INTERNATIONAL STANDARD

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Pneumatic fluid power — Determination of flow-rate characteristics of components using compressible fluids —

Part 2: Alternative test methods

Transmissions pneumatiques — Détermination des caractéristiques de débit des composants traversés par un fluide compressible —

Partie 2: Méthodes d'essai alternatives

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 6358-2 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*, Subcommittee SC 5, *Control products and components*.

This first edition of ISO 6358-2, together with ISO 6358-1 and ISO 6358-3, cancels and replaces ISO 6358:1989, which has been technically revised. However, ISO 6358-2 and ISO 6358-3 are new standards whose scopes were not included in ISO 6358:1989.

ISO 6358 consists of the following parts, under the general title *Pneumatic fluid power — Determination of flow-rate characteristics of components using compressible fluids*:

— *Part 1: General rules and test methods for steady-state flow*

— *Part 2: Alternative test methods*

— *Part 3: Method for calculating steady-state flow-rate characteristics of assemblies*

Introduction

In pneumatic fluid power systems, power is transmitted and controlled through a gas under pressure within a circuit. Components that make up such a circuit are inherently resistive to the flow of the gas and it is necessary, therefore, to define and determine the flow-rate characteristics that describe their performance.

ISO 6358:1989 was developed to determine the flow-rate characteristics of pneumatic valves, based upon a model of converging nozzles. The method included two characteristic parameters: sonic conductance, C, and critical pressure ratio, b, used in a proposed mathematical approximation of the flow behaviour. The result described flow performance of a pneumatic valve from choked flow to subsonic flow, based on static pressure. This new edition uses stagnation pressure instead, to take into account the influence of flow velocity on the measurement of pressures.

Experience has demonstrated that many pneumatic valves have converging–diverging characteristics that do not fit the ISO 6358:1989 model very well. Furthermore, new developments have allowed the application of this method to additional components beyond pneumatic valves. However, this now requires the use of four parameters (C, b, m, and Δp_c) to define the flow performance in both the choked and subsonic flow regions.

This part of ISO 6358 describes a set of three flow-rate characteristic parameters determined from test results. These parameters are described as follows and are listed in decreasing order of priority:

— The sonic conductance, C, corresponding to the maximum flow rate (choked) is the most important parameter. This parameter is defined by the upstream stagnation conditions.

— The critical back-pressure ratio, b, representing the boundary between choked and subsonic flow is second in importance. Its definition differs here from the one in ISO 6358:1989 because it corresponds to the ratio of downstream to upstream stagnation pressures.

— The subsonic index, m, is used if necessary to represent more accurately the subsonic flow behaviour. For components with a fixed flow path, m is distributed around 0,5. In these cases, only the first two characteristic parameters C and b are necessary. For many other components, m will vary widely. In these cases, it is necessary to determine C, b, and m.

Several changes to the test equipment were made to overcome apparent violations of the theory of compressible fluid flow. This included expanded inlet pressure-measuring tubes to satisfy the assumptions of negligible inlet velocity to the item under test and to allow the inlet stagnation pressure to be measured directly. Expanded outlet tubes allow the direct measurement of downstream stagnation pressure to better accommodate the different component models. The difference between stagnation pressure at upstream and downstream of component means a loss of pressure energy.

ISO 6358-3 can be used to calculate without measurements an estimate of the overall flow-rate characteristics of an assembly of components and piping, using the characteristics of each component and piping determined in accordance with this part of ISO 6358 or ISO 6358-1.

The discharge and charge test methods specified in this part of ISO 6358 have the following advantages over the test method specified in ISO 6358-1:

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) energy consumption is minimised; and

d) test time is shortened in the discharge test, and noise level is decreased in the charge test.

It should be noted that performance characteristics measured in accordance with this edition of ISO 6358 will differ from those measured in accordance with ISO 6358:1989.

Pneumatic fluid power — Determination of flow-rate characteristics of components using compressible fluids —

Part 2: Alternative test methods

1 Scope

This part of ISO 6358 specifies a discharge test and a charge test as alternative methods for testing pneumatic fluid power components that use compressible fluids, i.e. gases, and that have internal flow passages that can be either fixed or variable in size to determine their flow-rate characteristics. However, this part of ISO 6358 does not apply to components whose flow coefficient is unstable during use, i.e. components that exhibit remarkable hysteretic behaviour (because they can contain flexible parts that deform under the flow) or that have an internal feedback phenomenon (such as regulators), or components that have a cracking pressure such as non-return (check) valves and quick-exhaust valves. In addition, it does not apply to components that exchange energy with the fluid during flow-rate measurement, e.g. cylinders, accumulators, etc.

