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Rigid cellular plastics — Determination of water vapour transmission properties

*Plastiques alvéolaires rigides — Détermination des caractéristiques de
transmission de la vapeur d'eau*



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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 1663 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 10, *Cellular plastics*.

This third edition cancels and replaces the second edition (ISO 1663:1999), of which it constitutes a minor revision. The main changes are as follows:

- the tolerance limits required for the humidity in the constant-humidity chamber (see 5.6 and 8.1) have been relaxed from $\pm 2\%$ to $\pm 5\%$;
- in Table 1, the third set of test conditions has been corrected to 38 °C and 0 % to 88 % RH.

Rigid cellular plastics — Determination of water vapour transmission properties

1 Scope

This International Standard specifies a method of determining the water vapour transmission rate, water vapour permeance, water vapour permeability and water vapour diffusion resistance index for rigid cellular plastics.

The scope of this method provides for the testing of rigid cellular materials that have thicknesses from 10 mm upwards and which may, as an integral part of the material, contain natural skins or adhered facings of some different material.

Three different sets of temperature and humidity conditions are provided, as follows:

- a) 38 °C and a relative-humidity gradient across the test specimen of 0 % to 88 %;
- b) 23 °C and a relative-humidity gradient across the test specimen of 0 % to 85 %;
- c) 23 °C and a relative-humidity gradient across the test specimen of 0 % to of 50 %.

The results obtained by this method are suitable for design purposes and production control, and for inclusion in product specifications.

The method is suitable for materials which have water vapour transmission rates in the range 3 ng/(m²·s) to 200 ng/(m²·s).

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 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 483, *Plastics — Small enclosures for conditioning and testing using aqueous solutions to maintain the humidity at a constant value*

ISO 1923, *Cellular plastics and rubbers — Determination of linear dimensions*

3 Terms and definitions

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

3.1 water vapour transmission rate
quantity of water vapour transmitted through unit area of a test specimen in unit time under specified conditions of temperature, humidity and thickness

NOTE 1 It is expressed in micrograms per square metre per second ($\mu\text{g}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$).

NOTE 2 The values obtained for the water vapour transmission rate are specific to the thickness of the test specimen.

3.2 water vapour permeance
ratio of the water vapour transmission rate for a test specimen to the vapour pressure difference between the two specimen faces during the test

NOTE 1 It is expressed in nanograms per square metre per second per pascal ($\text{ng}\cdot\text{m}^{-2}\cdot\text{s}^{-1}\cdot\text{Pa}^{-1}$).

NOTE 2 Water vapour permeance values are specific to the thickness at which the specimen was tested.

3.3 water vapour resistance
inverse of water vapour permeance

3.4 water vapour permeability
numerical value of the product of permeance and thickness

NOTE 1 It is the quantity of water vapour transmitted per unit time through a given area of the material per unit vapour pressure difference between its faces for a unit thickness.

NOTE 2 It is expressed in nanograms per metre per second per pascal ($\text{ng}\cdot\text{m}^{-1}\cdot\text{s}^{-1}\cdot\text{Pa}^{-1}$).

NOTE 3 For homogeneous materials, values obtained for water vapour permeability are a property of the material.

3.5 water vapour diffusion resistance index
ratio of the water vapour permeability of air to that of the material concerned

NOTE 1 It indicates how much less permeable the material is than an equally thick layer of stationary air at the same temperature.

NOTE 2 It is dimensionless.

NOTE 3 For homogeneous materials, values obtained for water vapour diffusion resistance index are a property of the material.

4 Principle

A test specimen is sealed to the open mouth of a test dish containing a desiccant. The assembly is then placed in an atmosphere whose temperature and humidity are controlled. Periodic weighings of the assembly are made to determine the rate of water vapour transmission through the specimen into the desiccant.

5 Apparatus and materials

5.1 Shallow circular open containers, made of a material impermeable to water vapour, such as glass or metal, of 65 mm minimum diameter and with tops slightly belled out to admit a wax seal. See Annex A for typical assemblies and 5.3 for assemblies requiring a template.

