INTERNATIONAL STANDARD

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

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

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

Partie 3: Méthodes d'essai alternatives pour mesurer les caractéristiques de débit des régulateurs de pression

Reference number
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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.

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

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ISO 6953-3 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 5, *Control products and components*.

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 be included in literature from suppliers and product-marking requirements*

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

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

Introduction

This part of ISO 6953 defines alternative test methods for flow-rate characteristics of pneumatic pressure control valves. These alternative test methods do not use a flow meter but, instead, use an isothermal tank.

These methods measure the forward flow-rate characteristics by passing compressed air from a charged tank through the regulator under test, into an isothermal tank. Relief flow-rate characteristics are obtained by passing compressed air from an isothermal tank, through the regulator under test, and out to the atmosphere.

The test methods specified in this part of ISO 6953 have the following advantages over test methods specified in ISO 6953-2:

a) an air source with a large flow-rate capacity is not required;

b) components with larger flow-rate capacity can be tested more easily;

c) air consumption is minimized; and

d) test time is shortened.

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

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

1 Scope

This part of ISO 6953 specifies alternative test methods for testing pneumatic fluid power components that use compressible fluids, i.e. gases. This part of ISO 6953 is applicable only to the decreasing flow rate part of the hysteresis curve of forward flow and relief flow characteristics. This method can be applied when:

— the pressure regulation dynamics of a component under test is rapid enough to be negligible, compared to the response of pressure changes during charge and discharge tests;

— the pressure response does not show any overshoot or any oscillating behaviour.

This part of ISO 6953 specifies requirements for the test installation, the test procedure and the presentation of results.

Examples of test results are given, as well as various data processing methods, and visualization of data processing procedures. Illustrations of overshoot and undershoot on regulated pressure response and large variations on inlet pressure are also given.

This part of ISO 6953 applies to the following components:

— compressed air pressure regulators and filter-regulators according to ISO 6953-1;

— electro-pneumatic pressure control valves according to ISO 10094;

— other components such as relief valves.

NOTE If pressure regulation characteristics are needed, ISO 6953-2 is applicable.

2 Normative references

The following referenced documents are indispensable for the application 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 5598, *Fluid power systems and components — Vocabulary*

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

ISO 6358-2, *Pneumatic fluid power — Determination of flow-rate characteristics of components — Part 2: Alternative test methods*[1)]

ISO 6953-1, *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*

1) To be published.

ISO 6953-2, *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*

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 5598, ISO 6358-1, ISO 6953-1 and ISO 10094-1 apply.

4 Symbols and units

4.1 The symbols and units shall be in accordance with ISO 6358-1 and ISO 6358-2, except for the pressure, p, given as the gauge stagnation pressure in this part of ISO 6953.

4.2 The subscripts to the symbols shall be in accordance with ISO 6358-1 and ISO 6358-2, except as given in Table 1.

Table 1 — Subscripts

Subscript	Meaning
1	Inlet conditions
2	Outlet conditions
3	Isothermal tank conditions
4	Relief conditions
a	Atmospheric conditions
u	Upstream conditions
d	Downstream conditions
f	Forward flow conditions
r	Relief flow conditions

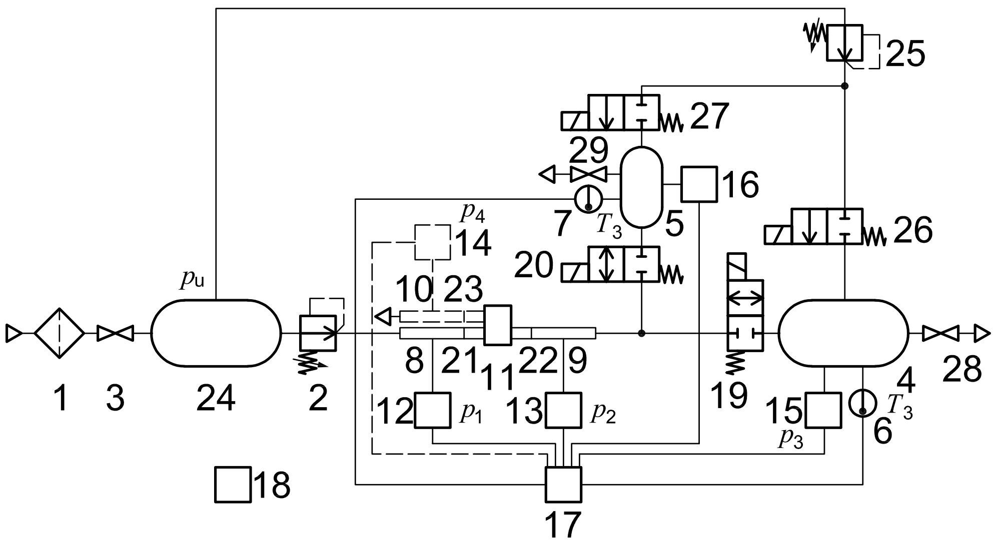
4.3 The graphical symbols used in Figure 1 are in accordance with ISO 1219-1.

