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

Part 2: Test methods to determine the main characteristics to be included in literature from suppliers

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

Reference number
ISO 6953-2:2015(E)

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Foreword

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 131, *Fluid power systems*, Subcommittee SC 4, *Connectors and similar products and components*.

This second edition cancels and replaces the first edition (ISO 6953-2:2000), which has been technically revised.

ISO 6953 consists of the following parts, under the general title *Pneumatic fluid power — Compressed air pressure regulators and filter-regulators*:

— *Part 1: Main characteristics to include in supplier's literature and product-marking requirements*

— *Part 2: Test methods to determine the main characteristics to be included in literature from suppliers*

— *Part 3: Alternative test methods for measuring the flow-rate characteristics of pressure regulators*

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 be included in literature from suppliers

1 Scope

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

The purpose of this part of ISO 6953 is the following:

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

— to 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 type of regulators and filter-regulators; they are not production tests to be carried out on each pressure regulator or filter-regulator manufactured.

NOTE 1 The tests related to electro-pneumatic pressure control valves are specified in ISO 10094–2.

NOTE 2 Use ISO 6953-3 for 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.

2 Normative references

The following documents, in whole or in part, are referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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 6953-1:2015, *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*

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 6953-1, ISO 6358-1, ISO 10094-1, and ISO 5598 apply; in the order shown.

4 Symbols and terms

4.1 Symbols and units

The symbols and units shall be in accordance with ISO 10094-2. See Table 1.

Table 1 — Symbols and units

Description	Symbol	SI unit	Practical unit
Reference atmosphere	p_{atm}	Pa	kPa (bar)
Inlet pressure	p_1	Pa	kPa (bar)
Regulated pressure	p_2	Pa	kPa (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)
Reference temperature	T_0	K or °C[a]	°C
Inlet temperature	T_1	K or °C[a]	°C
Temperature at the regulated port	T_2	K or °C[a]	°C

[a] emperature in K is used for calculations; temperature in °C is used for test conditions.

NOTE 1 bar = 100 kPa = 0,1 MPa = 10^5 Pa = 10^5 N/m^2.

4.2 Graphical symbols

The graphical symbols used in this part of ISO 6953 are in accordance with ISO 1219-1.

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, $p_{2,max}$, plus 200 kPa (2 bar);

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

5.5 Test pressures (regulated pressure)

The preferential test pressures are chosen as approximately equal to 25 %, 40 %, 63 %, and 80 % of the upper limit of 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:

— 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.

— 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 previous indent and test them using a proposed pressure rating for the outlet port.

6.3 The test should 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 as above 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 as above 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 as above until a level of five times the proposed rated pressure has been reached.

6.5 The criterion for a failure is 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 (for example, 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 part of ISO 6953.

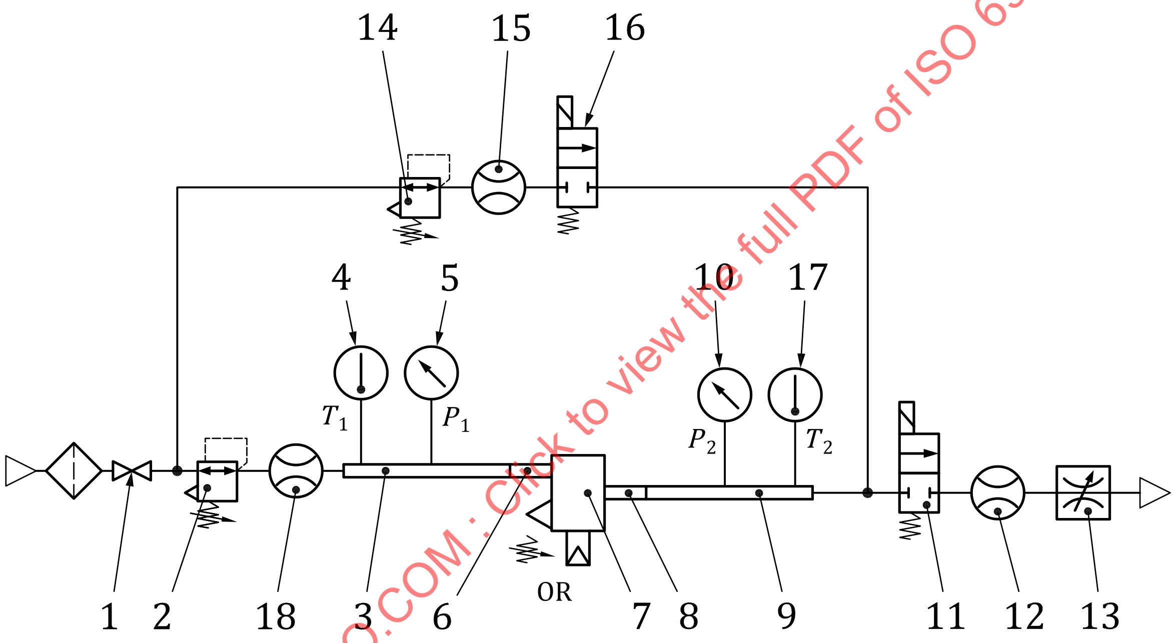
7 Flow characteristics tests

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	10	regulated pressure, p_2, gauge or transducer
2	inlet pressure regulator	11	solenoid valve
3	pressure-measuring tube	12	forward flow meter
4	inlet temperature, T_1, measuring-element	13	flow control valve (for forward flow rates)
5	inlet pressure, p_1, gauge or transducer	14	pressure regulator (for relief flow rates)
6	transition connector	15	relief flow meter
7	component under test	16	solenoid valve
8	transition connector	17	temperature, T_2, measuring-element (for relief flow rates)
9	pressure-measuring tube	18	flow meter

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 7 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 3 and 9 and transition connectors 6 and 8 shall be in accordance with ISO 6358-1.

7.2.3 Components 1, 2, 3, 4, 5, and 6 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 8, 9, 10, 11, 12, and 13 correspond to the downstream part of the test circuit used for forward flow rate measurements.