5.2 Measuring instruments, capable of determining linear dimensions in accordance with the requirements of ISO 1923.

5.3 Circular template (with edge tapered to facilitate removal after use), to duplicate the exposed area of the specimen to the nearest 0,1 cm². The template shall have an area that is at least 90 % of the exposed surface of the specimen in order to reduce the edge effect due to a non-linear vapour seal.

5.4 Pot or dish, for melting the sealant wax (5.8).

5.5 Analytical balance, capable of weighing the test assembly to an accuracy of 0,1 mg.

5.6 Constant-temperature, constant-humidity chamber, capable of being maintained within ± 5 % of the required relative humidity and within ± 1 °C of the required temperature, and with a provision for continuous monitoring of the temperature and humidity during the test period. The chamber may be a room. Alternatively, if the chamber corresponds to that shown in Figure 1, then the air circulation shall be capable of being switched off to permit accurate weighings.

NOTE If a conditioned room is used for the test, then it is not necessary to use the chamber shown in Figure 1.

5.7 The following solutions can be used with non-injection-type humidity cabinets:

5.7.1 For testing at 38 °C and a relative humidity of 88 %: **saturated potassium nitrate solution** containing a large excess of the undissolved salt at 38 °C.

5.7.2 For testing at 23 °C and a relative humidity of 85 %: **saturated chloride solution** containing a large excess of the undissolved salt at 23 °C.

NOTE 1 For testing at 23 °C and a relative humidity of 50 %, there is no suitable salt which would meet the tolerance required by 8.1.

NOTE 2 For laboratories which do not have a suitable humidity chamber, the following solutions are suggested as alternatives, although the user should be aware that they do not comply with this International Standard:

- a) a saturated aqueous solution of magnesium nitrate hexahydrate containing a large excess of the undissolved salt at 23 °C;
- b) a saturated aqueous solution of sodium dichromate dihydrate containing a large excess of the undissolved salt at 23 °C.

More information about constant-humidity solutions may be found in ISO 483.