5 Test installation

5.1 Test circuit

A suitable test circuit as shown in Figure 1 shall be used. The key of Figure 1 defines the test circuit components.

NOTE Figure 1 illustrates the basic circuit which does not incorporate all of the safety devices necessary to protect against damage in the event of component failure. It is important that those responsible for carrying out the test give due consideration to safeguarding both personnel and equipment.



Key

1	compressed gas source and filter	24	tank
2	adjustable pressure regulator	25	adjustable pressure regulator
3	shut-off valve	26, 27	solenoid valve, or manual valve
4, 5	isothermal tank, in accordance with ISO 6358-2	28, 29	exhaust valve
6, 7	temperature-measuring instrument		
8, 9, 10	pressure-measuring tube, in accordance with ISO 6358-1	p_1	inlet pressure
11	component under test	p_2	outlet pressure
12, 13, 14, 15, 16	pressure transducer	p_3	pressure in the isothermal tank
17	digital recorder	p_4	relief pressure
18	barometer	p_u	supply pressure
19, 20	solenoid valve, bi-directional flow type shall be used	T_3	temperature in the isothermal tank
21, 22, 23	transition connector, in accordance with ISO 6358-1		

Figure 1 — Test circuit

5.2 General requirements

5.2.1 The component under test shall be installed and operated in the test circuit in accordance with the manufacturer's operating instructions.

5.2.2 A filter shall be installed which provides a standard of filtration specified by the manufacturer of the component under test.

5.2.3 The test circuit of Figure 1 shall be constructed from the items listed in the key of Figure 1. Items 1, 2, 3, 4, 6, 8, 9, 11, 12, 13, 15, 17, 18, 19, 21, 22, 24, 25, 26 and 28 inclusive are essential, and the remaining items 5, 7, 10, 14, 16, 20, 23, 27 and 29 can be chosen in accordance with 5.2.4 and 5.2.13.

5.2.4 Items 10, 14, 23 are not required for a component under test that does not have a relief port, or when the mounting is not possible.

5.2.5 The sonic conductance of solenoid valve 19 shall be about four times as large as that of the component under test.

5.2.6 The sonic conductance of adjustable pressure regulator 2 shall be at least twice as large as the forward sonic conductance of the component under test. The upstream regulator 2 must be chosen to keep the inlet pressure, p_1, in the range of ±1 % of the pressure specified in 6.1.4.1. See 6.3.3 and Annex D.2.

5.2.7 The distance between pressure-measuring tube 9 and isothermal tanks 4 and 5 shall be as short as possible.

5.2.8 Pressure-measuring tubes 8, 9 and 10, and transition connectors 21, 22 and 23, shall be made in accordance with ISO 6358-1. It is not necessary to have a temperature-measuring connection in the pressure-measuring tubes because, in this test method, the temperature is measured in the isothermal tank.

5.2.9 Pressure transducer 12 shall be connected to the pressure tap of pressure-measuring tube 8.

5.2.10 Pressure transducer 13 shall be connected to the pressure tap of pressure-measuring tube 9.

5.2.11 Pressure transducer 14 shall be connected to the pressure tap of pressure-measuring tube 10.

5.2.12 solenoid valves 19 and 20 shall each have a rapid shifting time that ensures that test data collection starts after solenoid valves 19 and 20 each shift.

