H-56-14

International Standard ISO 4638

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Polymeric materials, cellular flexible — Determination of air flow permeability

Matériaux polymères alvéolaires souples — Détermination de la perméabilité à l'air

First edition — 1984-05-15

UDC 678.4-405.8 : 620.193.29 **Ref. No. ISO 4638-1984 (E)**

Descriptors: cellular materials, flexible cellular materials, tests, determination, permeability, air flow.

ISO 4638-1984 (E)

Price based on 7 pages

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been authorized 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.

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.

International Standard ISO 4638 was developed by Technical Committee ISO/TC 45, *Rubber and rubber products*, and was circulated to the member bodies in February 1982.

It has been approved by the member bodies of the following countries:

Austria	Germany, F.R.	Romania
Belgium	India	South Africa, Rep. of
Brazil	Indonesia	Spain
Canada	Ireland	Sri Lanka
China	Mexico	Thailand
Czechoslovakia	Netherlands	Turkey
Denmark	Nigeria	USA
Egypt, Arab Rep. of	Poland	USSR
France	Portugal	

The member body of the following country expressed disapproval of the document on technical grounds:

United Kingdom

Polymeric materials, cellular flexible — Determination of air flow permeability

0 Introduction

The air flow permeability of cellular materials indicates, in an indirect manner, some of their structural properties. It may be used to establish correlations between the structure of these materials and some of their physical properties. It also enables identification of the modifications to cellular structures produced by chemical agents used in foaming, for example catalysts or surfactants.

This International Standard is, therefore, useful for two purposes:

a) in studying the structure of cellular products in connection with their physical properties and their method of manufacture;

b) in ensuring product quality (quality assurance).

NOTE — Details of publications relating to flow behaviour in both laminar and turbulent conditions are given in a bibliography.

1 Scope and field of application

This International Standard specifies a method for the determination of the permeability of flexible cellular polymeric materials to air flow.

It is applicable to test pieces cut from products of cellular material.

NOTE — ISO 7231, *Polymeric materials, cellular flexible — Method of assessment of air flow value at constant pressure drop*,[1] specifies a simple quality control method which is also based on the flow of air through cellular materials. This can be used when it is not the intention to calculate the intrinsic properties of various materials in order to compare them, but merely to control the quality of a given cellular material.

2 References

ISO 471, *Rubber — Standard temperatures, humidities and times for the conditioning and testing of test pieces.*

ISO 845, *Cellular rubbers and plastics — Determination of apparent density.*

3 Principle

Passing air under controlled conditions through a test piece in the form of a cylinder or parallelepiped. Measurement of the pressure drop between the two free faces of the test piece.

4 Symbols and terminology

4.1 Air flow permeability, K, is given by Darcy's law (see figure 1), which describes the air flow in a homogeneous and isotropic (see note 1) porous medium under laminar flow conditions (see note 2) by the equation

$$u = \frac{q_V}{A} = \frac{K \, \Delta p}{\eta \, \delta}$$

where

u is the linear air flow velocity, in metres per second;

q_V is the volumetric air flow rate, in cubic metres per second, crossing the test piece;

A is the right cross-sectional area, in square metres, of the test piece;

K is the flow permeability, in square metres, of the porous medium;

Δp is the pressure drop, in pascals, across the test piece;

η is the dynamic viscosity, in pascal seconds, of air;

δ is the thickness, in metres, of the test piece.

NOTES

1 For anisotropic materials, it is necessary to define the direction of the flow.

2 For the flow of air to be laminar in the interior of the porous medium, it is necessary for the following conditions to be fulfilled:

$$Re^* = \frac{u\sqrt{K}}{\nu} < n$$

where

Re^* is the modified Reynolds number;

ν is the kinematic viscosity, in square metres per second, of air;

1) At present at the stage of draft.

η is a limiting value depending on the structure of the product. In the absence of precise data on this subject, it is sufficient to use several very low air flow rates of the order of centimetres per second, on a single type of material, to verify that K does not vary or varies only slightly, with changes in u (see 9.1).

