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Permeable sintered metal materials — Determination of fluid permeability

Matériaux métalliques frittés perméables — Détermination de la perméabilité aux fluides

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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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 119, *Powder metallurgy*, Subcommittee SC 3 *Sampling and testing methods for sintered metal materials (excluding hardmetals)*.

This third edition cancels and replaces the second edition (ISO 4022:1987), of which it constitutes a minor revision with the following changes:

— Clause 3 and Clause 4 order reversed, and Clause 3 split into 3.1 and 3.2;

— 3.1.3, 3.1.4, 3.1.5, 3.1.13 and 3.1.14 editorially revised;

— Clause 3: Terminological entries ‘length’ and ‘dynamic viscosity’ removed;

— 6.1.1 and 6.1.2, Figures 1 and 2 and keys editorially revised;

— 7.1.2, first Formula removed and Formula (2) corrected, “l” changed to “1”;

— 8.3, Formula (12) corrected, “ρ” changed to “ϱ”.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Permeable sintered metal materials — Determination of fluid permeability

1 Scope

This document specifies a method for the determination of the fluid permeability of permeable sintered metal materials in which the porosity is deliberately continuous or interconnecting, testing being carried out under such conditions that the fluid permeability can be expressed in terms of viscous and inertia permeability coefficients (see Annex A).

This document does not apply to very long hollow cylindrical test pieces of small diameter, in which the pressure drop of the fluid in passing along the bore of the cylinder might not be negligible compared with the pressure drop of the fluid passing through the wall thickness (see A.5).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 2738, *Sintered metal materials, excluding hardmetals — Permeable sintered metal materials — Determination of density, oil content and open porosity*

3 Terms, definitions, symbols and units

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Terms and definitions

3.1.1
permeability
ability of a porous metal to pass a fluid under the action of a pressure gradient

3.1.2
test area
area of a porous metal normal to the direction of the fluid flow

3.1.3
thickness
dimension of the test piece in the direction of fluid flow

Note 1 to entry: For flat test pieces it is equal to the thickness.

Note 2 to entry: For hollow cylinders it is given by Formulae (2) to (6).

3.1.4
viscous permeability coefficient
volume flow rate at which a fluid of unit viscosity is transmitted through unit area of porous metal permeated under the action of unit pressure gradient when the resistance to fluid flow is due only to viscous losses

Note 1 to entry: It is independent of the quantity of porous metal considered.

3.1.5
inertia permeability coefficient
volume flow rate at which a fluid of unit density is transmitted through unit area of porous metal permeated under the action of unit pressure gradient when the resistance to fluid flow is due only to inertia losses

Note 1 to entry: It is independent of the quantity of porous metal considered.

3.1.6
volume flow rate
mass flow rate of the fluid divided by its density

3.1.7
upstream pressure
pressure upstream of the test piece

3.1.8
downstream pressure
pressure downstream of the test piece

3.1.9
mean pressure
half the sum of the upstream and downstream pressures

3.1.10
pressure drop
difference between the pressures on the upstream and downstream surfaces of the porous test piece

3.1.11
pressure gradient
pressure drop divided by the thickness of the porous test piece

3.1.12
velocity
ratio of the volumetric flow rate to the test area

3.1.13
density
quotient of mass divided by volume of the test fluid at the mean temperature and pressure

3.1.14
apparatus correction
pressure difference observed between the upstream and downstream pressure tappings when the test apparatus is used without a porous test piece in position

Note 1 to entry: The apparatus correction is to be subtracted from the observed pressure drop.

Note 2 to entry: It varies with the flow rate through the apparatus and arises from venturi effects at the pressure tappings and other causes.

3.1.15
mean absolute temperature
half the sum of the temperatures of the fluid at the upstream side and the downstream side of the test piece

3.2 Symbols and units

Symbol	Term	Unit
A	Test area	m^2
e	Thickness	m
ψ_v	Viscous permeability coefficient	m^2
ψ_i	Inertia permeability coefficient	m
Q	Volume flow rate	m^3/s
p_1	Upstream pressure	N/m^2
p_2	Downstream pressure	N/m^2
p	Mean pressure	N/m^2
Δp	Pressure drop	N/m^2
$\Delta p/e$	Pressure gradient	N/m^3
Q/A	Velocity	m/s
ϱ	Density	kg/m^3
T	Mean absolute temperature	K

4 Principle

Passage of a test fluid of known viscosity and density through a test piece, and measurement of the pressure drop and the volumetric flow rate.