5.2.13 When the relief capacity of the component under test is very small, the size of components 5, 20 and 27 should be small in order to shorten the testing time. The sonic conductance of solenoid valve 20 shall be at least four times as large as the relief sonic conductance of the component under test.

5.2.14 The volume of the tank 24, or supply pressure from an air source should be determined to satisfy the following relation.

$$\frac{V_u}{V_d} > \frac{p_{2max}}{p_u - p_1} \tag{1}$$

where

V_u is the volume of tank 24 (m^3);

V_d is the volume of tank 4 (m^3);

p_u is the supply pressure (Pa);

p_1 is the inlet pressure (Pa);

p_{2max} is the maximum value of regulated pressure (Pa).

5.2.15 For the places where liquid is collected, installation of a drain valve is preferred.

5.3 Isothermal tank (items 4 and 5)

The structure, stuffed material and volume shall be in accordance with ISO 6358-2.

5.4 Special requirements

The special requirements shall be in accordance with ISO 6358-1 and ISO 6358-2.

6 Test procedures

6.1 Test conditions

6.1.1 Gas supply

The gas supply shall conform to the requirements of ISO 6358-1.

6.1.2 Checks

The checks shall be in accordance with ISO 6358-1.

6.1.3 Test measurements

6.1.3.1 Measurement shall be started only after steady-state conditions of temperature and pressure in the isothermal tank have been reached.

6.1.3.2 Measurements shall be in conformance with Table 2 for the measurement accuracy and for the allowed test condition variation.

Table 2 — Measurement accuracy and allowed test condition variation of parameters

Parameter	Measurement accuracy	Allowed test condition variation
Volume	±1 %	–
Time	±1 %	–
Inlet pressure	±0,5 %	±1 %
Tank pressure	±0,5 %	–
Regulated pressure	±0,5 %	0 % overshoot for charge test 0 % undershoot for discharge test
Temperature	±1 K	±3 K

6.1.3.3 The phase lag between p_1 and p_3 shall be smaller than two sampling periods.

6.1.4 Inlet and set pressures

6.1.4.1 The inlet pressure used for testing shall be the lower of

— the maximum regulated pressure plus 200 kPa (2 bar), and

— the specified maximum inlet pressure.

6.1.4.2 The set pressure shall be in accordance with ISO 6953-2.

6.1.4.3 The flow-rate data shall be obtained while the inlet pressure, p_1, is held within ±1 %.

6.2 Measuring procedures

6.2.1 General

According to the design of the component under test, either or both of the procedures specified in 6.2.2 and 6.2.3 shall be followed.

6.2.2 Forward flow characteristics test

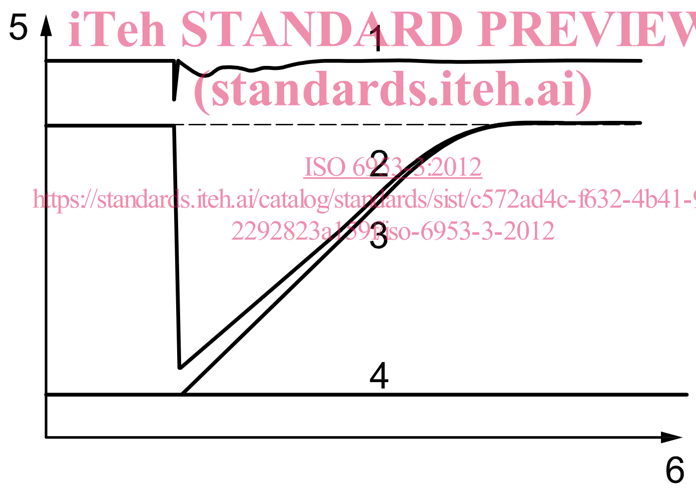
6.2.2.1 Close shut-off valve 3 and the solenoid valves 19 and 20 and install the component under test according to Figure 1 (make sure that its outlet pressure setting is at zero). Close solenoid valve 26 and open exhaust valve 28 and leave the isothermal tank 4 as it is until temperature and pressure in the tank reach steady-state conditions, then close exhaust valve 28.