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

7.2.6 The sonic conductances of the pressure regulator 2 and solenoid valve 11 should each be at least twice the forward sonic conductance of the component under test. The sonic conductances of the pressure regulator 14 and solenoid 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, solenoid 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 might 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 25 % 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 solenoid valve 11. 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 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 solenoid valve 11 and open the solenoid valve 16 to apply this pressure on the outlet side of the component under test. Air can (but might not) 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. 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 solenoid 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 %, 63 %, 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 Characteristic curves

7.4.1.1 For the regulated set pressure equal to 25 % 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 equal to 25 % 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 %, 63 %, and 80 % of the full scale.

7.4.2 Flow rate — pressure hysteresis

For each forward flow rate or relief flow rate value, 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, $\Delta p_{2h,max}$.

$$H = \frac{\left|\Delta p_{2h,max}\right|}{p_{2,max}} \times 100 \qquad (1)$$

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

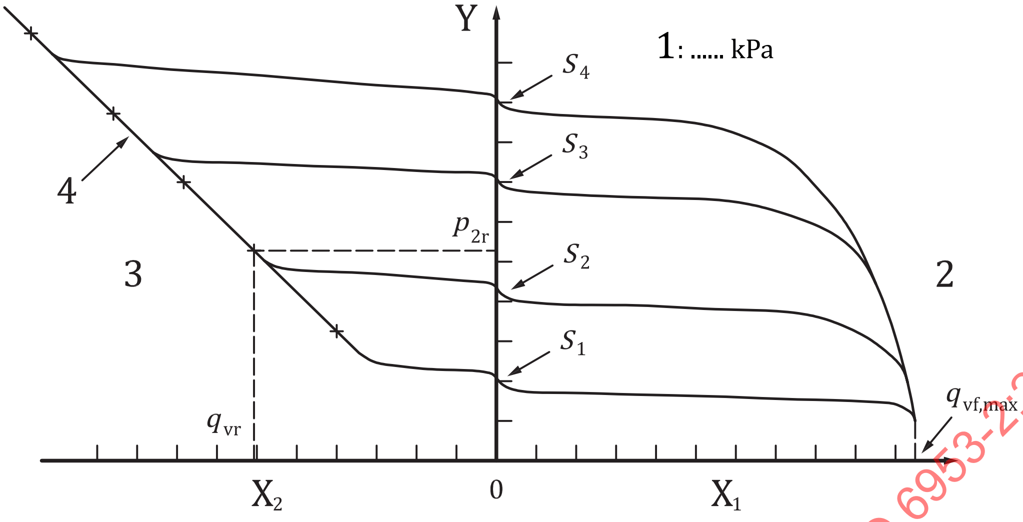
7.4.3 Maximum forward sonic conductance

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):

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

NOTE The square root is necessary to take into account the test upstream temperature, T_1, deviation from the reference temperature, T_0, according to ISO 6358-1.



Key

X1 forward flow rate, dm^3/min (ANR)

X2 relief flow rate, dm^3/min (ANR)

Y regulated pressure, p_2, kPa

1 inlet pressure, p_1, kPa

2 1st quadrant

3 2nd 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 volumetric sonic conductance value, C_r, by dividing the flow rate value by the regulated pressure according to 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 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 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. 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 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).

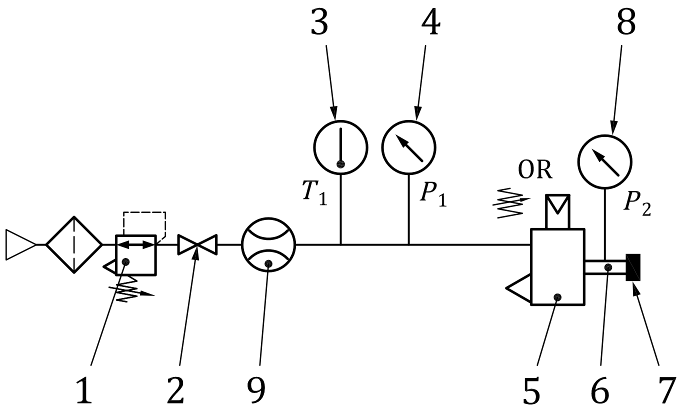
8.2.6 Keeping the same flow rate and regulated pressure setting of the test regulator, increase the inlet pressure, p_1, of regulator 2 in steps. When conditions have stabilized, record the corresponding regulated pressure, p_2. Continue these pressure-increasing steps until the inlet pressure, p_1, 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.



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

Figure 3 — Typical test circuit for air consumption characterization

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.

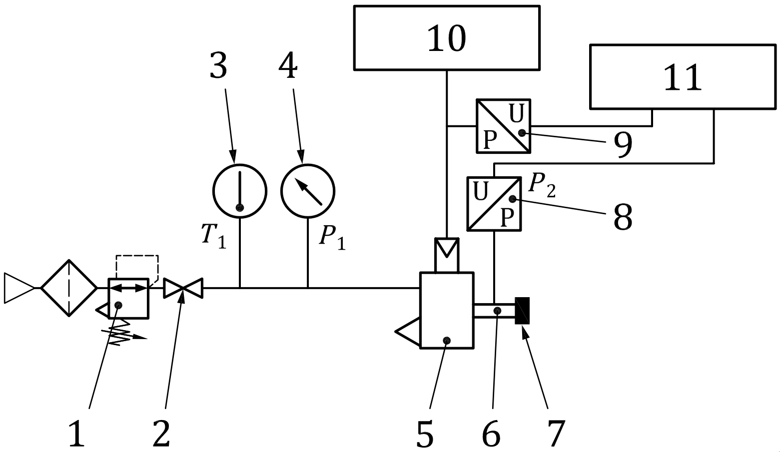
Determine the inlet air consumption flow rate maximum value.

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

Figure 4 represents a typical test circuit for the pilot pressure/regulated pressure characterization at null forward or relief flow rate. Apply the inlet pressure chosen according to 5.4.