4.2 Specific air flow resistance, R_s, is a parameter derived from the permeability of a material, used particularly in the field of acoustics, and is derived from permeability by the equation

$$R_s = \frac{\eta}{K}$$

It is expressed in pascal seconds per square metre ($Pa \cdot s \cdot m^{-2}$).

4.3 Air flow resistance, R, is related to the thickness of the material δ, whether it is homogeneous or not (it may even consist of a skinned surface or a coating which is more or less porous, such as paint etc.). If the material is homogeneous it is proportional to the specific air flow resistance by the relationship

$$R = \delta \cdot R_s$$

In every case, R can be derived directly from Darcy's law which is then written

$$u = \frac{q_V}{A} = \frac{\Delta p}{R_s}$$

The inverse relationship $R_s = R/\delta$ can only be used to calculate R if the material is homogeneous.

Air flow resistance is expressed in pascal seconds per metre ($Pa \cdot s \cdot m^{-1}$).

5 Apparatus

The apparatus consists of a measurement cell into which the test piece may be placed, and means for production of a steady flow of air, for measuring the volumetric air flow rate, for measuring the pressure drop and for measuring the thickness of the test piece when positioned for the test.

An example of a suitable apparatus is shown schematically in figure 2.

It shall include the following elements.

5.1 Measurement cell

The measurement cell shall be in the shape of a parallelepiped or a cylinder.

An example of a cylindrical measurement cell is illustrated in figure 3.

If the shape is cylindrical, an internal diameter between 50 and 120 mm is suitable (cross-section between 20 and 110 cm^2).

For parallelepipeds, the preferred cross-section is a square of side between 45 and 105 mm, corresponding to the same limits of cross-sectional area as for the cylindrical shape.

The total height of the cell shall be at least 100 mm greater than the thickness of the test piece. For tests other than for quality assurance, it is useful to make allowance for the use of test pieces of differing thicknesses, not exceeding half the total height of the measurement cell.

NOTE — Experience has shown that, for certain cellular products, it is necessary to use test pieces of thicknesses of the order of 100 mm, and a sufficiently deep measurement cell is therefore necessary.

The test piece shall rest inside the measurement cell on a perforated support positioned 50 mm above the base of the cell. This support shall have a minimum open proportion of 70 % of its overall area, evenly distributed.

The tapping points for the measurement of pressure and air flow shall be leak free and arranged below the level of the perforated support.

NOTE — Calculations in 8.6 are facilitated if the area of the test piece is standardized at 25 or 100 cm^2 (56,5 or 113 mm diameter; square of side 50 or 100 mm). Then u, in metres per second, is equal to 400 q_V or 100 q_V depending on whether the small or the large test piece is used. Calculations in clause 9 are facilitated if the area of the test piece is standardized at 18,5 cm^2 (48,5 mm diameter; square of side 45 mm) and the thickness of the test piece is 100 mm. Then

$$K = \frac{q_V}{\Delta p}$$

5.2 Means of providing air flow

5.2.1 Source

It is recommended that pressure depression systems, of the water reservoir or vacuum pump type, should be used. Alternatively, pressurization systems (air compressor, etc.) may be used. Whatever source is used, the installation shall permit fine control of the flow and shall ensure the stability of the flow in the lower part of the test cell.

5.2.2 Characteristics of the flow

The source shall provide a volumetric air flow rate, q_V, equal to uA cubic metres per second.

The area chosen for the cell, A, shall be within the limits indicated in 5.1 and the source shall permit air flow velocities up to 50 $mm \cdot s^{-1}$ to be obtained.

For example, for cylindrical specimens of diameters between 50 and 120 mm, and with an air flow velocity of the order of 10^{-2} $m \cdot s^{-1}$, the volumetric air flow rate through the apparatus will be approximately between 1 $dm^3 \cdot min^{-1}$ and 7 $dm^3 \cdot min^{-1}$. The source shall have sufficient stability so that the instantaneous volumetric air flow rate may be estimated to better than ±2,5 %, and so that the change in flow rate with time does not exceed 1 % per minute.

5.3 Means of measuring volumetric flow rate

The instrument for measuring the volumetric air flow rate shall be placed between the source and the test piece, as close as possible to the test piece. It shall be selected from a type capable of measuring the values of flow indicated in 5.2.2.