5.8 Sealant wax, unaffected by the test conditions. The following are examples of suitable sealants:

5.8.1 A mixture of 90 % microcrystalline wax and 10 % of a plasticizer (for example low-molecular-mass polyisobutylene).

5.8.2 A mixture of 60 % microcrystalline wax and 40 % refined crystalline paraffin.

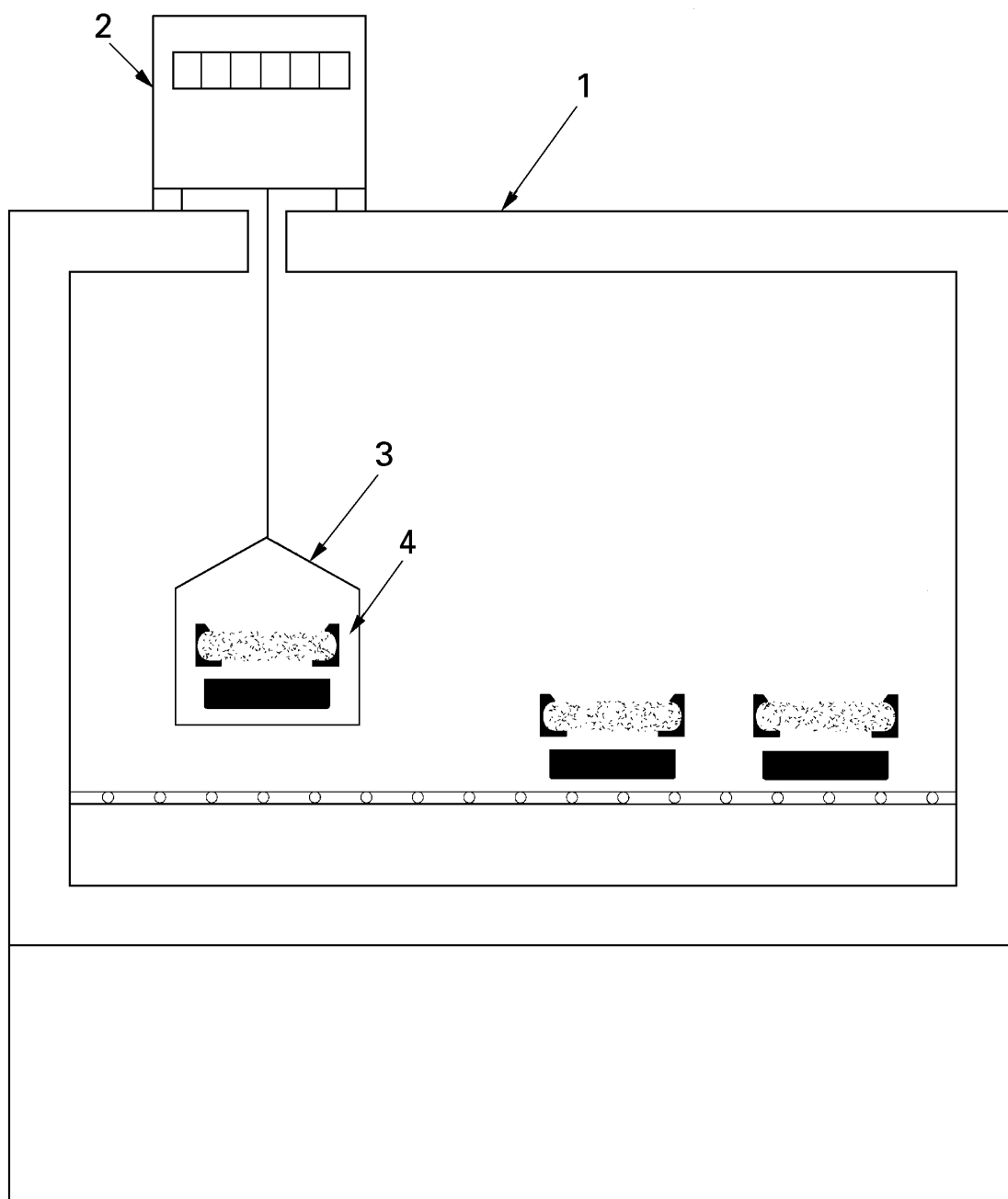
5.9 Anhydrous calcium chloride desiccant, with particles about 5 mm in diameter, free from fines, which would pass a No. 30 (600 μ m) sieve.

5.10 Limiting ring, for use with thin specimens (see Figure A.1).

6 Sample

The sample shall be representative of the material. It may contain the natural skin or facings adhered to it which constitute part of the material.

Some cellular plastics have skins of a density significantly different from that of the core material. If it is intended to determine the permeability of the material, the specimen shall be homogeneous and tested without the skin and facing.



Key

- 1 controlled-environment test chamber with "glove box" type access door
- 2 balance
- 3 suspended weighing platform
- 4 test assembly during weighing

Figure 1 — Recommended specimen exposure and measurement when operator cannot enter controlled environment

7 Test specimens

7.1 Dimensions

7.1.1 Shape and fit

Specimens shall be cut to fit the dimensions of the test assembly used (see Annex A).

7.1.2 Thickness

The thickness of specimens shall not be less than 10 mm, except for materials produced thinner than 10 mm which shall be tested at the manufactured thickness. A specimen thickness of 25 mm is preferred.

7.1.3 Exposed area

The diameter of specimens shall not be less than four times the specimen thickness. The minimum exposed area shall be 50 cm².

7.2 Number

A minimum of five specimens shall be tested.

When the material to be tested is suspected of being anisotropic, the test specimens shall be cut such that the parallel faces are normal to the direction of vapour flow through the product in its intended use.

When the material is faced with natural skins or adhered facings which are different for the two sides, the test specimens shall be tested with the vapour flow in the same direction as that in the intended use. If the direction of vapour flow in the intended use is not known, a duplicate set of specimens shall be prepared so that tests can be made and reported for each direction of vapour flow.

7.3 Conditioning

For precise measurement, test specimens shall be conditioned in one of the atmospheres specified in ISO 291.