NOTE This part of ISO 6358 does not provide a method to determine if a component has hysteretic behaviour; ISO 6358-1 does provide such a method.

Table 1 provides a summary of which parts of ISO 6358 can be applied to various components.

Table 1 — Application of ISO 6358 test methods to components

Components		Constant upstream pressure test		Variable upstream pressure test	
		ISO 6358-1 constant upstream pressure test	ISO 6358-2 charge test	ISO 6358-1 variable upstream pressure test	ISO 6358-2 discharge test
Group 1	Directional control valves	yes	yes	yes	yes
	Flow control valves	yes	yes	yes	yes
	Connectors	yes	yes	yes	yes
	Valve manifolds	yes	yes	yes	yes
	Group of components	yes	yes	yes	yes
Group 2	Filters and lubricators	yes	no	no	no
	Non-return (check) valves	yes	no	no	no
	Tubes and hoses	yes	no	no	no
Group 3	Silencers and exhaust oil mist separators	no	no	yes	yes
	Blow nozzles	no	no	yes	yes
	Quick-exhaust valves	no	no	yes	yes
	Cylinder end heads	no	no	yes	yes

The charge test cannot be performed on components that do not have downstream port connections.

This part of ISO 6358 specifies requirements for the test installation, the test procedure, and the presentation of results.

Evaluation of measurement uncertainties is described in Annex A. Requirements for a method to test the volume of an isothermal tank are given in Annex B. Guidance on the isothermal tank is given in Annex C. Requirements for a method to test isothermal performance are given in Annex D. Guidance on the equation for calculating characteristics is given in Annex E. Guidance on calculating flow-rate characteristics is given in Annex F.

2 Normative references

The following documents, in whole or in part, are normatively 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 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*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 5598 and ISO 6358-1 apply.

4 Symbols and units

4.1 The symbols and units shall be in accordance with ISO 6358-1 and Table 2.

Table 2 — Symbols and units

Reference	Description	Symbol	Dimension [a]	SI units	Practical units
5.5.2	Time	t	T	s	s
5.4.3	Tank volume	V	L^3	m^3	dm^3
[a] T = time; L = length					

4.2 The numerals used as subscripts to the symbols shall be in accordance with ISO 6358-1 and Table 3.

Table 3 — Subscripts

Subscript	Meaning
3	Tank conditions

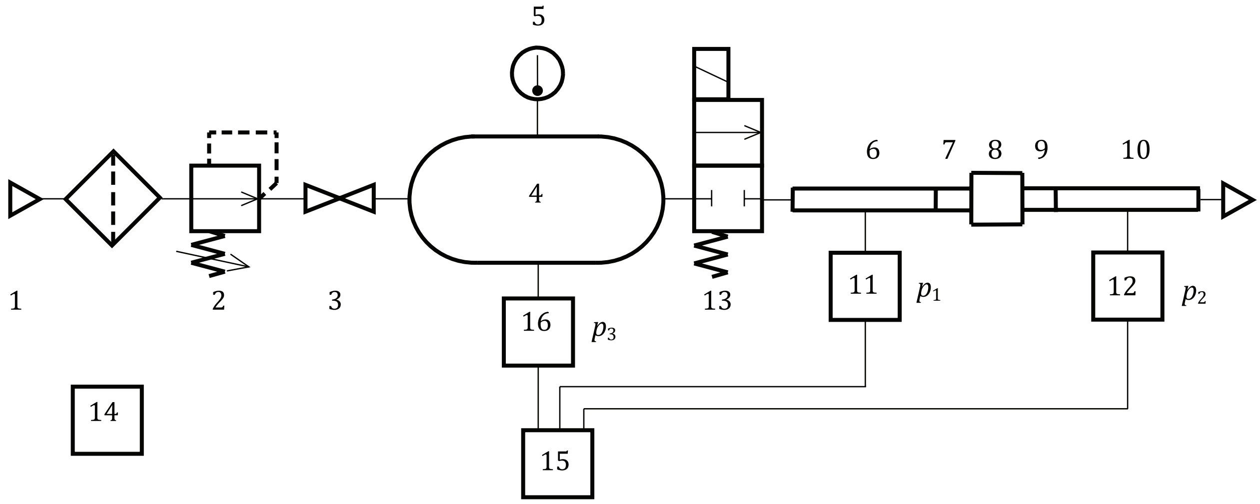
4.3 The graphic symbols used in Figures 1 and 2 are in accordance with ISO 1219-1.