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, sensor
9 pilot pressure sensor
10 external pressure regulator
11 X-Y recorder

Figure 4 — Typical test circuit for pilot pressure/ regulated pressure characteristics

The regulated pressure sensor is an external measurement sensor, even if the component under test has an internal pressure sensor. The connector 6, which allows the measurement of the regulated pressure in Figure 4, is plugged to guarantee a null operating flow rate. The length (volume) of this connector shall be as short (small) as possible.

10.1.2 Test procedures

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

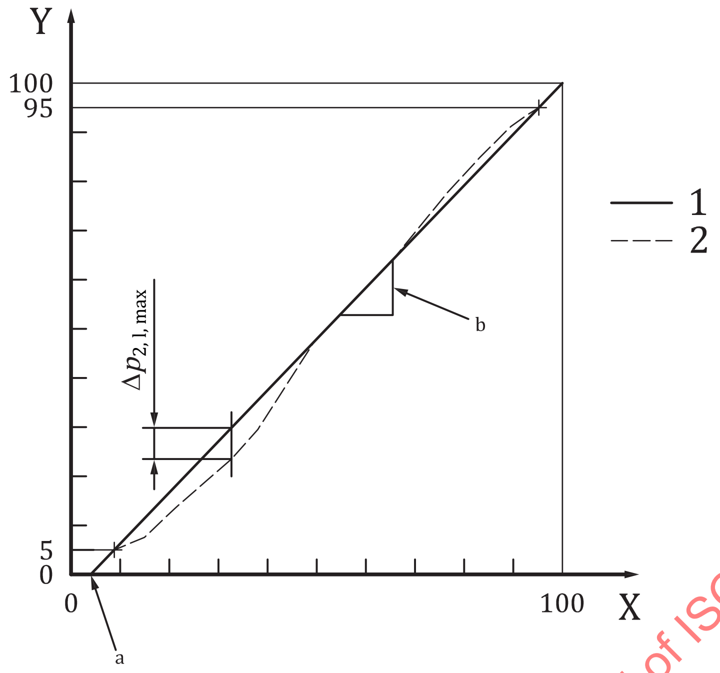
For each step of the pilot pressure, calculate the mean value of the two corresponding regulated pressures, p_2, measured according to the procedure described in 10.1.2, respectively with an increasing and a decreasing pilot pressure.

Plot the mean pressure curve as a function of the pilot pressure as represented in Figure 5.

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 5.

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 5.



Key

X pilot pressure, in %

Y regulated pressure in % of $p_{2,max}$

1 characteristic line

2 mean pressure curve

a Offset.

b Slope.

Figure 5 — 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, $\Delta p_{2,l,max}$, according to Figure 5, and calculate the linearity value, L, expressed as a percentage of the regulated pressure full-scale using Formula (4):

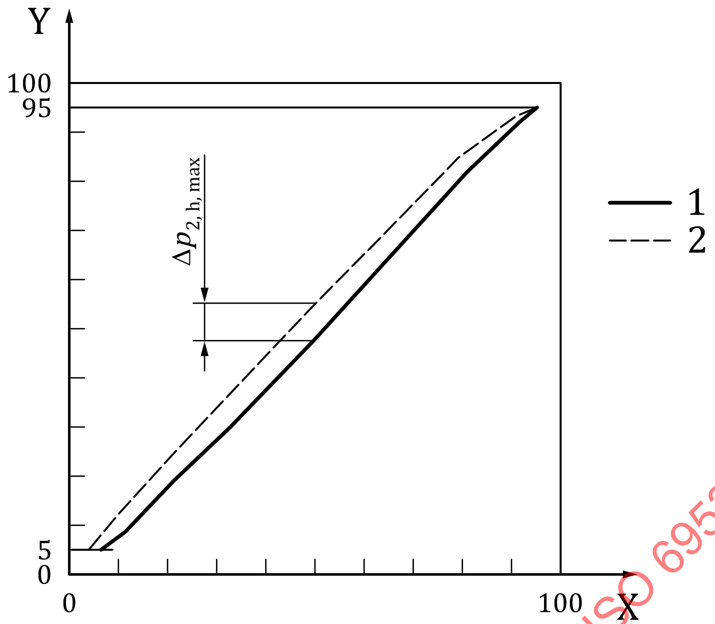
$$L = \frac{\left|\Delta p_{2,l,max}\right|}{p_{2,max}} \times 100 \quad (4)$$

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, $\Delta p_{2,h,max}$, according to Figure 6. Calculate the hysteresis characteristic value, H, evaluating this difference in percentage of the regulated pressure full-scale according to Formula (5):

$$H = \frac{\left|\Delta p_{2,h,max}\right|}{p_{2,max}} \times 100 \quad (5)$$



Key

X pilot pressure, in %

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

1 values measured with increasing pilot pressure

2 values measured with decreasing pilot pressure

Figure 6 — Representation of the maximal scattering of hysteresis difference

10.2 Optional resolution test for pilot-operated regulator with air bleed

10.2.1 General

The resolution, *S*, corresponds to the minimal difference between two rotating positions of the adjustable handle or two pilot pressure (set pressure) values for which there is a difference in the corresponding regulated pressure values.

The test shall be performed in accordance with 10.2.2 and 10.2.3.

The resolution, *S*, expressed in percentage of the regulated pressure full-scale, shall be determined in accordance with 10.2.4.