8 Procedure

8.1 Select the desired test environment from the three sets of conditions below:

- (38 ± 1) °C and a relative humidity of 0 % on one side of the specimen and (88 ± 5) % on the other side;
- (23 ± 1) °C and a relative humidity of 0 % on one side of the specimen and (85 ± 5) % on the other side;
- (23 ± 1) °C and a relative humidity of 0 % on one side of the specimen and (50 ± 5) % on the other side.

NOTE A tolerance is not applied to the 0 % RH condition because it is the condition deemed to be generated by the use of the desiccant.

Because the values obtained under one set of test conditions may differ from the values obtained under a different set of conditions, the conditions selected shall be those most closely approaching the conditions of use.

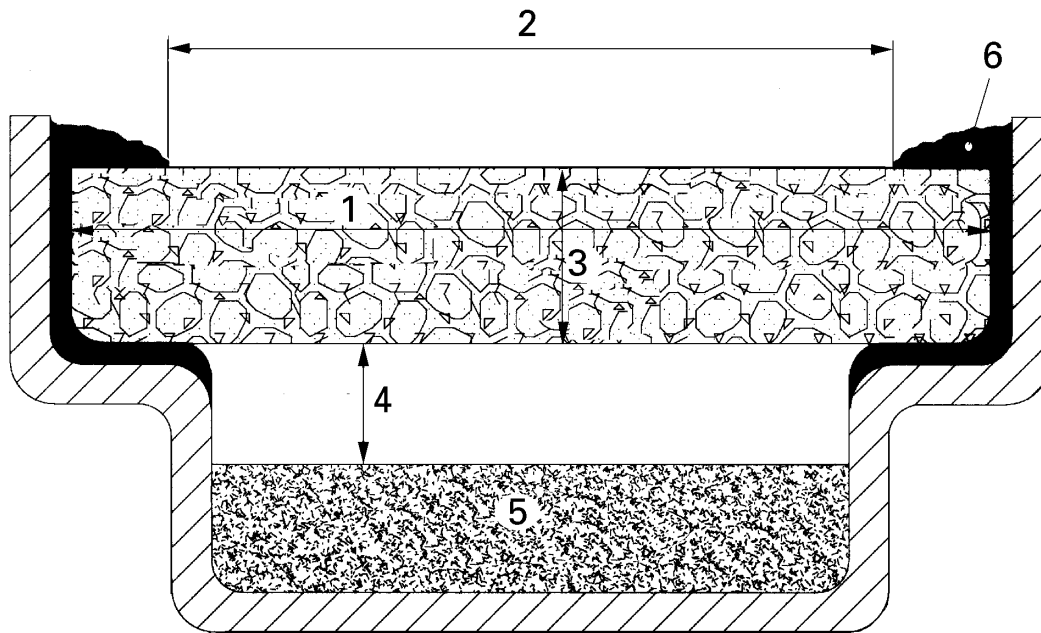
8.2 The environment in the test chamber (5.6) shall be monitored continuously and the temperature maintained within ± 2 °C of that of the test room.

8.3 Select a test assembly from the configurations given in Figure A.1.

8.4 Prepare the test specimens such that they fit the selected test assembly configuration.

8.5 In accordance with ISO 1923, measure the thickness of the test specimens at each quadrant to the nearest 0,1 mm, or to an accuracy of 5 %, whichever is the more precise. Calculate the average result for each test specimen.

8.6 Place the desiccant (5.9) in a layer (20 ± 5) mm thick at the bottom of each container. Heat the sealant wax (5.8) in its container until liquid. Then follow the procedure in Annex A which corresponds to the configuration selected. The air space between the desiccant and the specimen shall be (15 ± 5) mm. The diameter of the exposed area shall be at least 90 % of the diameter of the specimen. See Figure 2, which shows a typical test assembly.



Key

- 1 specimen diameter d
- 2 diameter of exposed area ($\geq 0,9d$)
- 3 specimen thickness (> 10 mm)
- 4 air gap [width (15 ± 5) mm]
- 5 desiccant [depth (20 ± 5) mm]
- 6 sealant wax

Figure 2 — Typical test assembly

8.7 If it is intended to determine the water vapour diffusion resistance index, the atmospheric pressure shall be measured and recorded daily.