5 Test installation

CAUTION — Figures 1 and 2 illustrate basic circuits that do not incorporate all 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.

5.1 Test circuit for discharge test

A suitable test circuit as shown in Figure 1 shall be used for the discharge test. See 5.3.5.

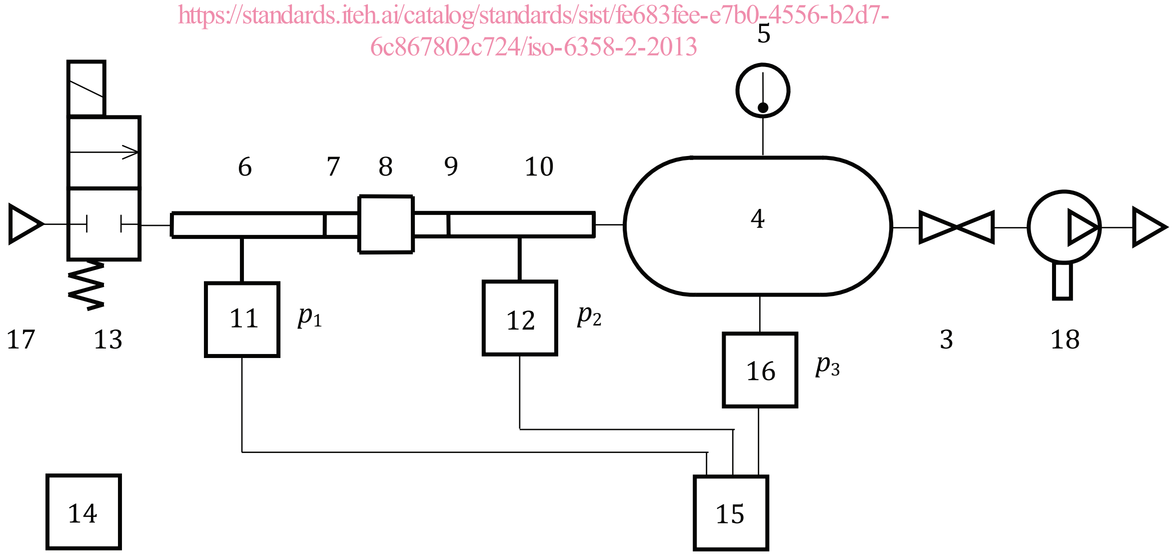


NOTE See Table 4 for the key to test circuit components.

Figure 1 — Test circuit for discharge test

5.2 Test circuit for charge test

A suitable test circuit as shown in Figure 2 shall be used for the charge test.



NOTE See Table 4 for the key to test circuit components.

Figure 2 — Test circuit for charge test

Table 4 — Key to test circuit components shown in Figures 1 and 2

Key item number	Relevant subclause or paragraph	Description	Additional requirements
1	5.3.2	Compressed gas source and filter for discharge test	
2	-	Adjustable pressure regulator for discharge test	
3	-	Shut-off valve	
4	5.4	Tank	
5	-	Temperature-measuring instrument	
6	5.3.7	Upstream pressure-measuring tube	
7	5.3.7	Upstream transition connector	
8	-	Component under test	
9	5.3.7	Downstream transition connector	
10	5.3.7	Downstream pressure-measuring tube	
11	5.3.10	Pressure transducer	
12	5.3.10	Pressure transducer	
13	5.3.4 and 5.3.9	Flow control solenoid valve (optional)	The sonic conductance of this flow control valve shall be about four times larger than that of the component under test.
14	-	Barometer	
15	-	Digital recorder	
16	5.3.10	Pressure transducer	
17	-	Suction port for charge test	
18	-	Vacuum pump for charge test	

5.3 General requirements

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

5.3.2 For the discharge test, a filter shall be installed which provides a standard of filtration specified by the manufacturer of the component under test.

5.3.3 A test set-up shall be constructed from the items listed in Table 4. Items 1 through 8, 11, and 14 through 16 are required for the discharge test. Items 3 through 12 and 14 through 18 are required for the charge test.

5.3.4 If the component under test has no control mechanism for shifting its position, install a flow control solenoid valve (item 13) upstream of pressure-measuring tube (item 6) in order to start the test.

5.3.5 Items 9, 10, and 12 are not required for the discharge test when the component under test does not have a downstream port. See the special instructions in 6.2.3.3.

5.3.6 The distance between the tank (item 4) and the upstream pressure-measuring tube (item 6) for the discharge test, or between the tank (item 4) and downstream pressure-measuring tube (item 10) for charge test, shall be as short as possible. The volumes of all components and conductors in Figures 1 and

2 between items 3 and 13 (if item 13 is used) or between items 3 and 8 (if item 13 is not used) shall be added to the volume of the tank.