The arrangement used shall permit measurement of the flow with an accuracy of ±2 % of the full scale value.

The arrangement may be, for example, an assembly of flowmeters arranged in parallel, one of which can be selected to suit the required range of measurement.

The flowmeter used for any measurement shall allow reading of the volumetric air flow rate at a graduation between 20 and 100 % of the full scale value of the meter.

Calibrated flowmeters with a scale at least 250 mm long are recommended.

5.4 Means of measuring pressure drop

The apparatus used for measuring differential pressures shall permit measurements of pressure drops as small as 1 Pa. Inclined water or alcohol manometers or any other apparatus allowing readings with an accuracy of 0,5 Pa may be used.

5.5 Means of measuring test piece thickness

For materials of sufficiently high density to possess well-defined surfaces and which are to be measured in the uncompressed state, the thickness of the test piece shall be measured in place in the holder with an accuracy of at least 1 %. A suitable means of doing this is to use the thickness measurement device shown in figure 3. This device consists of a perforated plate with a minimum open proportion of 70 % of its overall area evenly distributed, which may be brought progressively into contact with the test piece. This plate shall be parallel with the support plate.

NOTE — If it is wished to make measurements upon test pieces in a partially compressed state or those which have ill-defined surfaces, this device should be used to set and measure the thickness of the test piece while it is in position to an accuracy of at least 1 %.

6 Test pieces

6.1 Shape

The test piece may be a cylinder or a parallelepiped, according to the type of measurement cell available.

6.2 Dimensions

6.2.1 Lateral dimensions

Because of the elasticity of the materials for which this method is intended, it is necessary for test pieces to be prepared with lateral dimensions slightly larger than those of the measurement cell, in order to eliminate leaks along the sides of the cell.

The tolerance on diameter shall be ±1 mm.

If D_c is the internal diameter, in millimetres, of the cell and D is the cut diameter, in millimetres, of the test piece, then the relationship required is

$$D = (D_c + 2) \pm 1$$

By analogy, in the case of a test piece which is a rectangular parallelepiped of side L, in millimetres, after cutting, the side of the right cross-section of the measurement cell being L_c, in millimetres, then the relationship required is

$$L = (L_c + 2) \pm 1$$

6.2.2 Thickness

The thickness of the test piece shall be chosen to obtain pressure drops measurable under optimum conditions (see 8.8) and to suit the usable depth of the measurement cell (see 5.1).

If the test pieces available are not sufficiently thick to produce a suitable pressure drop, not more than five test pieces, chosen in the same way, may be superimposed. In general, thicknesses between 50 and 100 mm are sufficient.

6.3 Preparation

6.3.1 For tests intended to provide values of permeability or specific resistance, eliminate all surface skin or unevenness on the surface of the product (to ensure that the test piece will be planar and homogeneous). For tests for other purposes, cut test pieces from the product submitted for testing.

6.3.2 Adequate means of cutting the test pieces shall be used (for example a band-knife with moving table, cutting guide etc.) to ensure the necessary accuracy of the lateral dimensions (6.2.1). The faces through which the flow takes place shall be parallel to within ±1 mm and shall not be cut by hot wire.

6.3.3 Weigh the test piece.

6.4 Number of test pieces

For quality assurance purposes, reference shall be made to the specifications relating to the particular product being tested. If the tests are intended to characterize the structure of a cellular product, at least three samples shall be taken, from each of which four test pieces shall be cut.

7 Testing conditions

The tests shall be carried out under conditions as specified in ISO 471.

Materials shall only be tested after property stabilization. If the nature of the polymer requires wet-knife cutting, the test pieces shall be dried before testing commences.

8 Procedure

8.1 Place the test piece, prepared as described in clause 6, in the measurement cell.

8.2 Ensure that the edges are properly sealed.

8.3 Bring the device for measuring the thickness of the test pieces into contact with the upper surface of the test piece, compressing it lightly if necessary.

8.4 Note the thickness and use this measurement to determine the free or the compressed volume and from this derive the free or the compressed density of the test piece when in position.