6.2.2.2 Open shut-off valve 3 and set the inlet pressure, p_1, using adjustable pressure regulator 2. Then adjust the component under test at the set pressure for the test. Measure the initial temperature, T_3, using temperature measuring instrument 6 in isothermal tank 4 and the atmospheric pressure, p_a, using barometer 18.

6.2.2.3 Open solenoid valve 19 and allow compressed air to pass through the component under test into isothermal tank 4. Continuously record pressures for inlet (p_1) outlet (p_2), and isothermal tank (p_3) during this flow, using pressure transducers 12, 13 and 15 with digital recorder 17. Figure 2 is an idealized example of data recorded from a test run.

6.2.2.4 The temperature should be recorded to verify that the temperature variations are acceptable for an isothermal process during the charge test, using temperature measuring instrument 6 with digital recorder 17.

6.2.2.5 If the outlet pressure in Figure 2 shows an overshoot (see Annex D), the test data shall not be used to obtain the forward flow characteristics. The procedure of ISO 6953-2 should be used instead.



Key

1 inlet pressure
2 outlet pressure
3 pressure in the isothermal tank
4 atmospheric pressure
5 pressure scale
6 time scale

Figure 2 — Pressure response during charge

6.2.3 Relief flow characteristics test

6.2.3.1 Close solenoid valves 19, 20 and 27, open solenoid valve 26 and supply compressed air to isothermal tank 4 from adjustable pressure regulator 25. The supply pressure regulated by 25 shall be higher than the set pressure of the component under test by approximately 200 kPa. Leave isothermal tank 4 as it is until temperature and pressure in the tank reach steady-state conditions.

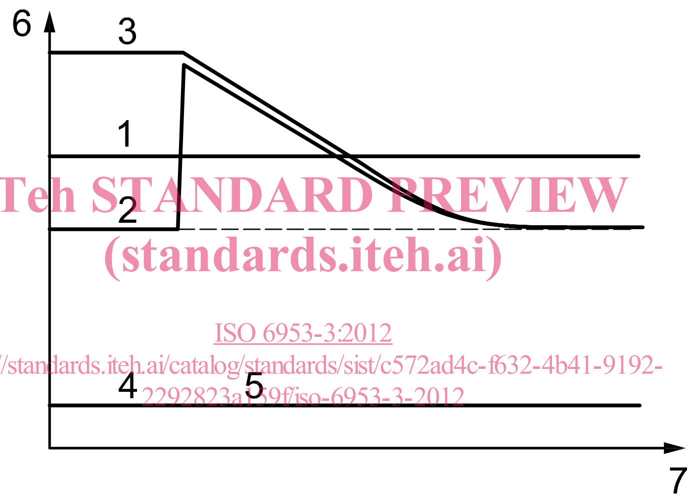
6.2.3.2 Close solenoid valve 26 and measure the initial temperature, T_3, using temperature measuring instrument 6 in isothermal tank 4, and the atmospheric pressure, p_a, using barometer 18.

6.2.3.3 Open solenoid valve 19 and allow compressed air to pass from the isothermal tank 4 through the relief port of the component under test. Continuously record pressures for inlet (p_1), outlet (p_2), relief (p_4), and isothermal tank (p_3) during this flow using pressure transducers 12, 13, 15 and 14 with digital recorder 17. Figure 3 is an idealized example of data recorded from a test run.

6.2.3.4 The temperature should be recorded to verify that the temperature variations are acceptable for an isothermal process during a discharge test using temperature measuring instrument 6 with digital recorder 17.

6.2.3.5 If the outlet pressure in Figure 3 shows an undershoot (see Annex D), the test data shall not be used to obtain the relief flow characteristics. The procedure of ISO 6953-2 should be used instead.

6.2.3.6 When the relief capacity of the component under test is very small, items 5, 7, 16, 20, 27 and 29 should be used instead of items 4, 6, 15, 19, 26 and 28.



Key

1 inlet pressure
2 outlet pressure
3 pressure in the isothermal tank
4 relief pressure
5 atmospheric pressure
6 pressure scale
7 time scale

Figure 3 — Pressure response during discharge

6.2.4 Other set pressures

Repeat the above procedures at other outlet pressure set points. These set points shall be adjusted at no flow conditions, and should be made with an increase in the set pressure. If the set pressure is decreased, the pressure must be lowered well below the desired set point; then increased to the desired setting.

