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

Part 2: **Precision method**

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

Partie 2: Méthode de précision

(Revision of ISO 6358:1989)

ICS 23.100.01

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Foreword

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

This second edition cancels and replaces the first edition (ISO 6358:1989), which has been technically revised.

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

— *Part 1: Simplified method*

— *Part 2: Precision method*

— *Part 3: Discharge test as an alternate test method*

— *Part 4: Charge test as an alternate test method*

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 and affect the flow rate 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 that make up a pneumatic circuit operate under conditions of choked flow. In recognition of this, ISO 6358:1989 defined test methods covering the whole range of flow from choked flow to subsonic flow and the definition of two characteristics parameters, sonic conductance, C, and critical pressure ratio, b. However, since the size of the pressure-measuring tubes connected upstream and downstream were the same as the connecting ports of the component under test, it was not possible to measure the flow-rate characteristics under stagnation condition, and also when components with large flow capacity were used, it was not possible to achieve choked flow for measurement. Furthermore, it was revealed that for some components, the flow-rate characteristics should not be approximated only with the characteristic parameters C and b.

This part of ISO 6358 improves the above-mentioned shortcomings regarding measurement by using a pressure-measuring tube whose internal diameter is larger than the connecting port of the component under test. At the same time, it defines a characteristic equation, to which new characteristic parameters subsonic index, m, and cracking pressure, Δp_c, have been added, in order to accurately indicate the flow-rate characteristics of any kinds of pneumatic components.

This part of ISO 6358 defines four characteristic parameters C, b, m and Δp_c. When these parameters are practically used, they should be applied in order of C, b, m and Δp_c to approximate the flow-rate characteristics. That is, only C should be used as the first priority, C and b used as the second priority, C, b and m used as the third priority and C, b, m and Δp_c used as the fourth priority.

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

Part 2: Precision method

1 Scope

This part of ISO 6358 specifies a method 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. This part of ISO 6358 does not apply to components that exchange energy with the fluid during flow rate measurement, e.g., cylinders, accumulators, etc. It specifies requirements for the test installation, the test procedure and the presentation of results. It also specifies a method for analysing the test results to enable the comparison of their flow-rate characteristics under steady-state conditions.

Accuracy of measurement is divided into two classes (A and B), which are explained in Annex A. Flowmeter calibration is given in Annex B. Guidance as to the use of practical units for the presentation of results is given in Annex C. Characteristic presentation equations and background information of the pneumatic fluid power components are given in Annexes D, E, F and G. Guidance as to the calculation of flow-rate characteristics is given in Annex H.

This part of ISO 6358 applies to the following components:

a) directional control valves, such as solenoid valves;

b) flow control valves;

c) air treatment components, such as silencers;

d) piping components, such as connectors and tubes;

e) combined components, such as valve manifolds and cylinder end heads;

f) other devices and combined systems that ports; and

g) non-return (check) valves, quick-exhaust valves and flexible tubes.

NOTE This part of ISO 6358 can be applied to the components in item g) with limitations as described herein.

This part of ISO 6358 does not apply to components whose flow coefficient is unstable during use (i.e., those that exhibit hysteretic behaviour or have an internal feedback phenomenon).

This part of ISO 6358 describes four sets of characteristic parameters: C, b, m, and Δp_c; these may be calculated from the test results. The sonic conductance, C, represents the choked flow rate. The critical back-pressure ratio, b, represents the range of choked flow. The subsonic index, m, represents the several conditions of flow in a component such as variable orifice. The parameter Δp_c, is the cracking pressure of a non-return (check) valve or similar component.

For testing an installation with a large nominal bore, to shorten testing time or to reduce energy consumption, it is desirable to apply the methods specified in part 3 of ISO 6358, which covers a discharge test as an alternate test method, or part 4 of ISO 6358, which covers a charge test as an alternate test method.