10.2.2 Test installation

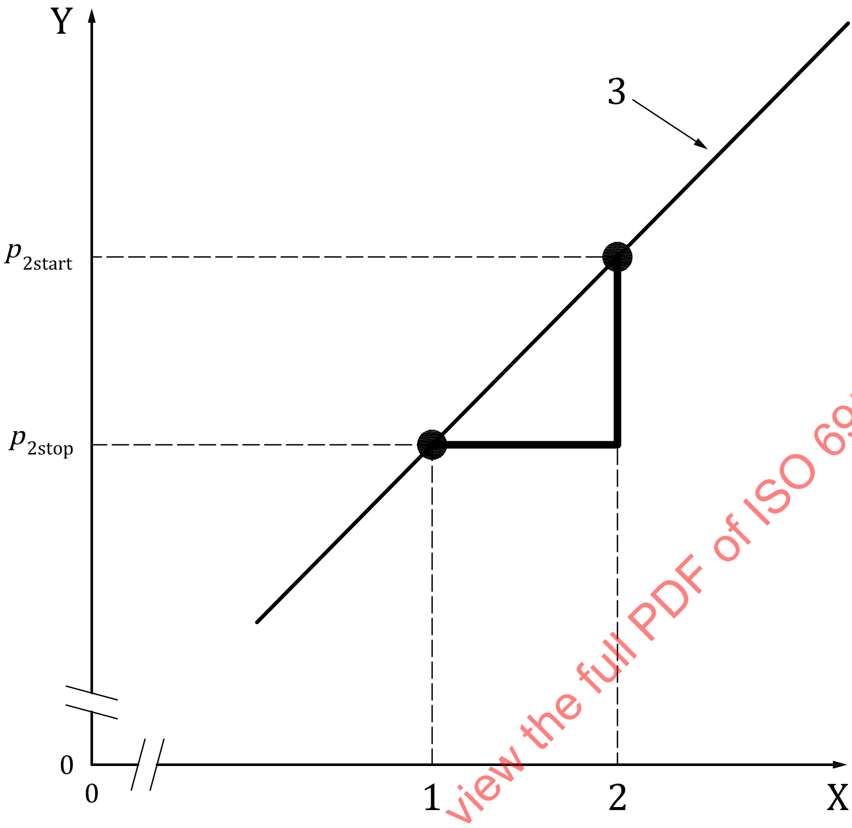
A suitable test circuit, as shown in Figure 4, shall be used for measuring resolution.

10.2.3 Test procedures

10.2.3.1 From fully released position of adjustable handle or the minimal pilot pressure (0 %), gradually modify the handle or pilot pressure by increasing values only, until reaching the value corresponding to 15 % of the regulated pressure full-scale.

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

10.2.3.3 Then gradually re-increase the rotating position of the handle or pilot pressure and stop increasing when the regulated pressure starts re-increasing as shown in Figure 7. Note the increased regulated pressure, p_{2start}.



Key

X handle rotation (turns) or pilot pressure (bar or MPa)

Y regulated pressure (bar or MPa)

1 condition 1: increasing start

2 condition 2: increasing stop

3 idealized pressure curve

NOTE For manual regulators, the resolution is the minimum step of regulated pressure obtained by handle rotation.

Figure 7 — Resolution test procedure

10.2.3.4 Repeat the operations described in 10.2.3.2 and 10.2.3.3 for 50 % and 85 % of the regulated pressure full-scale. Gradually modify the handle or pilot pressure, by increasing values only, until reaching these values.

10.2.4 Calculation of characteristics

10.2.4.1 For each of the three tests done according to 10.2.3, for 15 %, 50 %, and 85 % of the regulated pressure full-scale, calculate the corresponding resolution, expressed as a percentage of the regulated pressure full-scale, using Formula (6):

$$S = \frac{p_{2start} - p_{2stop}}{p_{2,max}} \times 100 \tag{6}$$

10.2.4.2 Calculate the resolution by taking the maximal value of the three values obtained in 10.2.4.1.

10.3 Optional repeatability test

10.3.1 General

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

The test shall be performed by the charging method in accordance with 10.3.3.1 and 10.3.3.2. See Annex A for comparison to a blowing test method.

The repeatability, *r*, expressed as a percentage of the regulated pressure full-scale, shall be determined in accordance with 10.3.4.

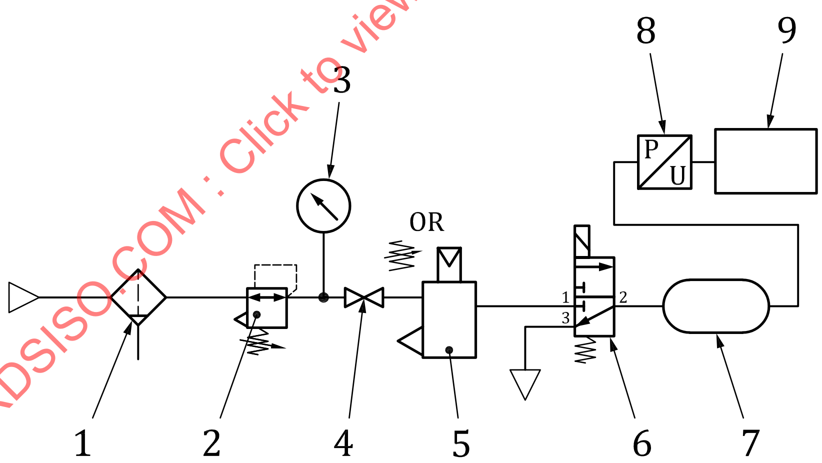
10.3.2 Test installation

A suitable test circuit, as shown in Figure 8, shall be used for measuring repeatability. The directional control valve 6 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 (7):

$$V = 1{,}0 \times 10^4 C \quad (7)$$

where

C is the forward sonic conductance of the regulator under test in m^3 / (s·Pa)(ANR)



Key

1 filter
2 supply pressure regulator
3 inlet pressure, p_1, gauge or transducer
4 shut-off valve
5 component under test
6 directional control valve
7 test volume
8 regulated pressure, p_2, sensor
9 time-based pressure recorder

Figure 8 — Typical charging test circuit for repeatability

10.3.3 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.

10.3.3.1 Test preparation

Set the input pressure of the component under test 5 by means of the supply pressure regulator 2 to the inlet pressure defined in 5.4.

Activate the directional valve 6 to pressurize volume 7 and adjust the regulated pressure, p_2, of the component under test to 50 % of the specified maximum regulated pressure, $p_{2,\max}$. This is the set pressure. Depressurize the volume completely by switching off the directional valve.