Determination of the viscous and inertia permeability coefficients, which are parameters of a formula describing the relationship between the pressure drop, the volumetric flow rate, the viscosity and density of the test fluid and the dimensions of the porous metal test piece permeated by this fluid.

5 Test piece

Before testing with gas, all liquid shall be removed from the pores of the test piece. Oil and grease shall be removed by using a suitable solvent with the extraction method given in ISO 2738. The test piece shall be dried before testing.

6 Apparatus

6.1 Equipment

The choice of apparatus is mainly dictated by the size, shape and physical characteristics of the test piece.

This document refers to two different types of apparatus suitable for determining the fluid permeability of porous test pieces.

6.1.1 Guard ring test head for flat test pieces.

This is a type of test apparatus which is recommended for carrying out non-destructive testing of partial areas of flat porous sheets.

The permeable metal sheet is clamped between two pairs of flexible seals. The inner pair, corresponding to the test area, has a mean diameter of D_1. The outer pair, of mean diameter D_2, forms a guard ring surrounding the test-area, which is pressurized to prevent side leakage from the test area (see Figure 1).

The width of the annulus formed by the guard ring test head shall be not less than the thickness of the sheet, see Formula (1):

$$\frac{D_2 - D_1}{2} \geq e \tag{1}$$

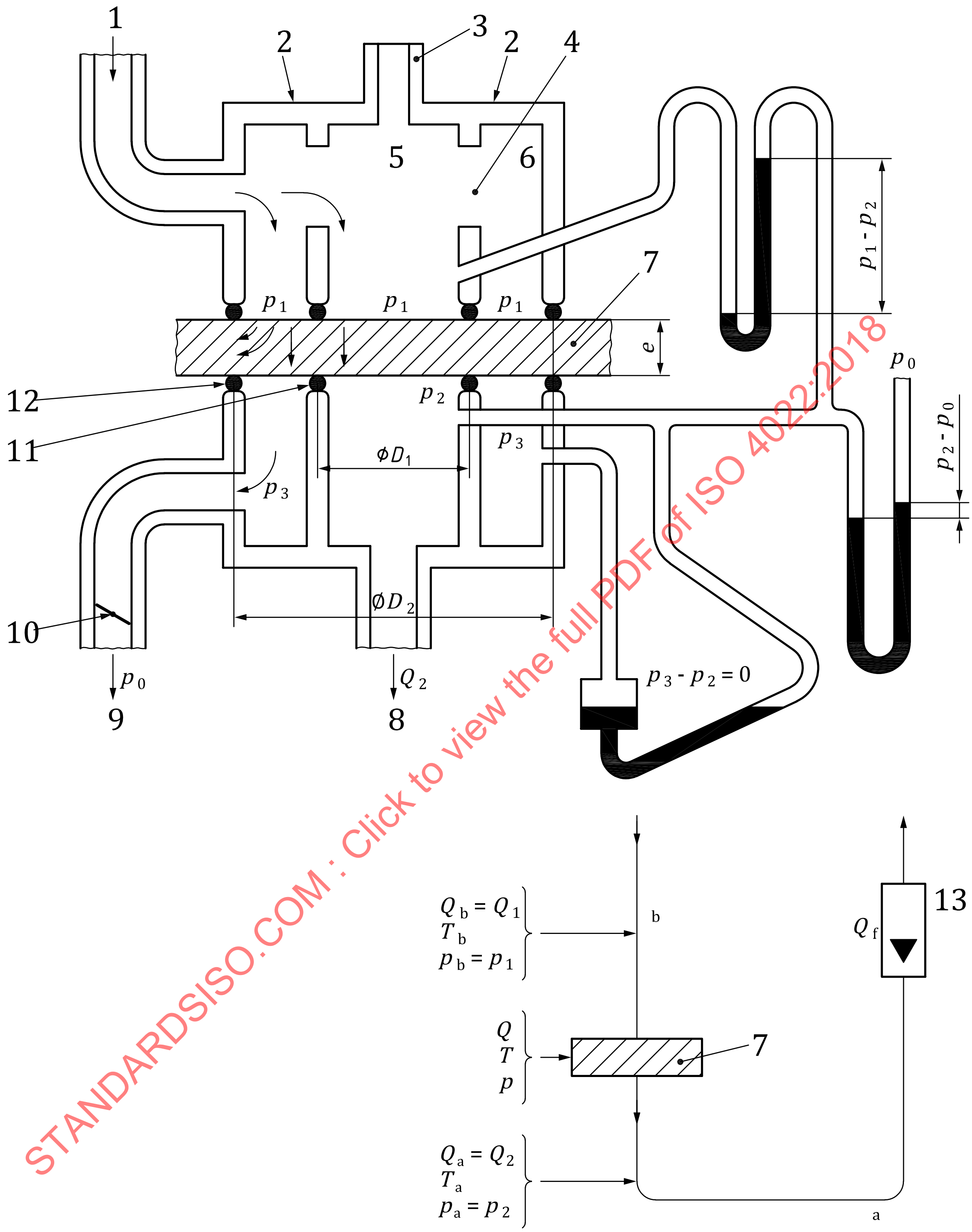
The guard ring test head minimizes side leakage by ensuring that the pressure is the same in the inner and outer chambers. On the upperstream face of the test piece, this is achieved by arranging that the port area connecting the upper chambers (as shown in Figure 1) is as large as possible. On the downstream face of the test piece, the inner chamber leads to a flowmeter, usually subject to a small back pressure, and the outer chamber leads to atmosphere via a pressure-equalizing valve. This valve is adjusted to equalize the pressure in the inner and outer chambers. The fitting of a restrictor between the test piece and the flowmeter, to increase the back pressure and thus permit more stable control of the pressure-equalizing valve, is allowed.