8.8 Condition each test assembly in the selected environment for a period of 24 h and weigh to the nearest 100 μ g.

8.9 At regular intervals of 24 h, weigh each test assembly. If a test assembly is removed from the test environment for weighing, then it shall be returned to the test environment with a minimum delay.

8.10 Continue the weighings until five successive determinations of change in mass per unit time are constant, within ± 2 % of the mean value (see 9.1). A plot of mass change against time will indicate when the state of constant rate of change is reached.

9 Expression of results

9.1 Calculation of constant rate of change of mass

If $m_2 - m_1$ is the difference in mass between any two successive weighings of the test assembly, in μg , and $t_2 - t_1$ is the time interval between two successive weighings of the test assembly, in h,

then $G_{12} = \frac{m_2 - m_1}{t_2 - t_1}$ = the change in mass per unit time for the two successive weighings, in $\mu\text{g}/\text{h}$.

Let G be the average of five successive values of G_{12} , in $\mu\text{g}/\text{h}$.

The test is completed when each of five successive values of G_{12} is within the range $0,980G$ to $1,020G$.

9.2 Calculation of water vapour transmission rate

The water vapour transmission rate g , in $\mu\text{g}/(\text{m}^2\cdot\text{s})$, is given by the equation

$$g = \frac{G}{A} \times \frac{100}{36}$$

where A is the area of the side of the test specimen exposed to humidity, in cm^2 .

9.3 Calculation of water vapour permeance

The water vapour permeance W_P , in $\text{ng}/(\text{m}^2\cdot\text{s}\cdot\text{Pa})$, is given by the equation

$$W_P = \frac{G}{AP} \times \frac{10^5}{36}$$

where P is the water vapour pressure difference, in pascals, and has one of the following values:

5 860 Pa at 38 °C and 0 to 88 % RH;

2 390 Pa at 23 °C and 0 to 85 % RH;

1 400 Pa at 23 °C and 0 to 50 % RH.

9.4 Calculation of water vapour permeability

The water vapour permeability δ , in $\text{ng}/(\text{m}\cdot\text{s}\cdot\text{Pa})$, is given by the equation

$$\delta = \frac{W_P \times s}{10^3}$$

where s is the specimen thickness, in mm.

9.5 Calculation of water vapour diffusion resistance index

Calculate the average daily atmospheric pressure for each period between weighings. Use these values to interpolate values for \bar{H} (defined below) from Table 1.

Table 1 — Determination of the value of \bar{H} for the calculation of water vapour diffusion resistance index

Test conditions		Atmospheric pressure kPa	\bar{H}
Temp. °C	RH %		
23	0 to 50	90	26,7
		95	25,3
		100	24,0
		105	22,9
		110	21,8
23	0 to 85	90	45,3
		95	43,0
		100	40,8
		105	38,9
		110	37,1
38	0 to 88	90	115,8
		95	109,7
		100	104,3
		105	99,3
		110	94,8

The water vapour diffusion resistance index μ can then be calculated from the equation

$$\mu = 115,74 \times \frac{\bar{H}}{g \times s}$$

where

s is the specimen thickness, in mm;

g is the water vapour transmission rate (see 9.2);

\bar{H} is the numerical value of the expression $24\,000 \times \delta_L \times (p_1 - p_2)$ (see Annex B) for the particular test conditions used and the atmospheric pressure, taken from Table 1.

10 Precision

The precision of this test method is not known because interlaboratory data are not available.

11 Test report

The test report shall contain the following information:

- a) a reference to this International Standard;
- b) a complete description of the material tested, including its thickness, details of any facings and the location/date of manufacture and/or manufacturing-lot identification;
- c) the temperature and relative-humidity gradient used for the determination;
- d) the test configuration used;
- e) the conditioning used and how the test conditions were achieved;
- f) the water vapour transmission property or properties calculated (transmission rate, permeance, permeability and/or diffusion resistance index) (where appropriate, all properties shall be reported), including the direction of the vapour flow relative to the facings if the two facings are different;
- g) the individual test results;
- h) the arithmetic mean of the test results;
- i) any deviation from this International Standard, and details of any incidents which may have influenced the results;
- j) the location where the test was conducted and the date when the test exposure was completed.