8.5 With all valves to manometers closed, slowly establish the air flow by opening the appropriate valve.

8.6 Change the flow rate through the test piece progressively until the desired rate is obtained and calculate the velocity from the equation

$$u = \frac{q_V}{A}$$

8.7 Measure the corresponding pressure drop, Δp.

8.8 Carry out measurements of Δp for five different values of air flow velocity, these velocities being such that conditions of laminar flow are obtained. If these flow velocities do not allow accurate measurement of Δp to be made, increase the thickness of the test pieces.

NOTE — If measurements for quality assurance of a known product are being carried out, this procedure is not necessary.

9 Calculation and expression of results

9.1 For homogeneous test pieces

For each test piece, calculate the air flow permeability from the equation

$$K = \eta \frac{u}{\Delta p} \delta$$

NOTE — The dynamic viscosity η of air at 23 °C is $1{,}85 \times 10^{-5}$ Pa·s.

If it is wished to express the results in terms of the specific air flow resistance, calculate this characteristic from the equation

$$R_s = \frac{\Delta p}{u\,\delta}$$

See 4.2 for explanation of the symbols and units.

Using the results obtained on the group of test pieces, complete a summary table, as shown below, in which the entries are completed by calculated mean values of permeability for each flow velocity. (A similar table can be drawn up expressing the results in the form of specific resistances, R_{s_1}, R_{s_2}, R_{s_3}, etc.)

Summary table

u \ K	K_1	K_2	K_3	K_4	K_5	...	K_n	$\overline{K}$
u_1								
u_2								
u_3								
u_4								
u_5								

In reporting the results, the dimensions of the test piece, measured when in position for the test, shall be indicated together with the corresponding apparent density of the product.

Draw a graph of $\overline{K}$ as a function of u.

For research purposes, and in order to draw up specifications appropriate to each material, the result may be shown in different ways:

a) for quality assurance for a given material, it is sufficient to choose a single value of flow velocity, the summary table then consisting only of the first line of results;

b) if studying a new material, or for particular applications, $\overline{K}$ should be examined for the maintenance of a substantially constant value within any part of the field of variation of u, and this value used as representative of the material.

In both cases, the result shall be given in the form of a mean value $\overline{K}$, to two significant figures.

For the former purpose, the arithmetic mean value $\overline{K}$ obtained on the group of test pieces, together with the mean value of the apparent density, $\overline{\varrho}_a$, shall be given and a note made of the air flow velocity used for the test.

Example: $\overline{K} = 4{,}0 \times 10^{-10}$ m^2;
$u = 0{,}010$ m·s^{-1}; $\overline{\varrho}_a = 35$ kg·m^{-3}.

For the latter purpose, the arithmetic mean value of K obtained on the group of test pieces within a given range of velocities shall be quoted together with the mean value of the apparent density, $\overline{\varrho}_a$.

Example: $\overline{K} = 2{,}5 \times 10^{-10}$ m^2;
for $0{,}005 < u < 0{,}02$ m·s^{-1}; $\overline{\varrho}_a = 40$ kg·m^{-3}.

The results can equally well be expressed in terms of the specific resistance R_s instead of $\overline{K}$. If $\overline{K}$ is being determined for acoustic purposes, the value of $\overline{K}$ or R_s extrapolated graphically to a velocity of 0,50 mm·s^{-1} shall be shown if a significant variation of $\overline{K}$ is observed within the range of velocities under consideration.

9.2 For non-homogeneous test pieces

In this case, the calculation of K or R_s is meaningless and the air flow resistance R shall be calculated for each test piece from the equation

$$R = \frac{\Delta p}{u} = \frac{A\,\Delta p}{q_V}$$

See 4.3 for an explanation of the symbols and units.

The requirements of 9.1 shall be observed when considering R instead of R_s (or K).

9.3 Precision

Experimental data on the precision of results are not yet available.