10.3.3.2 Test execution

Activate the directional valve and observe that pressure builds up in the volume. The measured value, p_2, shall be recorded after a fixed stabilization time (t = 5 s after p_2 has reached 90 % of the adjusted value, p_2). Then the directional valve is switched off to depressurize the volume completely.

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

10.3.4 Calculation of the repeatability value

Using the stabilized regulated pressure values, p_{2j}, 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 (8):

$$r = \frac{p_{2j,\max} - p_{2j,\min}}{p_{2,\max}} \times 100 \qquad (8)$$

11 Presentation of data

Data from which the performances of the pressure regulator can be compared shall be presented as follows.

11.1 Flow-pressure characteristics

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

— a data graph in accordance with of ISO 6953-1:2015, 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.

11.2 Pressure regulation characteristics

A data graph is presented in accordance with ISO 6953-1:2015, Figure 3.

11.3 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.

11.4 Additional characteristics for pilot operated pressure regulators

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

— a data graph in accordance with ISO 6953-1:2015, Figure 4;

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

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

11.5 Optional data

Calculation results for resolution and repeatability are presented in accordance with Formulae (6) and (7), respectively.

Annex A
(informative)

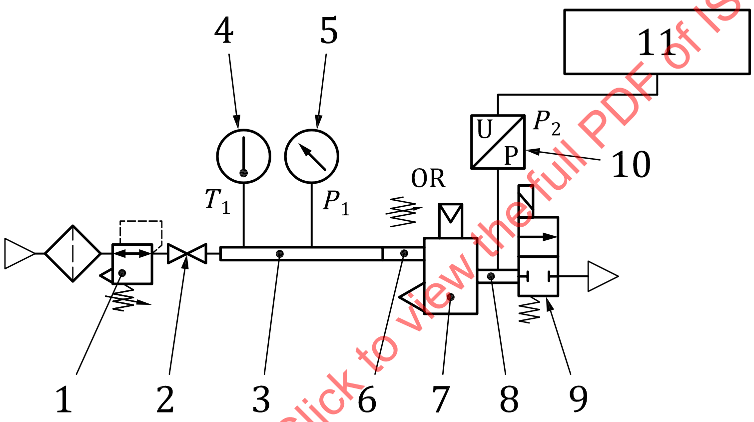
Comparison of repeatability test methods

A.1 General

A blowing test method was considered for this part of ISO 6953 and was tested for comparison to the charging test method of 10.3. Results of the testing are described in this annex.

A.2 Test circuit

Test circuit for blowing test method is shown in Figure A.1 (the charging test method is shown in Figure 8).



Key

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

NOTE Flow control valve is connected downstream from 9.

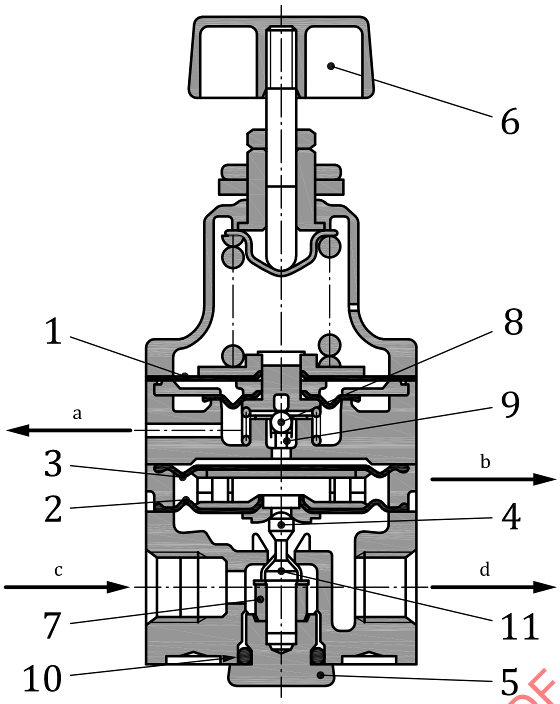
Figure A.1 — "Blowing test" circuit for repeatability

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

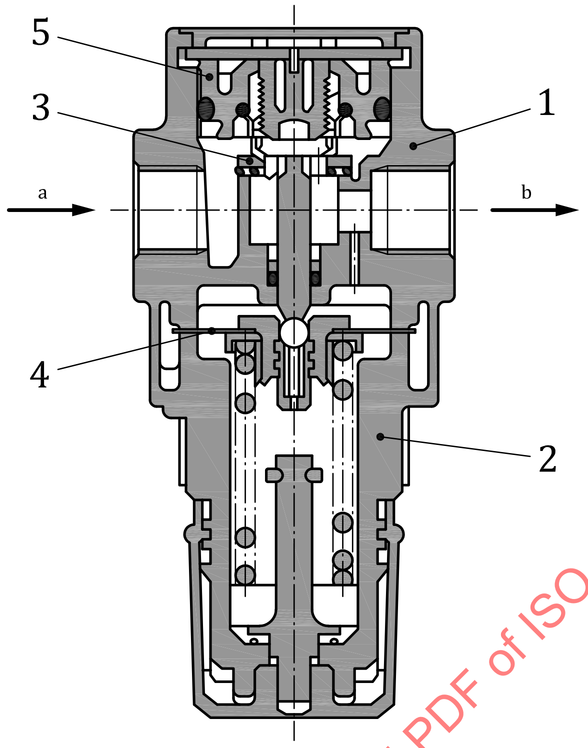
Model	PB1 – REG	DO – REG
	Pilot-type regulator with air bleeding (see Figure A.2)	**Direct operated regulator** (see Figure A.3)
Max. inlet pressure	1,0 MPa	1,0 MPa
Regulated pressure range	0,01 to 0,8 MPa	0,01 to 0,85 MPa
Port size	Rc 1/8	Rc 1/4
Forward sonic conductance	1,8 $dm^3/(s·bar)$ (ANR)	4 $dm^3/(s·bar)$ (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; 590; 10 cm^3	985; 590; 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 to 3 000 kPa Accuracy: ±0,02 % of reading	



Key

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

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 5 and 6 in Figure 8.