Annex A **(normative)**

Preparation of test assemblies

A.1 Procedure A

This procedure describes the preparation of assembly A in Figure A.1.

Apply a thin film of liquid sealant wax (5.8) to the inside floor of the upper ring of the container (5.1) at the point where the test specimen will be seated. Put the specimen into position so that it is in the middle of the container. Place the template (5.3) in position in the middle of, and resting on, the specimen. In stages, fill with liquid wax the space between the container and the specimen with its template, such that the space is filled up to the rim of the container without air bubbles and the wax is uniformly touching the edge of the specimen. When the wax has cooled to room temperature, carefully remove the template.

Figure A.1 shows assembly A immediately before removal of the template.

A.2 Procedure B

This procedure describes the preparation of assembly B in Figure A.1.

For this procedure, cut the specimen such that the edges are tapered and so that the larger surface fits snugly into the container. Warm the walls of the container, in the region where the specimen will be placed, to the softening temperature of the wax. Coat liberally and uniformly the edges of the specimen with hot wax. The warmed inside walls of the container may also be coated with a thin film of liquid wax. Quickly place the specimen on top of the container and place the template in position in the middle of, and resting on, the specimen. Immediately push uniformly down on the specimen until it is in the desired horizontal position. Fill with liquid wax the space between the container and the template, to the rim of the container, making sure that the wax is uniformly touching the edge of the specimen. When the wax has cooled to room temperature, carefully remove the template.

Figure A.1 shows assembly B immediately before removal of the template.

A.3 Procedure C

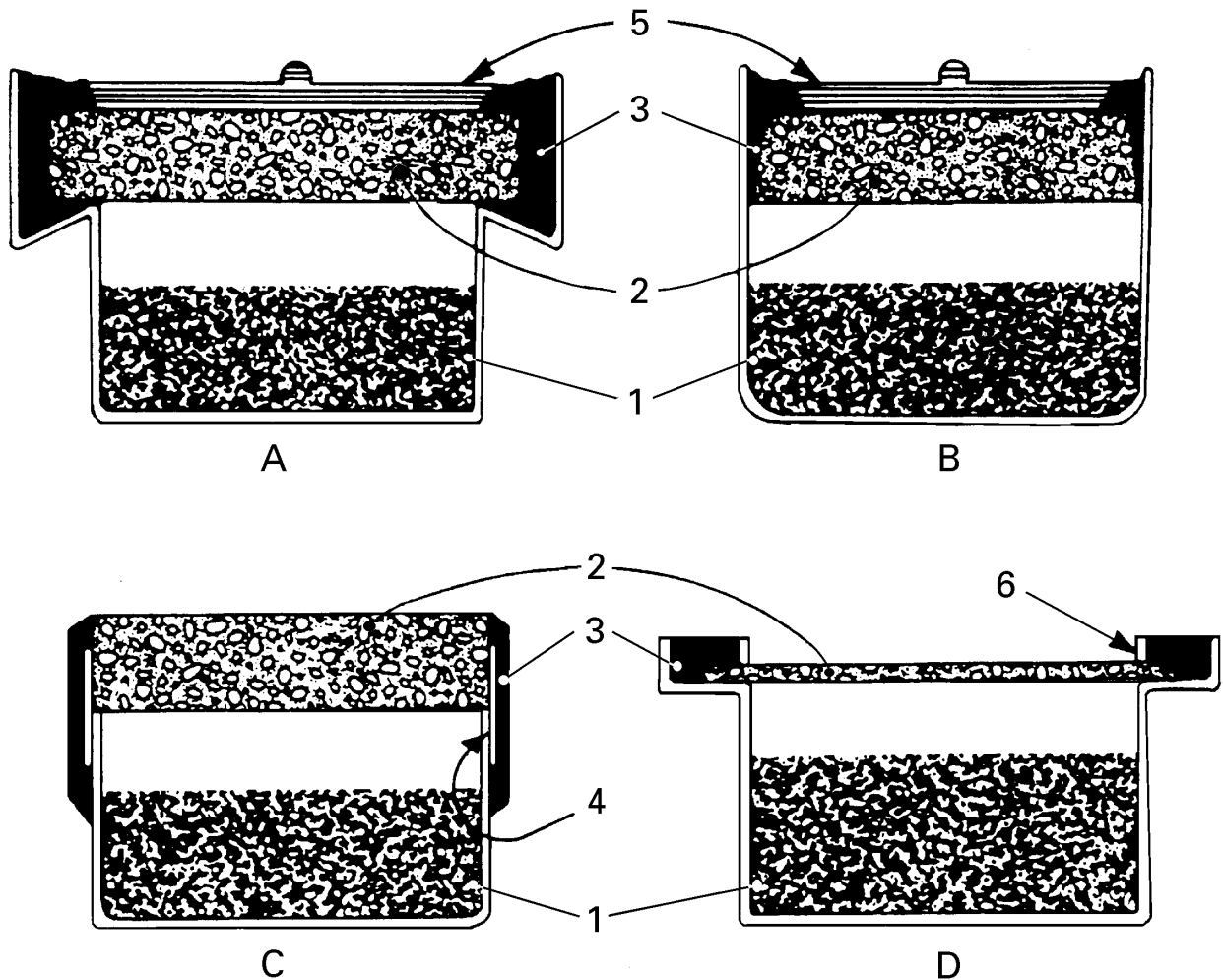
This procedure describes the preparation of assembly C in Figure A.1.