5.3.7 The pressure-measuring tubes (items 6 and 10) and the transition connectors (items 7 and 9) shall be in accordance with ISO 6358-1. It is not necessary to have a temperature-measuring connection in the pressure-measuring tubes because the temperature is measured in the tank.

5.3.8 For any locations where liquid can collect, installation of a drain separator is recommended.

5.3.9 The shifting time of the flow control solenoid valve (item 13) shall be sufficiently short to limit the transient time at the beginning of test data collection.

5.3.10 When connecting pressure measuring instruments, the dead volume shall be limited as much as possible to avoid long response time, delays, and phase lag for measurements.

5.4 Requirements for the tank (item 4)

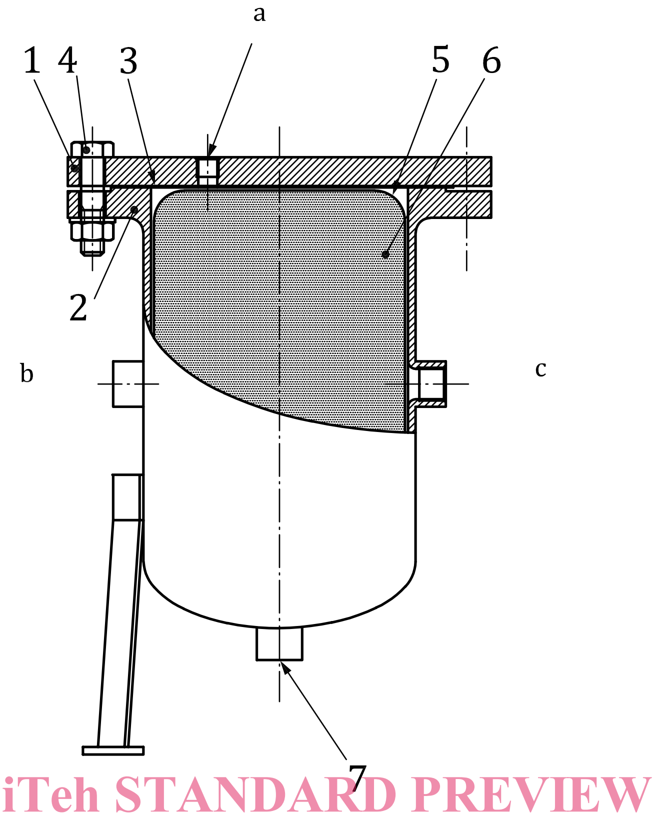
5.4.1 Structure

The tank shall be suitably structured as shown in Figure 3 and consist of the components listed in Table 5. Dimensions of the flow port shall conform to the dimensions given in Table 6.

The tank shall conform to any local, national, and/or regional regulations and standards related to pneumatic containers.

The ratio of the height of the tank to its diameter should not exceed 2:1.

The junction of the flow port with the internal surface of the tank shall be convergent shaped so as to avoid pressure loss. The dimensions and arrangement of connection ports other than the flow port are determined by the test operator.



Key

a	Measuring ports (temperature and pressure)

b	Source port

c	Flow port

Figure 3 — Structure of the tank

Table 5 — Key to tank components

Key item number	Description	Comments
1	Lid	
2	Tank body	
3	Gasket	
4	Flange fastener (nut and bolt)	Six or more pieces, equally arranged
5	Metal net	See 5.4.2.
6	Stuffed material	See 5.4.2.
7	Drain valve	

Table 6 — Thread size of flow port

Tank volume, *V*, in m^3	Thread size
$V \leq 0{,}0025$	G 1/8
$0{,}0025 < V \leq 0{,}0063$	G 1/4
$0{,}0063 < V \leq 0{,}014$	G 3/8
$0{,}014 < V \leq 0{,}032$	G 1/2
$0{,}032 < V \leq 0{,}066$	G 3/4
$0{,}066 < V \leq 0{,}100$	G 1
$0{,}100 < V \leq 0{,}190$	G 1 1/4
$0{,}190 < V \leq 0{,}310$	G 1 1/2
$0{,}310 < V \leq 0{,}510$	G 2
$0{,}510 < V \leq 0{,}730$	G 2 1/2
$0{,}730 < V \leq 1{,}100$	G 3

5.4.2 Stuffed material

The stuffed material, which is used to reduce the change in air temperature, shall be resistant to corrosion and pressure and shall be distributed evenly in the tank. If copper wires are used as the stuffed material, wires of equivalent diameter 3×10^{-5} m to 5×10^{-5} m shall be stuffed in the tank at a density of 3×10^{-4} kg/m^3.

