INTERNATIONAL STANDARD

ISO 6358

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

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

Reference number
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Contents

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 6358 was prepared by Technical Committee ISO/TC 131, *Fluid power systems*.

Annex A forms an integral part of this International Standard. Annexes B, C, D and E are for information only.

Introduction

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

Components composing such a circuit are inherently resistive and affect the flow through it. It is therefore necessary to carry out tests to ascertain the characteristics of these components in order to determine their suitability.

Many components composing a pneumatic circuit operate under conditions of choked flow. This International Standard specifies tests at choked flow in recognition of these conditions.

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

1 Scope

This International Standard specifies a method for testing pneumatic fluid power components which use compressible fluids, i.e. gases, to enable their flow-rate characteristics under steady-state conditions to be compared.

It specifies requirements for the test installation, the test procedure and the presentation of results.

Accuracy of measurement is divided into two classes (A and B) which are explained in annex A.

General background information is given in annex B and the basic theoretical equations are given in annex C. Guidance as to the use of practical units for the presentation of results is given in annex D.

This International Standard generally applies to those fluid power components up to and including 20 mm nominal bore used with compressible fluids (gases), the internal flow passages of which remain constant during testing. Examples of such components are

a) directional control valves, flow control valves, quick exhaust valves, etc.;

b) moving part logic devices.

It may also apply to components larger than 20 mm nominal bore but this may require the provision of exceptionally large flow generating equipment.

Two test methods are described according to the type of component. There are also two sets of characteristic constants: C and b; and A and s, respectively (as defined in 3.2 to 3.5). These may be calculated from the results.

The first set of characteristics (C and b) applies to cases where comparison of similar components is required, or when calculations of pressure and flow involve a single component only.

The second set of characteristics (A and s) is necessary when the flow behaviour of several components which are connected in series is to be estimated. This set may also be used as an optional alternative to the first set for simple flow calculations and for comparison of components.

This International Standard does not apply to components which exchange energy with the fluid (gas), for example cylinders, accumulators, etc.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 228-1 : 1982, *Pipe threads where pressure-tight joints are not made on the threads — Part 1: Designation, dimensions and tolerances.*

ISO 261 : 1973, *ISO general purpose metric screw threads — General plan.*

ISO 1179 : 1981, *Pipe connections, threaded to ISO 228-1, for plain end steel and other metal tubes in industrial applications.*

ISO 5598 : 1985, *Fluid power systems and components — Vocabulary.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 5598 and the following definitions apply. It should be borne in mind, however, that the following definitions may differ from those given in other specific International Standards.

3.1 choked flow: Occurrence when upstream pressure, p_1, is high in relation to the downstream pressure, p_2, such that the velocity in some part of the component becomes sonic. The mass flow of the gas is proportional to the upstream pressure, p_1, and independent of the downstream pressure, p_2.

3.2 critical pressure ratio, b: Pressure ratio (p_2/p_1) below which flow becomes choked.

3.3 sonic conductance, C: Mass flow rate through the component, q_m^*, divided by the product of the upstream pressure, p_1, and the mass density at standard conditions ϱ_0 (see table 2) when the flow is choked, i.e.

$$C = \frac{q_m^*}{\varrho_0 \, p_1} \text{ at } T = T_0$$

NOTE — The numerical value of C depends upon the values chosen for the standard reference atmosphere.

3.4 coefficient of compressibility effect, s**:** Coefficient which takes into account the effects of the gas compressibility when flow is subsonic (see D.2.3).

3.5 effective area, A**:** Mass flow rate throughout the component, q_m, divided by the square root of twice the product of the pressure drop, Δp, and the mass density of the gas ϱ_2, i.e.

$$A = \frac{q_m}{\sqrt{2 \varrho_2 \, \Delta p}}$$

This applies only when the pressure drop is small in relation to p_1 such that compressibility effects are insignificant, i.e. when $\Delta p / p_1 < 0{,}02$.

4 Symbols and units

4.1 The symbols and units used throughout this International Standard are as shown in table 1.

Table 1 — Symbols and units

Reference	Description	Symbol	Dimension 1)	SI units 2)
3.5	Effective area	A	L^2	m^2
3.2	Critical pressure ratio	b	pure number	
3.3	Sonic conductance	C	L^4TM^{-1}	$s \cdot m^4/kg$
—	Absolute static pressure (equal to the relative static pressure plus the atmospheric pressure)	p	$ML^{-1}T^{-2}$	Pa 3)
—	Mass flow rate	q_m	MT^{-1}	kg/s
—	Volume flow rate at standard conditions	q_V	L^3T^{-1}	m^3/s
—	Gas constant (for a perfect gas)	R	$L^2T^{-2}\Theta^{-1}$	J/(kg·K)
3.4	Coefficient of compressibility effect	s	pure number	
—	Absolute temperature	T	Θ	K
—	Pressure drop $(p_1 - p_2)$	Δp	$ML^{-1}T^{-2}$	Pa 3)
—	Mass density	ϱ	ML^{-3}	kg/m^3

1) M = mass; L = length; T = time; Θ = temperature

2) The use of practical units for the presentation of results is described in annex D.