However, ideally, the pressure on the downstream face of the test piece should be as near as possible to atmospheric pressure and a restrictor should not be used unless necessary for the adjustment of the pressure drop in the flowmeter.

Toroidal sealing rings (“O”-rings) are recommended for the inner seals.

The seals shall be sufficiently flexible to overcome all surface imperfections and lack of flatness of the porous metal. In some instances it might be necessary to load the inner and outer seals separately to ensure leak-free sealing.

Two upper and two lower seals are required and these shall be in line with each other.


1
2
3
2
4
5
6
7
p_1
p_1
p_1
e
$p_1 - p_2$
p_0
$p_2 - p_0$
12
11
p_2
p_3
ϕD_1
p_3
$\emptyset D_2$
10
p_0
9
Q_2
8
$p_3 - p_2 = 0$
$Q_b = Q_1$
T_b
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b
13
Q_f
Q
T
p
7
$Q_a = Q_2$
T_a
$p_a = p_2$
a

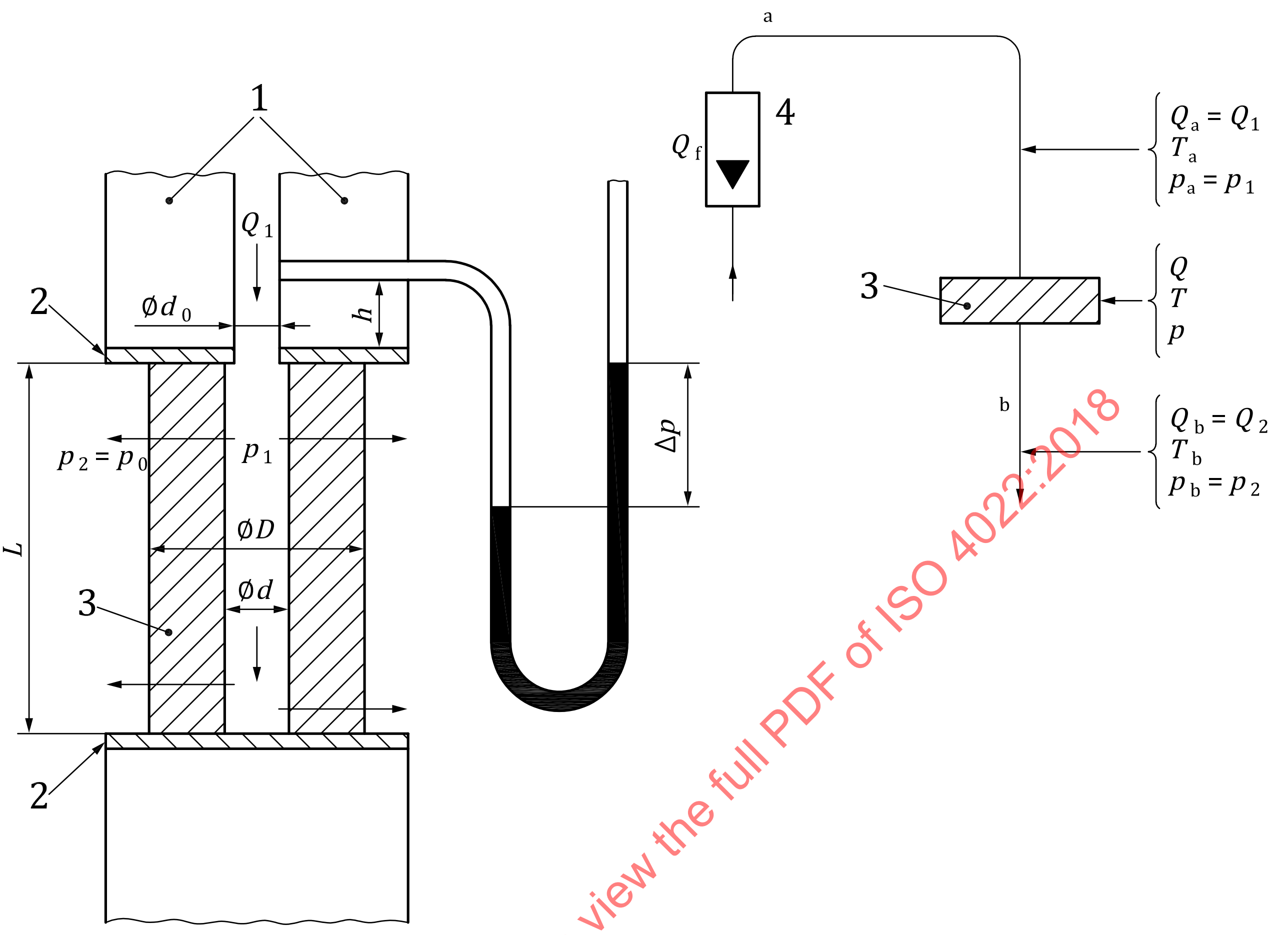
Key

1	test fluid (for example air) from adjustable pressure-control valve	12	outer seal
2	clamping force	13	flowmeter
3	alternative entry for test fluid	D_1	mean diameter of the inner seals
4	port area as large as possible	D_2	test head diameter
5	inner chamber	p_0	atmospheric pressure
6	outer chamber	p_3	downstream guard ring pressure, adjusted to be equal to p_2
7	test piece	$p_2 - p_0$	pressure drop across flowmeter
8	to flowmeter	$p_1 - p_2$	pressure drop across porous metal
9	to atmosphere	Q_2	volumetric flow rate, at pressure p_2
10	adjustable pressure equalizing valve	a	Line a.
11	inner seal (“O” rings)	b	Line b.

Figure 1 — Guard ring test head