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

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

ISO 1219-1, *Fluid power systems and components — Graphic symbols and circuit diagrams — Part 1: Graphic 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: Simplified method*

ISO 6358-3, *Pneumatic fluid power — Components using compressible fluids — Determination of flow-rate characteristics — Part 3: Discharge test as an alternate test method*

ISO 6358-4, *Pneumatic fluid power — Components using compressible fluids — Determination of flow-rate characteristics — Part 4: Charge test as an alternate test method*

ISO 8778, *Pneumatic fluid power — Standard reference atmosphere*

ISO 14743, *Pneumatic fluid power — Push-in connectors for thermoplastic tubes*

ISO 16030, *Pneumatic fluid power — Connections — Ports and stud ends*

3 Terms and definitions

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

3.1
choked flow
occurrence when upstream pressure is high in relation to the downstream pressure such that the velocity in some part of the component becomes sonic

3.2
subsonic flow
flow whose velocity is lower than local speed of sound

3.3
critical back-pressure ratio, *b*
ratio of the downstream stagnation pressure to the upstream stagnation pressure at which the mass flow rate of the gas through the component is at its maximum

3.4
sonic conductance, *C*
value of the volume flow at standard reference atmosphere divided by the upstream absolute stagnation pressure for the choked flow through a component, when the upstream temperature is equal to the standard reference atmosphere temperature

3.5
subsonic index, *m*
index for expressing the characteristic function of the mass flow rate and the pressure ratio of downstream absolute stagnation pressure to upstream absolute stagnation pressure in a subsonic region.

3.6
cracking pressure, Δp_c
differential pressure between upstream and downstream pressures, when mass flow rate becomes 0 after gradually reducing flow rate in the component under test

3.7
transition connector
connector with taper passage for connecting the ports of component under test to a pressure-measuring tube whose inner diameter is more than two size. The pressure measured in the pressure-measuring tube can be considered as stagnation pressure.

4 Symbols and units

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

Table 1 — Symbols and units

Reference	Description	Symbol	Dimension [a]	SI unit [b]
3.3	Critical back-pressure ratio	b	pure number	
3.4	Sonic conductance	C	L^4TM^{-1}	$s \cdot m^4/kg$
3.5	Subsonic index	m	pure number	
-	Absolute stagnation pressure	p_s	$ML^{-1}T^{-2}$	Pa [c]
-	Total pressure	p_t	$ML^{-1}T^{-2}$	Pa [c]
-	Mass flow rate	q_m	MT^{-1}	kg/s
-	Volume flow rate at standard reference atmosphere	q_v	L^3T^{-1}	m^3/s(ANR)
-	Gas constant (for a perfect gas)	R	$L^2T^{-2}\Theta^{-1}$	$J/(kg \cdot K)$
-	Absolute temperature	T	Θ	K
3.6	Cracking pressure	Δp_c	$ML^{-1}T^{-2}$	Pa [c]
-	Mass density	ρ	ML^{-3}	kg/m^3

[a] M = mass; L = length; T = time; Θ = temperature

[b] The use of practical units for the presentation of results is described in Annex C.

[c] 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 shall be used as specified in Table 2.

Table 2 — Subscripts and superscripts

Superscript	Subscript	Meaning
	0	Conditions of standard reference atmosphere defined in ISO 8778, i.e.: T_0 = 293,15 K p_0 = 100 kPa (1 bar [a]) ρ_0 = 1,185 kg / m^3 65% relative humidity
	1	Upstream conditions
	2	Downstream conditions
*		Atmosphere during choked flow tests

