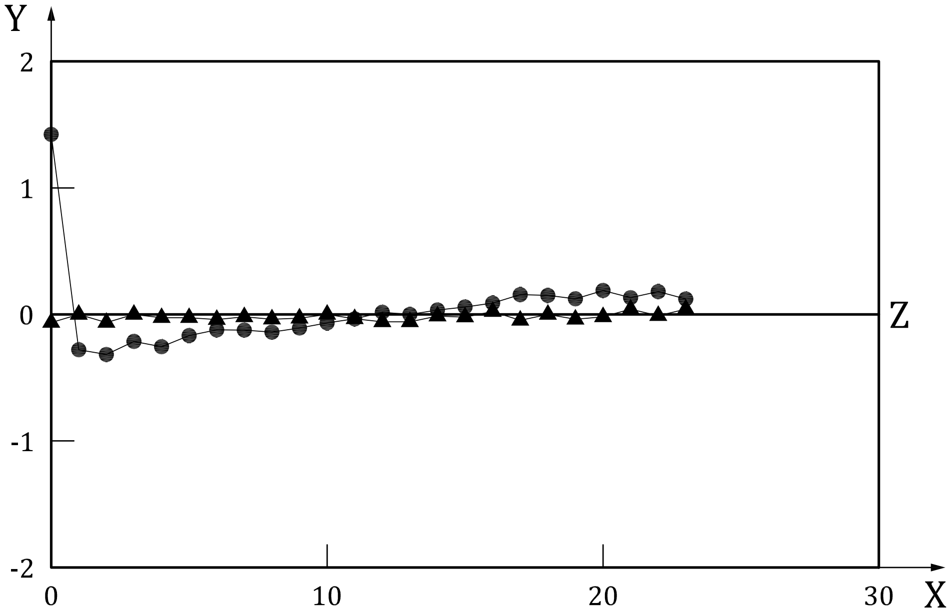
Table A.5 — Verification test results

Trial	Charging test[a] kPa	
	PB1-REG Volume 205 cm^3	**PB2-REG**[b] Volume 985 cm^3
Initial	399,46	399,33
1	(399,52)[c]	(397,64)
2	(399,46)	(397,59)
3	(399,53)	(397,69)
4	399,50	397,66
5	399,50	397,74
6	399,47	397,79
7	399,51	397,79
8	399,47	397,78
9	399,49	397,80
10	399,50	397,85
11	399,48	397,86
12	399,48	397,92
13	399,48	397,91
14	399,52	397,95
15	399,50	397,96
16	399,55	397,99
17	399,48	398,07
18	399,54	398,06
19	399,49	398,04
20	399,51	398,09
21	399,56	398,03
22	399,52	398,09
23	399,56	398,04
Average	399,51	397,92
Max.	399,56	398,09
Min.	399,47	397,66
Repeatability, *r* %	0,01	0,05

[a] Regulated pressures are measured in the volume (7 in Figure 7) after 5 s. Cycle time is 15 s.

[b] Rc1/4, forward sonic conductance 9,1 $dm^3/(s \cdot bar)$ (ANR). Air consumption 11,5 dm^3 (ANR)/trial or less at inlet pressure of 1,0 MPa. Other specifications are same as PB1-REG. Sonic conductance of control valve is 7,9 $dm^3/(s \cdot bar)$ (ANR).

[c] The first three data points are excluded for calculation.



Key

X trials

Y pressure deviation [kPa]