3) 1 Pa = 1 N/m^2

4.2 The numerals used as subscripts and the asterisk (*) used as a superscript to the symbols listed in table 1 are as specified in table 2.

Table 2 — Subscripts and superscripts

Superscript	Subscript	Meaning
	0	Standard reference conditions, i.e.: T_0 = 293,15 K; p_0 = 100 kPa (1 bar 1)) 65 % relative humidity
	1	Upstream conditions
	2	Downstream conditions
*		Conditions during sonic flow tests

1) 1 bar = 100 kPa = 0,1 MPa; 1 Pa = 1 N/m^2

4.3 The graphical symbols used in figures 1 and 2 are in accordance with ISO 1219.

5 Test installation

5.1 Test circuit for components with inlet and outlet ports

A suitable test circuit as shown in figure 1 shall be used.

5.2 Test circuit for components which exhaust directly to atmosphere

A suitable test circuit as shown in figure 2 shall be used.

NOTE — Figures 1 and 2 illustrate basic circuits which 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.

5.3 General requirements

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

5.3.2 A filter shall be installed which provides a standard of filtration approved by the test component manufacturer.

5.3.3 A test set-up shall be constructed from the items listed in table 3.

NOTE — Items A to H inclusive are essential and the remaining items I to L are chosen by the experimenter to suit the prevailing conditions.

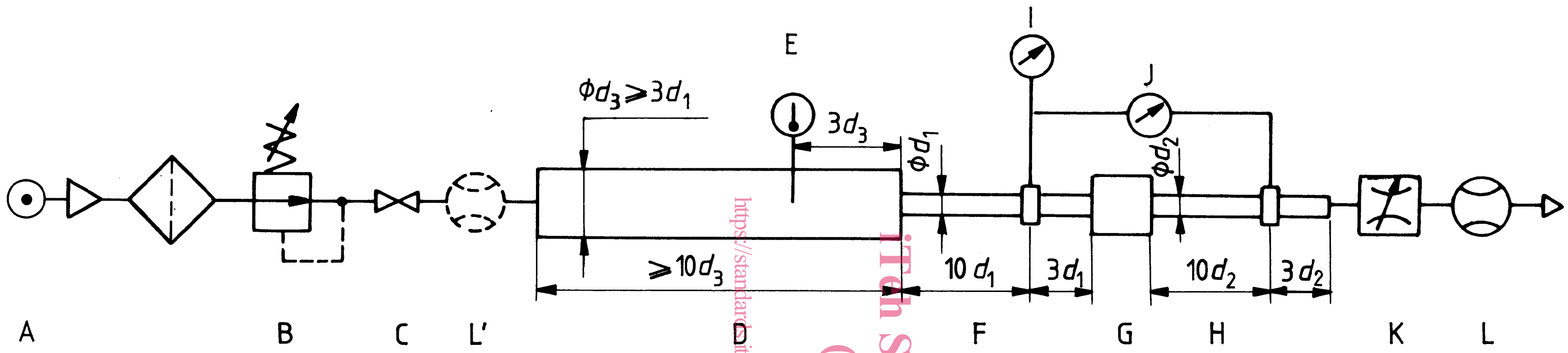


Figure 1 — Test circuit for components with inlet and outlet ports [1)]