[a] 1 bar = 100 kPa = 0,1 MPa; 1 Pa = 1 N/m^2

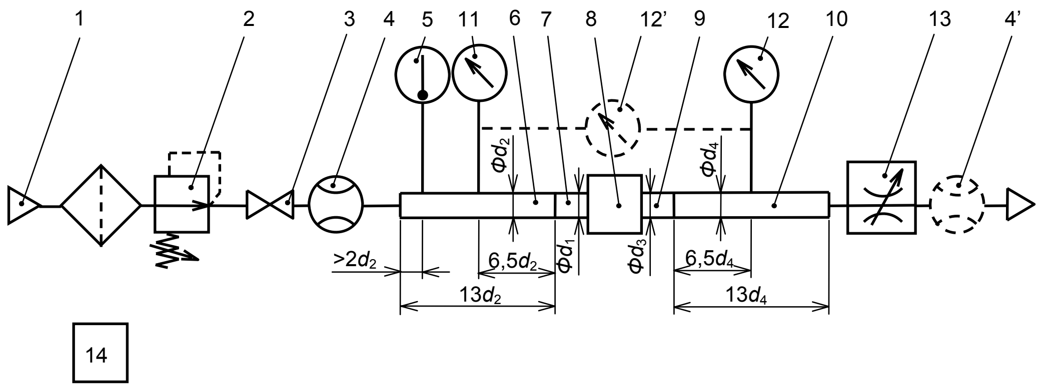
4.3 The graphical symbols used in Figures 1 and 2 are in accordance with ISO 1219-1.

5 Test installation

NOTE 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 in-line test

If pressure-measuring tubes are connected on the upstream and downstream sides of the component under test, a suitable test circuit as shown in Figure 1 shall be used.

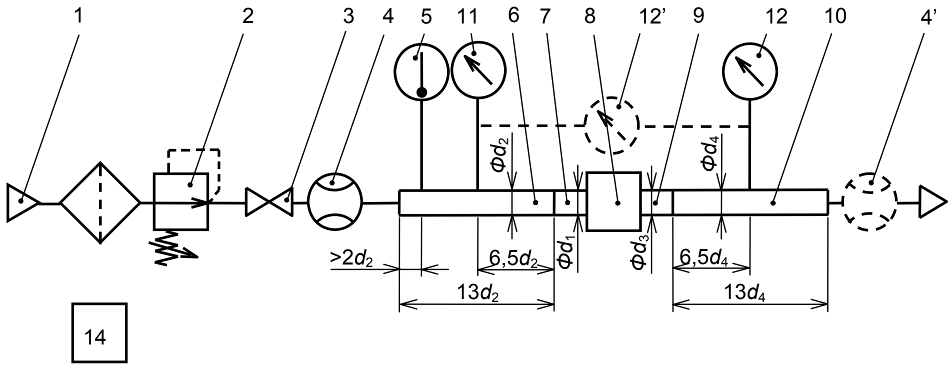


NOTE See Table 3 for the key to test circuit components.

Figure 1 — Test circuit for in-line test

5.2 Test circuit for exhaust-to-atmosphere test

If the component under test exhausts directly to atmosphere on its downstream side, a suitable test circuit as shown in Figure 2 shall be used



NOTE See Table 3 for the key to test circuit components.

Figure 2 — Test circuit for exhaust-to-atmosphere test

Table 3 — Key to test circuit components shown in Figures 1 and 2

Reference letter	Relevant subclause	Description	Comments
1	5.3.2	Compressed gas source and filter	
2	-	Adjustable pressure regulator	
3	-	Shut-off valve	Preferably with straight path
4	-	Flowmeter	May also be placed in position 4' (i.e. downstream of 10.
5	-	Temperature-measuring instrument	Sensor located on axis of 6. See 5.4.2 and 5.4.3
6	5.4	Upstream pressure-measuring tube	
7	5.5	Upstream transition connector	Apply to tube or thread connector
8	-	Component under test	
9	5.5	Downstream transition connector	Apply to tube or thread connector
10	5.4	Downstream pressure-measuring tube	
11	-	Upstream pressure gauge or transducer	
12	-	Downstream pressure gauge or transducer	Alternative a differential pressure gauge or transducer, 12', may be used.
13	-	Flow control valve	To have a flow-rate capacity greater than the component under test
14	-	Barometer	

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 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 3. Items 1 through 8, 11 and 14 are required

5.3.4 Item 13 is only required for in-line test. Item 9, 10 and 12 are not required for exhaust-to-atmosphere test when using component under test without downstream port. Items 7 and 9 shall be chosen in accordance with 5.5.