Table A.2 — Regulated pressures in kPa for PB1-REG

Trial	Blowing test[a]				Charging test[b]					
	Full opened[c]		Restricted[d]		Volume 985 cm3		Volume 590 cm3		Volume 10 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	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 $dm^3/(s \cdot bar)$ (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 $dm^3/(s \cdot bar)$ (ANR). Flow rate is 435 dm^3/min (ANR). Air consumption is 7,2 dm^3 (ANR).

Table A.3 — Regulated pressures in kPa for DO-REG

Trial	Blowing test[a]				Charging test[b]					
	Full opened[c]		Restricted[d]		Volume 985 cm^3		Volume 590 cm^3		Volume 25 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	426,05		425,30		425,05		425,50		425,89	
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

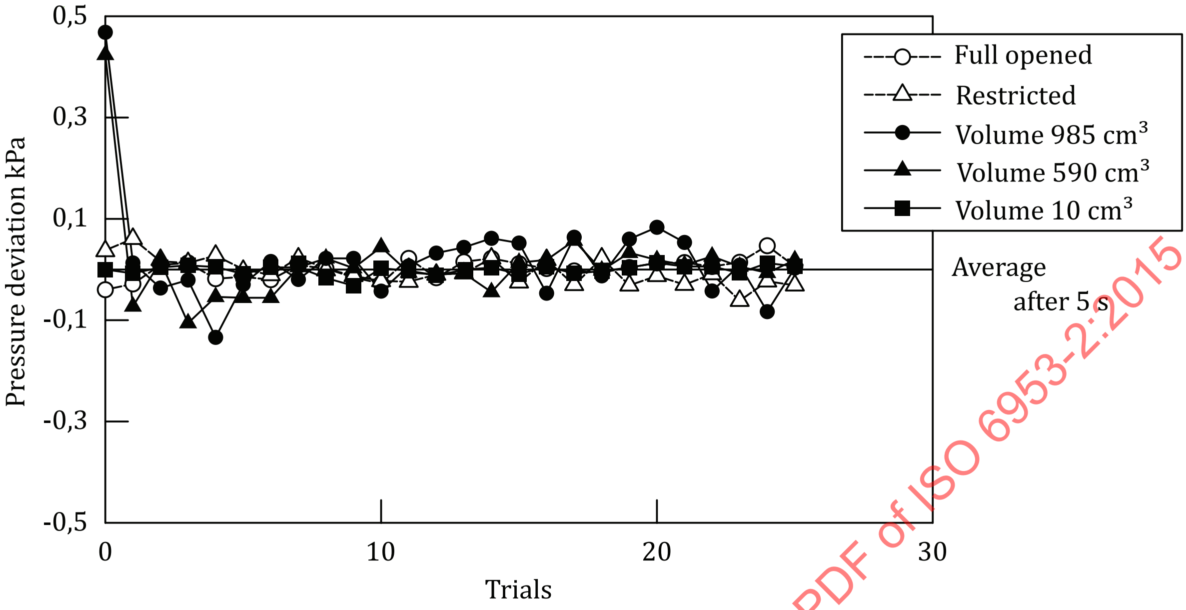
a) Blowing time is 1,0 s. Cycle time is 30 s.

b) Charging time is 15 s. Cycle time is 30 s.

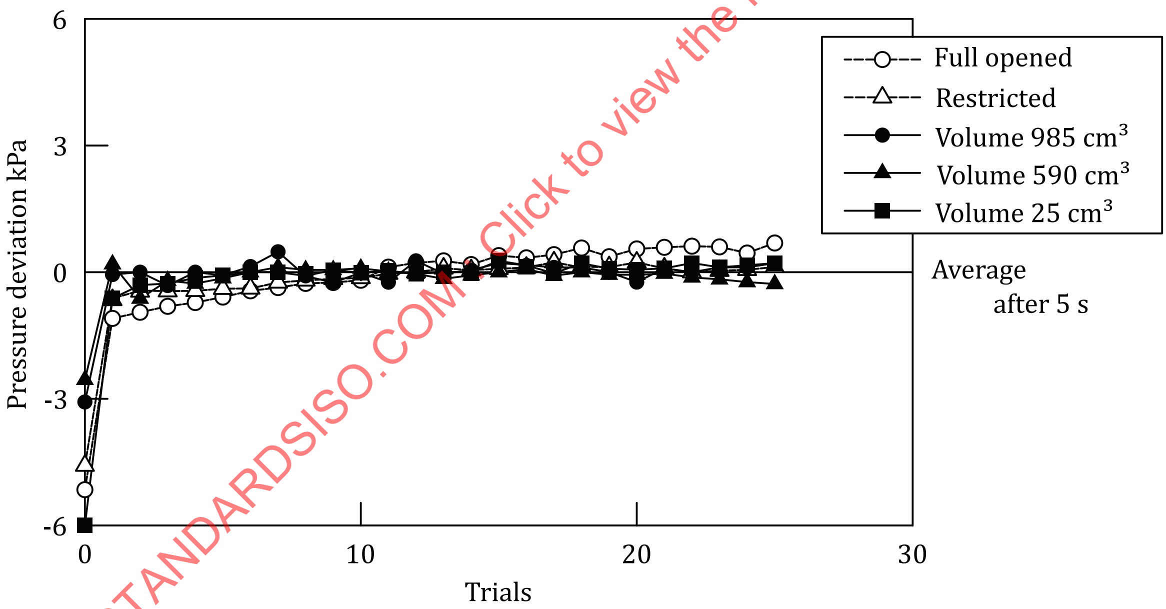
c) Sonic conductance of flow control valve is 8,22 $dm^3/(s \cdot bar)$ (ANR). Flow rate is 1 530 dm^3/min (ANR). Air consumption is 25,5 dm^3 (ANR).

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 and A.5.