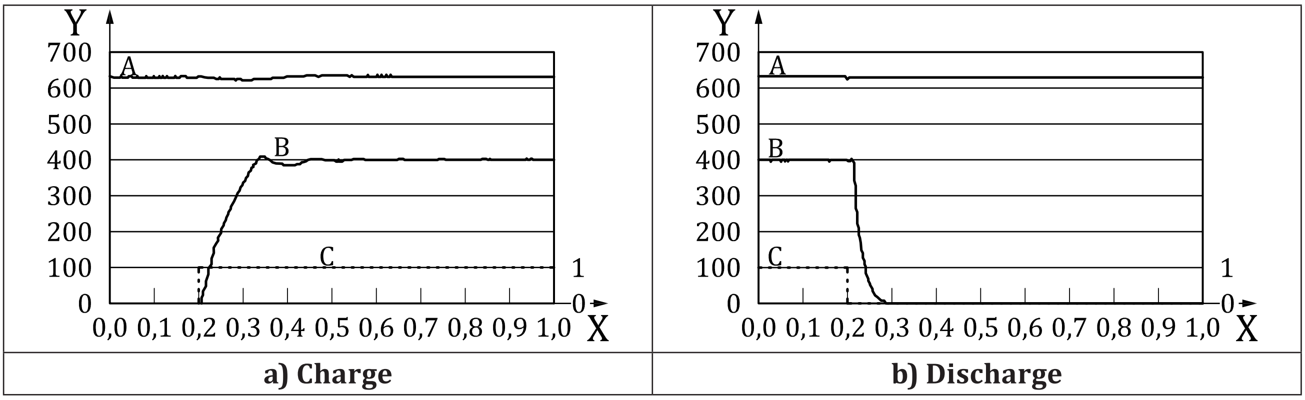
Z average

PB1-REG 205 cm^3 (triangle markers)

PB1-REG 985 cm^3 (circle markers)

Figure A.13 — Regulated pressures

A.8.2 Pressure response waveforms are shown in Figure A.14 and Figure A.15.



Key

X time [s]

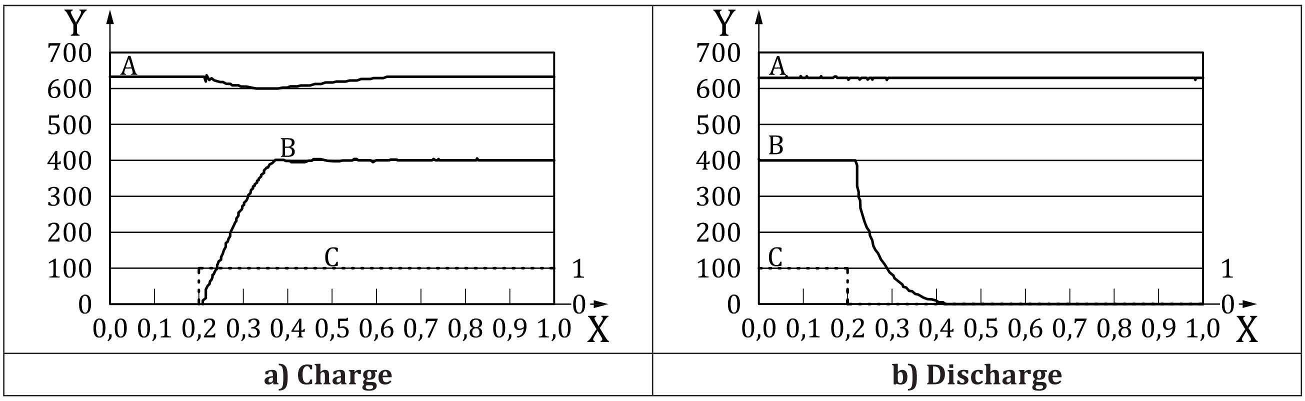
Y pressure [kPa]

A inlet pressure

B regulated pressure

C signal

Figure A.14 — Pressure response waveforms for PB1-REG



Key

X time [s]

Y pressure [kPa]

A inlet pressure

B regulated pressure

C signal

Figure A.15 — Pressure response waveforms for PB2-REG

NOTE Repeatability is 0,05 % or less and is almost the same as the test result in A.4.

A.9 Conclusion

The charging test is selected for this document. Its test time can be longer than that of the blowing test, but the charging test reduces the air consumption to about 1/10 and has a lower noise level.

Bibliography

[1] ISO 1219-1, *Fluid power systems and components — Graphical symbols and circuit diagrams — Part 1: Graphical symbols for conventional use and data-processing applications*

[2] ISO 2944, *Fluid power systems and components — Nominal pressures*

[3] ISO 6358-2, *Pneumatic fluid power — Determination of flow-rate characteristics of components using compressible fluids — Part 2: Alternative test methods*

[4] ISO 6953-3, *Pneumatic fluid power — Compressed air pressure regulators and filter-regulators — Part 3: Alternative test methods for measuring the flow-rate characteristics of pressure regulators*

[5] ISO 8778, *Pneumatic fluid power — Standard reference atmosphere*

[6] ISO 10094-2, *Pneumatic fluid power — Electro-pneumatic pressure control valves — Part 2: Test methods to determine main characteristics to include in the supplier's literature*

[7] ISO 11727, *Pneumatic fluid power — Identification of ports and control mechanisms of control valves and other components*

[8] ISO 80000-1:2022, *Quantities and units — Part 1: General*

ICS 23.100.50

Price based on 38 pages