6.1.2 Jig for hollow cylindrical test pieces.

The permeability of hollow cylindrical test pieces is conveniently measured by clamping the cylinder axially between two flat surfaces and causing the test fluid to permeate outwards through the wall of the cylinder. An example is shown in Figure 2. The flowmeter is placed upstream of the test piece. When clamping the porous metal cylinder under test, sufficiently flexible seals shall be used to overcome surface irregularities so as to ensure leak-free sealing.



Key

1	clamping force	4	flowmeter
2	seal	a	Line a.
3	test piece	b	Line b.

The diameter d_0 should be approximately equal to diameter d, and the distance h should be as small as possible to minimize the apparatus correction.

Figure 2 — Jig for testing hollow cylindrical test pieces

6.2 Test fluids

In the majority of cases, gases are more convenient test fluids than liquids (see Annex B).

Test gases shall be clean and dry.

By agreement between the interested parties, liquids may be used where the permeability with reference to a specific liquid is required. This liquid shall be clean and free from dissolved gases.

7 Procedure

7.1 Measurement of thickness and area of the test piece

7.1.1 Flat test pieces

The size of micrometer anvils shall not be larger than the size of the surface irregularities, nor smaller than the pore size.

The test area is defined as that area normal to the direction of fluid flow, and, provided that the pressure gradient is uniform, this definition is meaningful and the test area is readily measured.