10 Test report

The test report shall contain the following information, in addition to the results calculated for the test pieces as described in clause 9 (in particular, the summary table and corresponding graph, if any) and their mean as well as other statistical parameters (standard deviation etc.) if these are demanded by the product specification:

a) the nature of the product and its apparent density as measured by ISO 845;

b) a reference to this International Standard;

c) the test conditions used, particularly the shape and dimensions of the measurement cell;

d) the method of preparation of the test pieces;

e) the number of test pieces and their lateral dimensions;

f) if necessary, the orientation of the axis of the test pieces with respect to the principal axes of symmetry;

g) the presence and nature of any skin;

h) the thickness and density of the material as tested;

j) any deviation from the procedures specified in this International Standard which may have influenced the results.

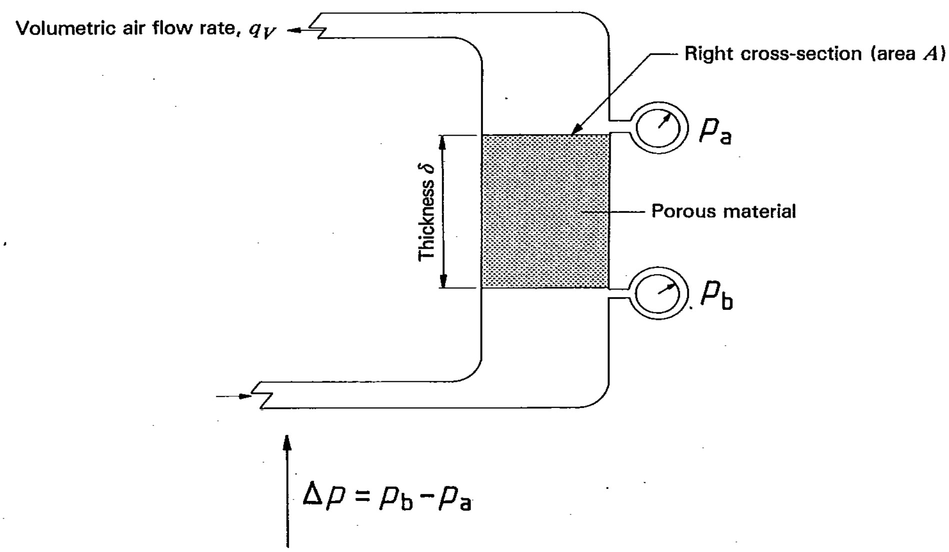

Figure 1 — Basic principle of the test (according to Darcy's laws)