5.3.5 All connections for pressure measurement shall be arranged so that entrained liquid cannot be trapped and/or retained; a drain may be provided at any locations where liquid collects.

5.3.6 The inlet connector of the upstream pressure-measuring tube shall have a gradual profile to avoid disturbance of the flow.

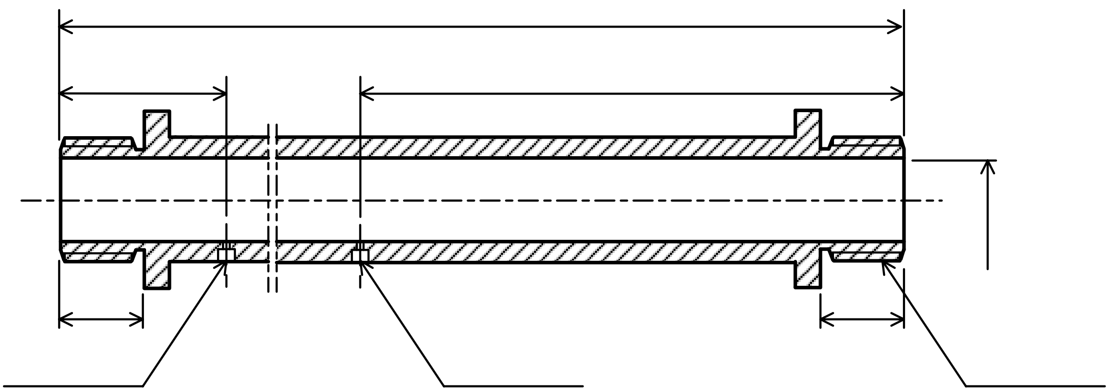
5.3.7 Calibrate the flowmeter in accordance with Annex B before conducting the test. For tests conducted to determine or verify catalogue data, the flowmeter shall have been calibrated no more than five days before the tests are conducted.

5.3.8 Perform a dead weight test of the pressure-recording instrumentation at least annually.

5.3.9 Instrumentation in a circuit should not be located where vibration can affect its accuracy.

5.4 Pressure-measuring tubes (items 6 and 10)

5.4.1 Pressure-measuring tubes that conform to Figure 3 shall be provided. Typical dimensions of the pressure-measuring tubes are also specified in Table 4. The tube shall be straight, with a smooth, circular internal surface, and a constant diameter throughout its length. The junction of the hole with the internal surface of the tube shall have a sharp edge and be free from burrs. There shall be no obstruction or branch connection other than those specified.



a Thread type to suit the connection

b Thread length to suit the connection

c Actual inner diameter of tube

d Pressure-tapping hole

e Temperature-tapping hole (may be deleted for the downstream pressure-measuring tube)

Figure 3 — Pressure-measuring tube

Table 4 — Typical dimensions of pressure-measuring tubes

Dimensions in millimetres

Thread[a]	d_2	L^b max.
G 1/8	6	5,5
G 1/4	9	6,5
G 3/8	13	7,5
G 1/2	16	9
G 3/4	22	10,5
G 1	28	11,5
G 1 1/4	36	16,5
G 1 1/2	43	17,5
G 2	53	19,5
G 2 1/2	68	23
G 3	81	25,5