7.1.2 Hollow cylindrical test pieces

For hollow cylinders, the thickness e and the test area A are given by the relationships in Formulae (2) to (4):

$$e=\frac{D\times(\ln r)^2}{2(r-1)} \tag{2}$$

$$A=\frac{\pi\times D\times L\times \ln r}{r-1} \tag{3}$$

where ln is logarithmus naturalis and

$$r=\frac{D}{d} \tag{4}$$

(see Figure 2)

When the wall thickness $\frac{D-d}{2}$ is small compared with d, for example less than 0,1 × d, the thickness e and test area A are given by Formulae (5) and (6):

$$e=\frac{D-d}{2} \tag{5}$$

$$A=\frac{\pi\times L\times(D+d)}{2} \tag{6}$$

7.2 Measurement of pressure drop

The pressure drop may be determined either by measuring the upstream and downstream pressures separately and taking the difference or by using a differential pressure gauge.

The apparatus correction is obtained by using the equipment with no test piece in place and observing the pressure drop over the required range of flow rates. The apparatus correction should preferably not exceed 10 % of the pressure drop.

7.3 Measurement of flow rate

A primary standard for the measurement of the flow rate of the test fluid is preferred. The flow rate shall be corrected to the mean pressure and temperature of the test piece. However, a standard flowmeter (previously calibrated against a primary standard) might be more convenient to use.

7.4 Measurement of pressures and temperatures

It is necessary to measure the pressure and temperature at the flowmeter and the test piece in order to

— correct the reading of the flowmeter;

— calculate the mean flow rate through the test piece;

— determine the density and the viscosity of the test fluid.

8 Expression of results

8.1 Mean flow rate

The reading of the flowmeter Q_f is corrected if it is not being used at its calibration pressure and temperature, by using the flowmeter correction factor C_f given by the manufacturer. The corrected flowmeter reading Q_a is given by Formula (7):

$$Q_a = C_f \times Q_f \tag{7}$$

The corrected flowmeter reading Q_a is converted to the mean flow rate Q within the porous test piece using the correction term C_s, which can be calculated from the gas law in Formula (8):

$$C_s = \frac{Q}{Q_a} = \frac{p_a}{p} \times \frac{T}{T_a} \tag{8}$$

The mean flow rate is shown in Formula (9).

$$Q = C_s \times Q_a \tag{9}$$

When tabulating data, it is convenient to use the overall correction factor C_o, as in Formula (10).

$$C_o = C_f \times C_s \tag{10}$$

to obtain the mean flow rate, use Formula (11).

$$Q = C_o \times Q_f \tag{11}$$

8.2 Mean density and viscosity

The mean pressure and the mean absolute temperature within the test piece will enable mean density and mean viscosity to be obtained from published data.

8.3 Calculation of results

The viscous and inertia permeability coefficients are determined by taking a number of simultaneous flow rate and pressure drop readings. The number of flow rate readings shall be at least five, equally spaced within an interval of flow rate readings where the highest is at least 10 times greater than the lowest.

The results are processed using Formula (12):

$$\frac{\Delta p \times A}{e \times Q \times \eta} = \frac{1}{\psi_i} \times \frac{Q \times \varrho}{A \times \eta} + \frac{1}{\psi_v} \tag{12}$$

See Annex A, Formula (A.2).

This formula can be rewritten in the form $y = ax + b$, as shown in Formulae (13) and (14).

$$y = \frac{\Delta p \times A}{e \times Q \times \eta} \tag{13}$$

$$x = \frac{Q \times \varrho}{A \times \eta} \tag{14}$$

The values x and y are calculated at each level of flow rate/pressure drop. The corresponding values of x and y are plotted on linear graph paper and the straight line which best fits the points is drawn.

The intercept of this line on the y-axis gives the reciprocal of the viscous permeability ($1/\psi_v$).

The slope of this line gives the reciprocal of the inertia permeability ($1/\psi_i$).

In case of doubt, the straight line should be determined by the least-squares method.

NOTE If measurement is made with flow in the laminar regime, only the viscous permeability coefficient can be determined (see Annex A).

8.4 Final result

Report of the viscous permeability coefficient in 10^{-12} m^2 (1 µm^2) and the inertia permeability coefficient in 10^{-6} m (1 µm), to an accuracy of ± 5 % in relative value.

NOTE The unit of viscous permeability coefficient (micrometre squared) is sometimes called a darcy.

9 Test report

The test report shall include the following information:

a) reference to this document, i.e. ISO 4022;

b) all details necessary for identification of the test sample;

c) the type of apparatus used;

d) the test fluid used;

e) the result obtained;

f) all operations not specified by this document or regarded as optional;

g) details of any occurrence which might have affected the result.