NOTE The equivalent diameter means the diameter of the cross-sectional area of a noncircular shape assumed as equivalent to the diameter of the cross-sectional area of a circular shape.

The stuffed material shall be wrapped with a metallic net to prevent it from flowing out of the flow port. It is desirable that a suitable frame supports the stuffed material to prevent it from leaning inside the tank. Further information is given in Annex C.

5.4.3 Volume

The volume of the tank, *V*, in m^3 should be calculated using Formula (1):

$$V \geq 5 \times 10^5 C \tag{1}$$

where

C is the estimated sonic conductance of the component under test, in m^3/(s·Pa)(ANR).

NOTE 1 The tank volume is the net value obtained by subtracting the volume of the stuffed material from the volume of the empty air tank.

NOTE 2 The test method to determine the tank volume is given in Annex B.

5.5 Special requirements

5.5.1 The special requirements given in 5.6 of ISO 6358-1 apply for this part of ISO 6358.

5.5.2 The digital recorder shall be set to sample pressure at a time interval determined in accordance with Formulae (2) or (3). Approximately 1000 pressure data points will be obtained during discharge or charge tests. These criteria have an effect on the calculations performed in 6.3.

— For discharge tests:

$$\Delta t \approx 2{,}5 \times 10^{-8} \frac{V}{C} \quad (2)$$

— For charge tests:

$$\Delta t \approx 1{,}5 \times 10^{-8} \frac{V}{C} \quad (3)$$

where

Δt is the time interval for sampling pressure, in s;

C is the estimated sonic conductance of the component under test, in $m^3/(s \cdot Pa)$(ANR);

V is the tank volume, in m^3.

6 Test procedures

6.1 Test conditions

6.1.1 Test fluid

6.1.1.1 Air should be used as the test fluid. If a different fluid is used, it shall be stated in the test report.

6.1.1.2 The gas shall be filtered and conditioned to comply with the recommendations of the manufacturer of the component under test.

6.1.2 Checks

Periodically check that the pressure-tapping holes are not blocked by liquids or solid particles.

6.1.3 Test measurements

6.1.3.1 Each set of test readings shall be recorded after steady-state conditions of temperature and pressure in the tank have been reached. The variations of pressures and temperature indications shall not exceed the limits given in the column “Allowed test conditions variation” of Table 7.

6.1.3.2 Pressure and temperature shall be measured within the measurement accuracy specified in Table 7.

Table 7 — Measurement accuracy and allowed test condition of parameters

Parameter	Measurement accuracy	Allowed test condition variation
Volume	±1 %	-
Time	±1 %	-
Upstream pressure	±0,5 %	±1 %
Downstream pressure	±0,5 %	±1 %
Tank pressure	±0,5 %	±1 %
Temperature	±1 K	±3 K

6.1.3.3 Flow-rate conditions in each flow path shall be maintained constant within the component while taking measurements to ensure there is no inadvertent movement of component parts.

6.2 Measuring procedures

6.2.1 Requirements for testing to publish catalogue ratings

If data are to be used for publishing ratings in a catalogue, a sample consisting of a minimum of five test units selected from a random production lot shall be tested in accordance with the following procedures.

6.2.2 Selection of measuring procedure

Either the procedure described in 6.2.3 or the procedure described in 6.2.4 shall be selected in accordance with the scope of this part of ISO 6358.

6.2.3 Measuring procedures for discharge test

6.2.3.1 Set the pressure of the pressure regulator (item 2) at 700 kPa (7 bar), and open the shut-off valve (item 3) to charge air into the tank (item 4). Leave the tank in this state until temperature and pressure in the tank reach steady-state conditions.

6.2.3.2 Close the shut-off valve (item 3) and measure the initial pressure, p_3, using pressure transducer 16, initial temperature, T_3, using the temperature-measuring instrument (item 5) in the tank, and atmospheric pressure using the barometer (item 14).

6.2.3.3 Open the component under test (item 8) or the solenoid valve (item 13) to discharge air from the tank (item 4) into the atmosphere. Measure pressure in the tank, p_3, upstream pressure, p_1, and downstream pressure, p_2, during discharge using the pressure transducers (items 16, 11, and 12), and record the values using the digital recorder (item 15) as shown in Figure 4. If the downstream transition connector cannot connect to a component under test, measure atmospheric pressure as downstream pressure, p_2.