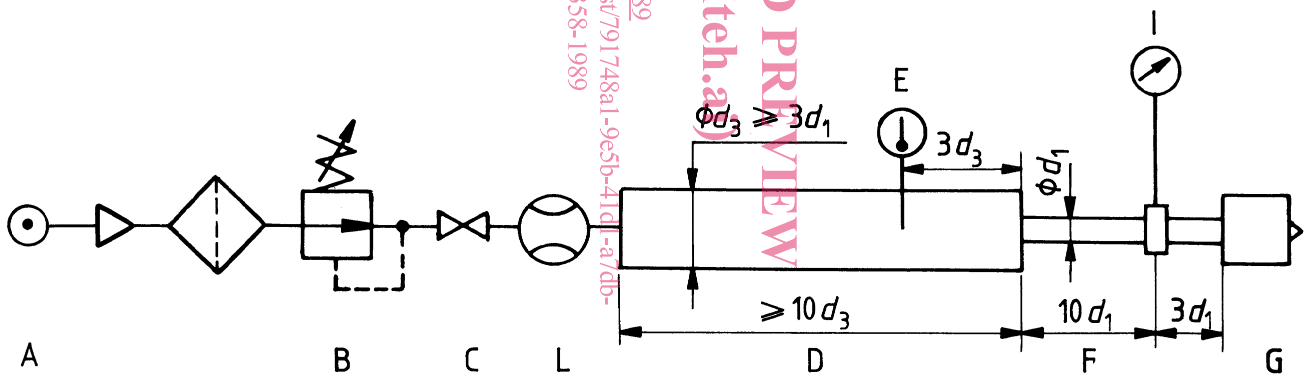


Figure 2 — Test circuit for components which exhaust directly to atmosphere [1)]

1) See table 3 for key to circuit items.

Table 3 — Key to test circuit components

Reference letter	Relevant sub-clause(s)	Description	Comments
A	5.3.2 6.1.1.2	Compressed gas source and filter	
B	—	Adjustable pressure regulator	
C	—	Shut-off valve	Preferably with straight flow path
D	5.4	Temperature-measuring tube	
E	—	Temperature-measuring instrument	Sensor located on axis of D at a distance $3d_3$ upstream of end of D
F	5.5	Upstream pressure-measuring tube	
G	—	Component under test	
H	5.5	Downstream pressure-measuring tube	
I	—	Upstream pressure gauge or transducer	
J	—	Differential pressure gauge or transducer	When Δp > 100 kPa (1 bar), this gauge may be replaced by a downstream pressure gauge or transducer
K	—	Flow-control valve	To have a flow-rate capacity greater than the component under test
L	—	Flow-rate measuring device	May also be placed in position L′ upstream of D

5.3.4 All connections for pressure measurement shall be arranged in such a manner that no trap can form or retain entrained liquid; a drain may be provided.

5.4 Temperature-measuring tube (item D)

A tube shall be provided with an internal diameter, d_3, which is not less than three times the internal diameter, d_1, of the inlet pressure-measuring tube (item F) and with a length not less than ten times its internal diameter, d_3.

5.5 Pressure-measuring tubes (items F and H)

5.5.1 Tubes which conform with figure 3 shall be provided. Typical dimensions of the pressure-measuring tubes are also stated in table 4.

The tube shall be straight with a smooth, circular internal surface, and a constant diameter throughout its length.

There shall be no obstruction or branch connection other than those specified.

5.5.2 One or more pressure-tapping holes shall be provided in accordance with figure 3.

The longitudinal centreline of the tube shall intersect with the centrelines of the holes and the centrelines of the holes shall be normal to the longitudinal centreline.

The junction of each hole with the internal surface of the tube shall be sharp edged and free from burrs.

5.6 Special requirements

5.6.1 When the component under test has ports which are not threaded and other means of connecting to pipes or hoses are used, measuring tubes having internal diameters which correspond to the appropriate pipe or hose internal diameters shall be used.

5.6.2 If these diameters do not correspond, measuring tubes of the next largest internal diameter in the range shall be used.

5.6.3 When the component under test has ports which differ in size, measuring tubes which are suited to the relevant port shall be used.

6 Test procedures

6.1 Test conditions

6.1.1 Gas supply

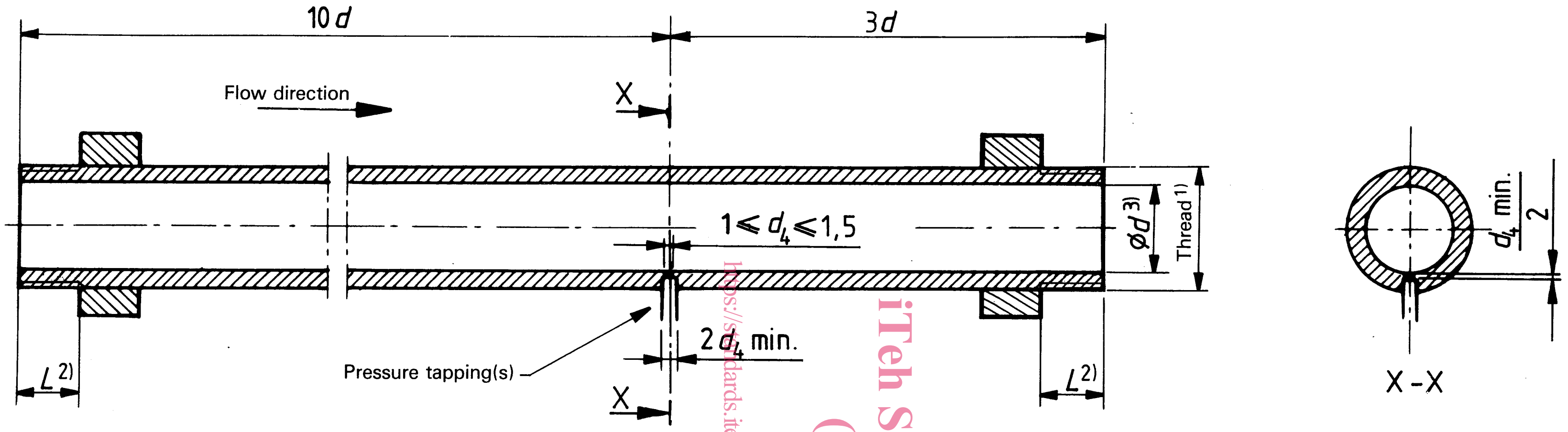
6.1.1.1 The gas used shall be stated in the test report.