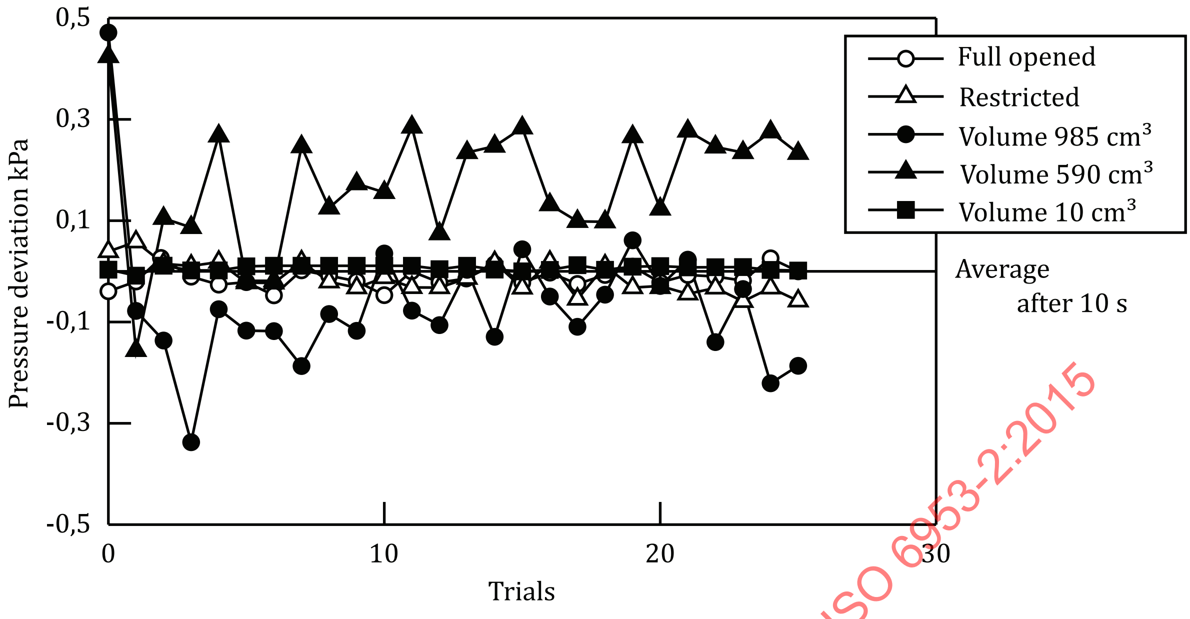
a) PB1-REG



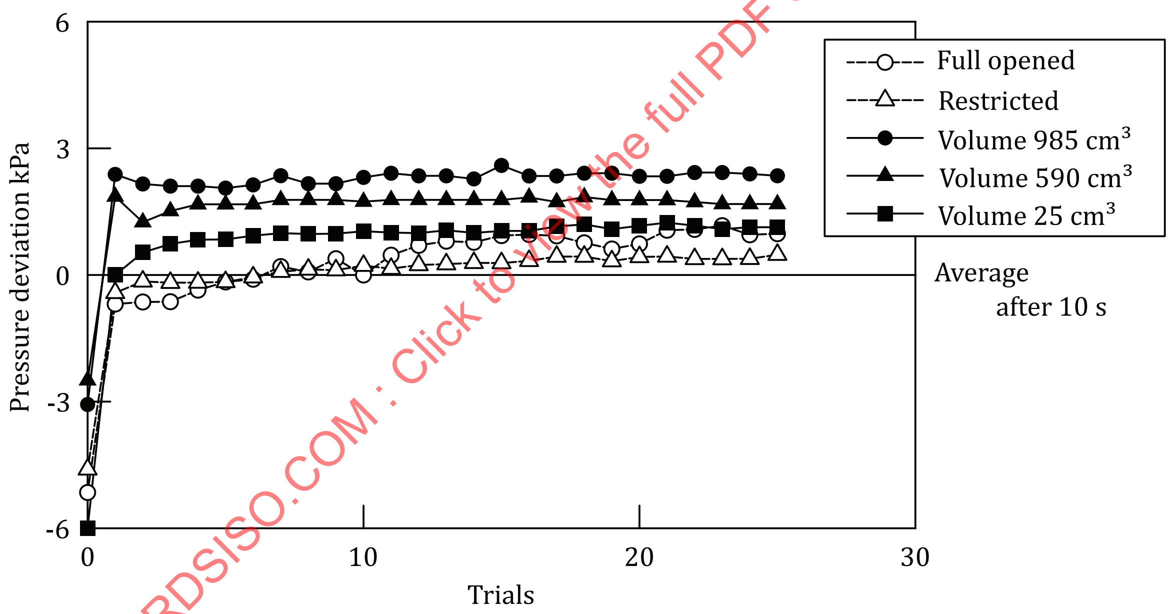
b) DO-REG

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

Figure A.4 — Pressure deviations after 5 s



a) PB1-REG

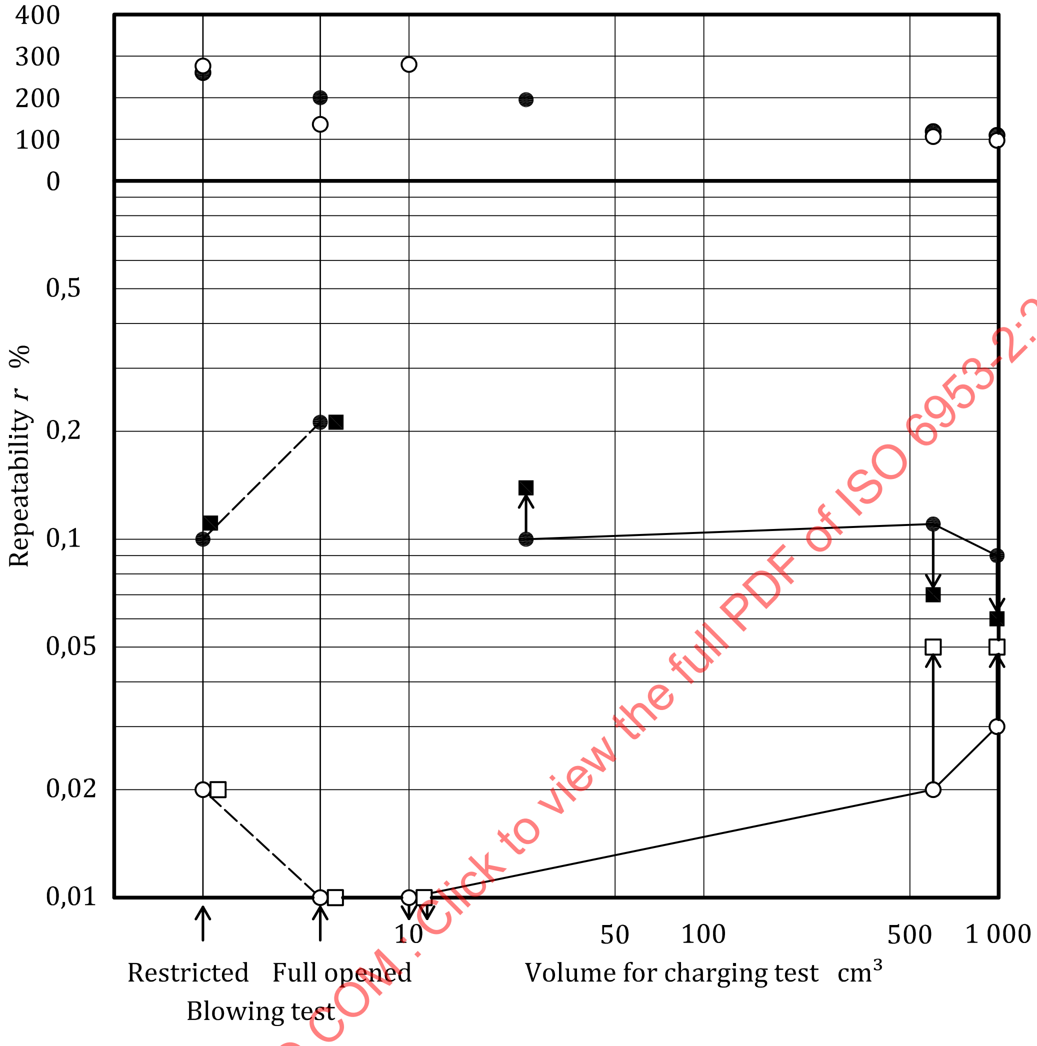


b) DO-REG

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

Figure A.5 — Pressure deviations after 10 s

A.4.1.3 Calculation results of the repeatability are shown in Figure A.6.



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

NOTE Repeatability, r = (Max. value − min. value)/(Regulated pressure full scale) × 100.

Figure A.6 — Repeatability

A.4.2 Observations

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

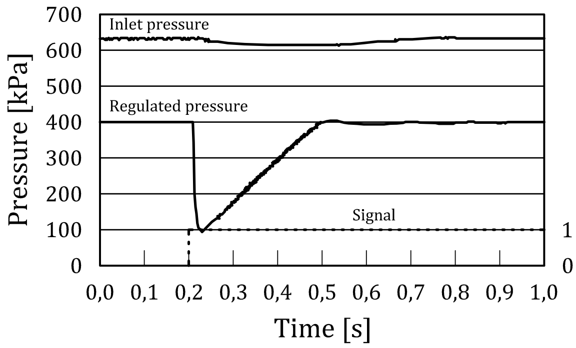