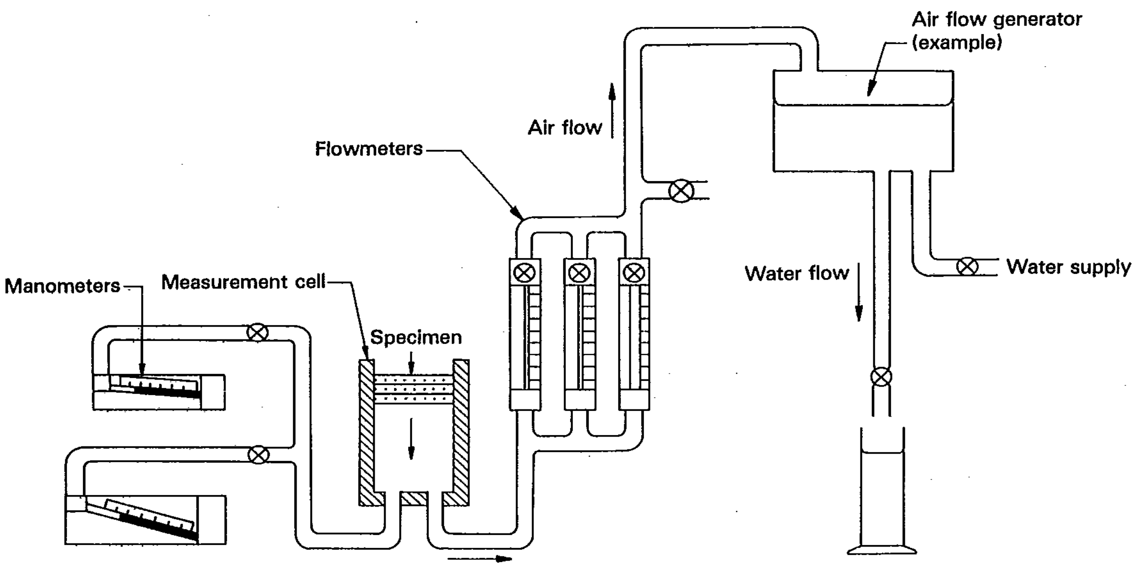

Figure 2 — Schematic diagram of an air flow permeability apparatus

Dimensions in millimetres

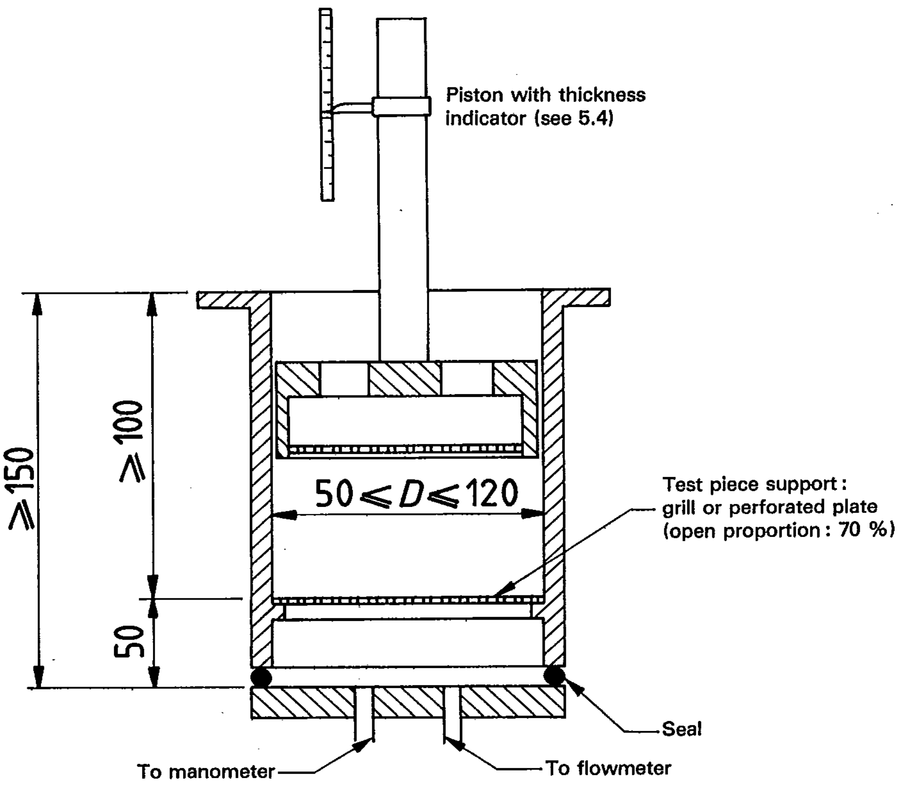

Figure 3 — Measurement cell (cylindrical section)

Bibliography

[1] MUSKAT, M. *The flow of homogeneous fluids through porous media*. J.W. Edwards, Ann Arbor, Michigan, 1946.

[2] CARMAN, P.C. *Flow of gases through porous media*. Butterworths Scientific Publications, London, 1956.

L'écoulement des gaz à travers les milieux poreux. Institut national des Sciences et techniques nucléaires et Presses Universitaires de France, 1961.

[3] COLLINS, R.E. *Flow of fluids through porous materials*. Reinhold Chemical Engineering Series. Reinhold Publishing Corporation, New York, 1961.

[4] SCHEIDEGGER, A.E. *The physics of flow through porous media*. University of Toronto Press, 1963.

[5] BEAR, J. *Dynamics of fluids in porous media*. American Elsevier Publishing Company Inc., 1972.

[6] PERRY, R.H. *Chemical Engineers' Handbook*, 5th Edition, Chapter 5, p. 54. McGraw-Hill Book Company, 1973.

[7] GENT, A.N., and RUSCH, K.C. Permeability of open-cell foamed materials. *Journal of Cellular Plastics*, January 1966 : 46-50.