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

6.1.2 Checks

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

Dimensions in millimetres



1) Thread to suit component under test.

2) Thread length to suit component under test.

3) Actual internal diameter of tube.

Figure 3 — Pressure-measuring tube

Table 4 — Typical dimensions of pressure-measuring tubes

Dimensions in millimetres

Thread 1)	d	L 2) max.
M5 × 0,8	2	2,5
G 1/8	6	7,4
G 1/4	9	11
G 3/8	13	11,4
G 1/2	16	15
G 3/4	22	16,3
G 1	28	19,1
G 1 1/4	36	21,4
G 1 1/2	43	21,4

1) M threads in accordance with ISO 261; G threads in accordance with ISO 228-1.

2) G thread lengths in accordance with ISO 1179.

6.1.3 Test measurements

6.1.3.1 Each set of test readings shall be recorded after steady-state conditions have been reached.

6.1.3.2 The variations in upstream parameters shall be within the tolerances stated in table 5.

Table 5 — Permissible variations in indicated values of upstream parameters

Class of measurement accuracy (see annex A)	A	B
Variation in temperature indication, K	± 1	± 2
Variation in pressure indication, %	± 1	± 2
Variation in flow rate indication, %	± 2	± 4

6.1.3.3 Maintain flow conditions constant in each flow path within the component while taking measurements to ensure there is no inadvertent movement of component parts.

6.2 Measuring procedure

According to the design of the component under test, either of the procedures described in 6.2.1 or 6.2.2 shall be followed.

6.2.1 Component with upstream and downstream measuring tubes

6.2.1.1 Maintain a constant upstream pressure, p_1, of not less than 400 kPa (4 bar) and preferably higher.

6.2.1.2 Decrease the downstream pressure, p_2, using the flow control valve K, until a further decrease no longer produces an increase in the mass flow rate, q_m; this is the indication of choked flow.

6.2.1.3 Measure temperature, T^*, upstream pressure, p_1^*, mass flow rate, q_m^*, and downstream pressure, p_2^*.

6.2.1.4 Partly close the flow control valve K to reduce the mass flow rate, q_m, to approximately 80 % of q_m^*.

6.2.1.5 Adjust the pressure regulator B as required to maintain p_1 at a constant value throughout the test.

6.2.1.6 Measure the flow rate, q_m, temperature, T, and pressure differential, Δp.

6.2.1.7 Repeat the steps described in 6.2.1.4, 6.2.1.5 and 6.2.1.6 with q_m equal to 60 %, 40 % and 20 % of q_m^*.

6.2.2 Component exhausting directly to atmosphere

6.2.2.1 Measure atmospheric pressure, p_2, and temperature, T_0, and set the upstream pressure, p_1, to approximately 10 kPa (0,1 bar) higher than p_2.

6.2.2.2 Measure the mass flow rate, q_m, temperature, T, and upstream pressure, p_1.

6.2.2.3 Set the upstream pressure successively at approximately 150 kPa (1,5 bar), 300 kPa (3 bar), 500 kPa (5 bar), etc., and repeat the step described in 6.2.2.2.

6.2.2.4 Compute values for $q_m\sqrt{T/T_0}$ and plot them against p_1, as shown in figure 4.

NOTE — Choked flow is indicated when the plotted points are found to lie on a straight line directed from the origin.