— For test components with only forward flow capability (such as non-relieving pressure regulators), repeat the procedures of 6.2.2 for other set pressures.

— For test components with only relief flow capability (such as relief valves), repeat the procedures of 6.2.3 for other set pressures.

— For test components with both forward flow and relief flow capabilities (such as relieving pressure regulators), repeat the procedures of 6.2.2 and 6.2.3 for other set pressures.

6.3 Calculation of characteristics

6.3.1 Calculation of flow rate

The characteristic curve is represented by the outlet pressure and flow rate, calculated from the pressure data in the isothermal tank. Data processing procedures are described in Annex C.

6.3.1.1 Data processing interval

Calculate the data processing interval for smoothing by the following equation:

$$\omega = \sqrt{n} \tag{2}$$

where

n is the number of pressure response data points (square of an even number);

ω is the data processing interval (even number).

6.3.1.2 Smoothing of outlet pressure data

Calculate to smooth the regulated pressure with the following moving average and median processing:

$$p'_{2(j)} = \frac{1}{\omega+1} \sum_{i=j-\frac{\omega}{2}}^{j+\frac{\omega}{2}} p_{2(i)} \tag{3}$$

$$p''_{2(k)} = \mathrm{Median}\left(p'_{2\left(k-\frac{\omega}{2}\right)}, p'_{2\left(k-\frac{\omega}{2}+1\right)}, \cdots, p'_{2\left(k+\frac{\omega}{2}\right)} \right) \tag{4}$$

where

$p_{2(i)}$ is the outlet pressure (Pa) (i = 1, 2, ⋯, n–1, n)

$p'_{2(j)}$ is the outlet pressure after the moving average processing (Pa) (j = ω/2+1, ω/2+2, ⋯, n–ω/2–1, n–ω/2)

$p''_{2(k)}$ is the outlet pressure after the median processing (Pa) (k = ω+1, ω+2, ⋯, n–ω–1, n–ω)

6.3.1.3 Smoothing of flow-rate data

Calculate the flow rate using Formula (6) after smoothing the pressure in the isothermal tank with the moving average using Formula (5) and smoothing the flow rate with median processing Formula (7).

$$p'_{3(j)} = \frac{1}{\omega+1} \sum_{i=j-\frac{\omega}{2}}^{j+\frac{\omega}{2}} p_{3(i)} \tag{5}$$

$$q_{V(j)} = \frac{V}{\rho_0 R T_3} \frac{p'_{3(j+1)} - p'_{3(j-1)}}{2\Delta t} \tag{6}$$

$$q'_{v(k)} = \text{Median}\left(q_{v\left(k-\frac{\omega}{2}\right)}, q_{v\left(k-\frac{\omega}{2}+1\right)}, \cdots, q_{v\left(k+\frac{\omega}{2}\right)} \right) \tag{7}$$

where

$p_{3(i)}$ is the pressure in the tank [Pa] ($i = 1, 2, \cdots, n-1, n$);

$p'_{3(j)}$ is the pressure in the tank after moving average processing [Pa] ($j = \omega/2+1, \omega/2+2, \cdots, n-\omega/2-1, n-\omega/2$);

$q_{v(j)}$ is the volumetric flow rate at standard reference atmosphere [m^3/s(ANR)] ($j = \omega/2+2, \omega/2+3, \cdots, n-\omega/2-2, n-\omega/2-1$);

$q'_{v(k)}$ is the volumetric flow rate after median processing [m^3/s(ANR)] ($k = \omega+2, \omega+3, \cdots, n-\omega-2, n-\omega-1$);

Δt is the sampling time for the pressure data [s];

V is the isothermal tank volume [m^3];

R is the gas constant [287 J/(kg·K) for air];

T_3 is the absolute temperature in the tank [K];

ρ_0 is the mass density of air at standard reference atmosphere [1,185 kg/m^3].

6.3.2 Characteristic curve

The volumetric flow rate shall be indicated by curves on a graph as shown in Figure 4. Each curve describes the outlet pressure versus volumetric flow rate for given inlet pressure.