[a] G threads in accordance with ISO 228-1

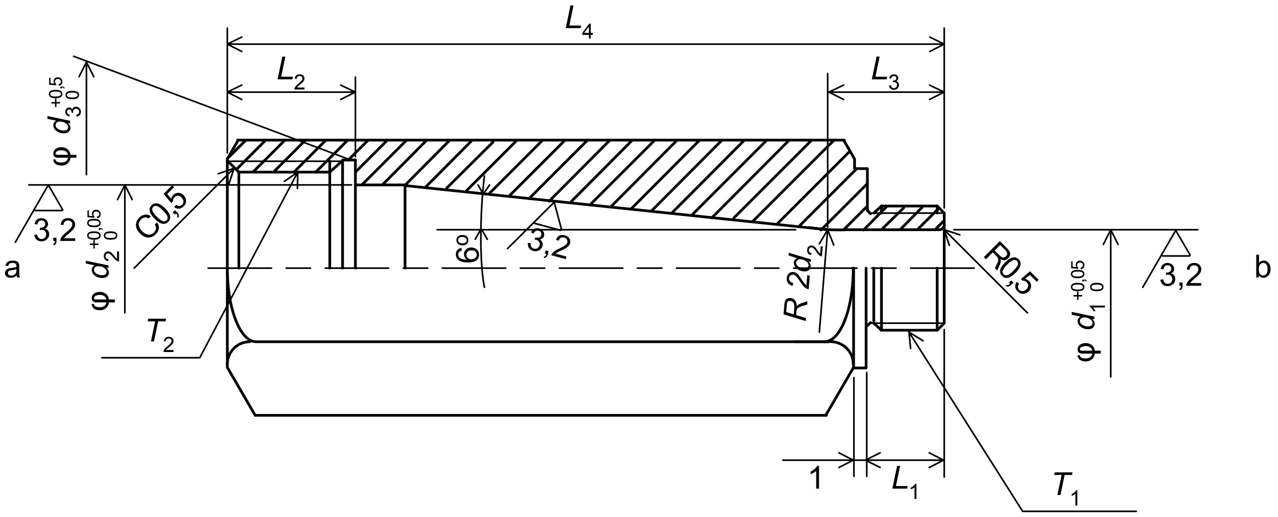
[b] G thread lengths in accordance with ISO 16030.

5.4.2 One temperature tapping hole shall be provided on the upstream pressure-measuring tube in accordance with Figure 3. The longitudinal centreline of the tube shall intersect with the centreline of the holes, and the centreline of the holes shall be normal to the longitudinal centreline.

5.4.3 The location of the temperature sensor does not have a significant impact on the test results. The temperature sensor can be located in a convenient location upstream from the component under test. Alternate locations of the temperature sensor should be in a large diameter section of the supply system piping, away from any areas of sudden expansion.

5.5 Transition connectors (items 7 and 9)

5.5.1 Components under test that have female ports shall be connected to a type 1 transition connector, as shown in Figure 4. Typical dimensions of type 1 transition connectors are given in Table 5. When the connector use at the upstream, a shorter connector with steeper taper or round shaped internal passage may be used. The same theory may be applied to type 2 and type 3 connectors.



a End that connects to the pressure-measuring tube

b End that connects to the component under test

Figure 4 — Type 1 transition connector (threaded connection)