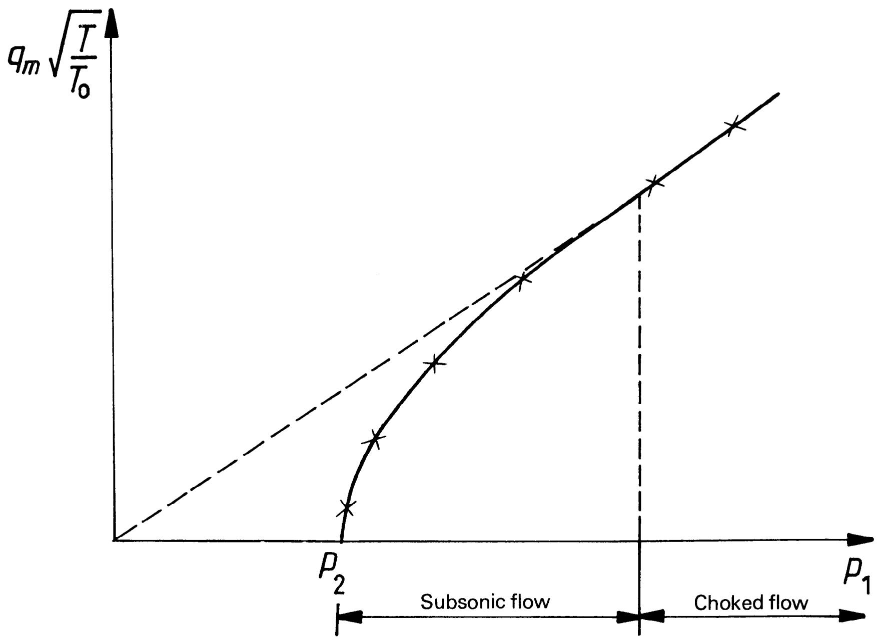


Figure 4 — Plot of mass flow rate against upstream pressure

6.3 Calculation of characteristics

6.3.1 Sonic conductance, C

Calculate the sonic conductance from the following equation:

$$C = \frac{q_m^*}{\varrho_0 \, p_1^*} \sqrt{\frac{T_1^*}{T_0}}$$

where T_1^* is the value of T measured while the flow is choked.

6.3.2 Critical pressure ratio, b

6.3.2.1 If the upstream temperature remained constant during the test, calculate the value of b, for each value of q_m, from the following simplified equation:

$$b = 1 - \frac{\dfrac{\Delta p}{p_1}}{1 - \sqrt{1 - \left(\dfrac{q_m}{q_m^*}\right)^2}}$$

6.3.2.2 If variations in p_1 and T occurred during the test, calculate the value of b, for each value of q_m, from the following equation:

$$b = 1 - \frac{\dfrac{\Delta p}{p_1}}{1 - \sqrt{1 - \left(\dfrac{q_m}{C \, \varrho_0 \, p_1} \sqrt{\dfrac{T_1}{T_0}}\right)^2}}$$

6.3.2.3 Calculate the critical pressure ratio as the mean value of b, for each value of q_m, calculated in accordance with either 6.3.2.1 or 6.3.2.2.

6.3.2.4 Calculate the ratio p_2^*/p_1^*. If this ratio is greater than the critical ratio b, retest with lower values of p_2 or higher values of p_1 to ensure that choked flow has been achieved.

6.3.3 Coefficient of compressibility effect, s

Calculate the coefficient of compressibility effect from the following equation:

$$s = \frac{1}{1 - b}$$

6.3.4 Effective area, A

Calculate the effective area from the following equation:

$$A = C \, \varrho_0 \sqrt{s \, R \, T_0}$$

NOTE — If, when testing a component in accordance with 6.2.2, it is found that choked flow is not reached, the effective area A may be calculated from the equation defined in 3.5.

7 Presentation of test results

7.1 All measurements and the results of calculations shall be tabulated by the testing agency and, where specified or when appropriate, shall also be presented graphically as described in 6.2.2.4.

7.2 The following performance characteristics related to flow-rate capacity and flow, which are calculated in accordance with 6.3, shall be stated; from these characteristics the performance of the component can be predicted and compared, either in the form a) and b), or the form a) or b):

a) sonic conductance, C, and critical pressure ratio, b;

NOTE — Parameters C and b will be valid only for the gas used in the test.

b) effective area, A, and coefficient of compressibility effect, s.

NOTE — Parameter s will also be valid only for the gas used in the test.

7.3 The class of measurement accuracy, i.e. A or B from annex A, shall be stated and the calibration record shall be available.

8 Identification statement (Reference to this International Standard)

Use the following statement in test reports, catalogues and sales literature when electing to comply with this International Standard:

"Test for the determination of flow-rate characteristics conforms to ISO 6358, *Pneumatic fluid power — Components using compressible fluids — Determination of flow-rate characteristics.*"