A.4.2.2 Measurement values after 10 s are approximately the same level as the values after 5 s on the blowing test, but there is a large difference in the measurement values after 10 s and 5 s on the charging test.

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.

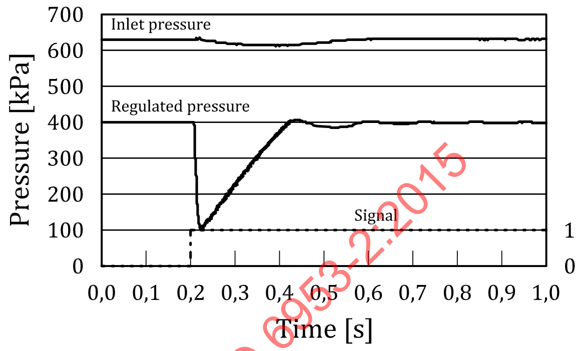
A.4.2.4 The repeatability of DO-REG is 10 times larger than that of PB1-REG.

A.5 Measurement results of pressure response

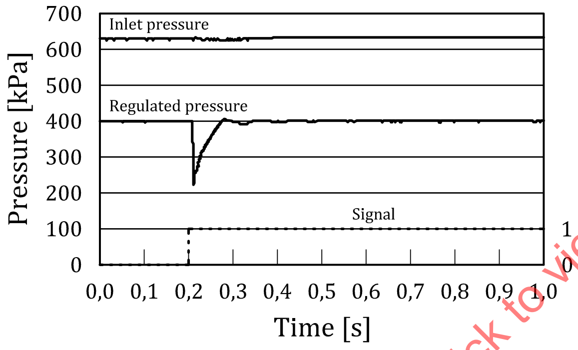
A.5.1 Measurement results of the charging waveform are shown in Figure A.7 and Figure A.8.



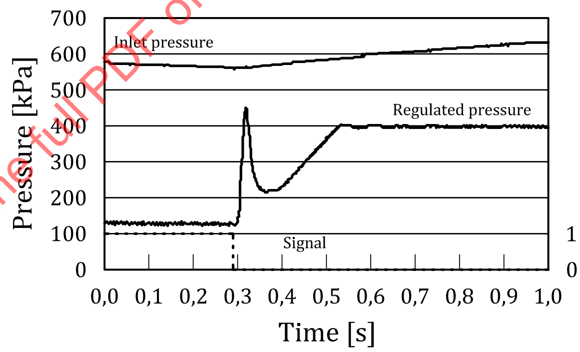
1) volume 985 cm^3



2) volume 590 cm^3



3) volume 10 cm^3



4) blowing test at full opened flow rate

Figure A.7 — Charging waveforms for PB1-REG