Table 5 — Typical dimensions of type 1 transition connectors

Dimensions in millimetres

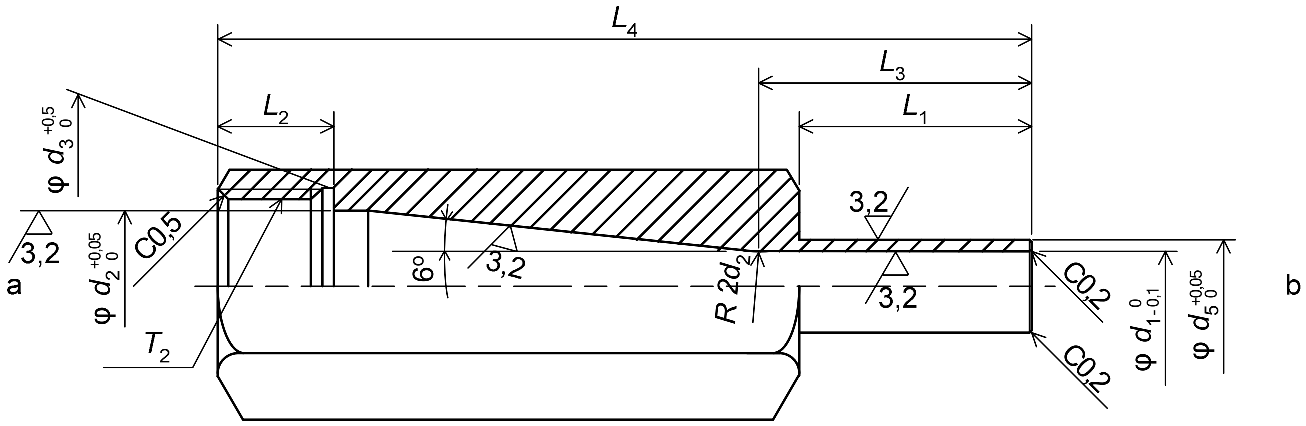
Size	L_1 [a]	L_2	L_3	L_4	d_1	d_2	d_3	T_1 [b]	T_2 [b]
M3 × 1/8	3	7,5	5	35	1,8 [c]	6	9,9	M3	G 1/8
M5 × 1/8	4	7,5	6	35	2,5	6	9,9	M5	G 1/8
M7 × 1/4	5,5	9	9	45	4	9	13,4	M7	G 1/4
1/8 × 3/8	5,5	10	9	56	6	13	16,9	G 1/8	G 3/8
1/4 × 1/2	6,5	11,5	10	58	9	16	21,2	G 1/4	G 1/2
3/8 × 3/4	7,5	15	11	72	13	22	26,6	G 3/8	G 3/4
1/2 × 1	9	16	13	90	16	28	33,7	G 1/2	G 1
3/4 × 1 1/4	10,5	21	15	107	22	36	43,2	G 3/4	G 1 1/4
1 × 1 1/2	11,5	22	16	114	28	43	49,7	G 1	G 1 1/2
1 1/4 × 2	16,5	24	21	130	36	53	62,7	G 1 1/4	G 2
1 1/2 × 2 1/2	17,5	27,5	22	173	43	68	79,4	G 1 1/2	G 2 1/2
2 × 3	19,5	30	24	192	53	81	92,1	G 2	G 3

a Thread lengths in accordance with ISO 16030.

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

c The inside diameter of the mating connection for size M3 × 1/8 shall be at least diameter d_1.

5.5.2 Components under test that have ports for push-in connections shall be connected to a type 2 transition connector as shown in Figure 5. Typical dimensions of type 2 transition connectors are given in Table 6.



a End that connects to the pressure-measuring tube

b End that connects to the component under test

Figure 5 — Type 2 transition connector (push-in connection)

Table 6 — Typical dimensions of type 2 transition connectors

Dimensions in millimetres

Size	L_1 [a]	L_2	L_3	L_4	d_1 [b]	d_2	d_3	d_5 [b]	T_2 [c]
3 × 1/8	16	7,5	18	47	1,8	6	9,9	3	G 1/8
4 × 1/8	18	7,5	20	47	2,5	6	9,9	4	G 1/8
6 × 1/4	19	9	22,5	59	4	9	13,4	6	G 1/4
8 × 3/8	20	10	23,5	70	6	13	16,9	8	G 3/8
10 × 1/2	24	11,5	27,5	83	7,5 [d]	16	21,2	10	G 1/2
12 × 3/4	25	15	28,5	109	9 [d]	22	26,6	12	G 3/4

a L_1 lengths in accordance with ISO 14743.

b d_1 and d_5 in accordance with Annex A of ISO 14743.

c G threads in accordance with ISO 228-1.

d Dimension d_1 is smaller than those in Tables 5 and 7.