Warm the rim of the container to the softening temperature of the wax. Apply a uniform film of liquid wax to the rim and immediately position the specimen on it. Immediately, while the wax is still warm, apply adhesive tape completely around the joint, ensuring that the wax adheres uniformly, without air bubbles, to both the specimen and the container. Apply a liberal coat of wax to the tape and to the joints of the tape with the specimen and with the container. Ensure that the edge of the specimen is sealed, as are both joints and the tape. Allow the wax to cool to room temperature.

A.4 Procedure D

This procedure describes the preparation of assembly D in Figure A.1, and is suitable for thin specimens.

Apply a thin film of liquid wax to the inside floor of the upper ring of the container at the point where the test specimen will be seated. With the wax still soft, put the specimen into position so that it is centred in the container. Place the limiting ring (5.10) in position in the middle of, and resting on, the specimen. The inside diameter of the limiting ring shall be the same as the inside diameter of the container. Fill the space between the container and the limiting ring in stages with liquid wax free of air bubbles, building it up to the rim of the container. Allow the wax to cool. Leave the limiting ring in position for the test.



Key

- 1 desiccant
- 2 specimen
- 3 sealant
- 4 tape
- 5 template
- 6 limiting ring

Figure A.1 — Permissible test assemblies

Annex B (informative)

Derivation of the formula for calculating the water vapour diffusion resistance index

B.1 General

The equivalent air layer thickness S_d for water vapour diffusion indicates how thick a stationary air layer would have to be to have the same resistance to water vapour diffusion as a specimen of thickness s . It is given, in metres, by the equation

$$S_d = \mu \times s \quad (\text{B.1})$$

where μ is the water vapour diffusion resistance index.

The equivalent air layer thickness S_d is calculated from the following equation:

$$S_d = \delta_L \times A \times \frac{p_1 - p_2}{I} - S_L \quad (\text{B.2})$$

where

δ_L is the permeability of water vapour in air, in kg/(m·h·Pa);

A is the test area of the specimen, in m²;

p_1, p_2 are the partial pressures of water vapour at the specimen surface, in Pa;

I is the water vapour diffusion rate, in kg/h;

S_L is the mean thickness of the layer of air in the test vessel beneath the specimen, in m.

In the case of homogeneous substances which are also used in thicknesses other than that used for the test, the diffusion resistance index μ is calculated from Equation (B.3) below:

$$\mu = \frac{1}{s} \left(\delta_L \times A \times \frac{p_1 - p_2}{I} - S_L \right) \quad (\text{B.3})$$

For samples with an equivalent air layer thickness $> 1,0$ m, S_L may be ignored.

The permeability of water vapour in air δ_L depends on the atmospheric pressure and the atmospheric temperature during measurement, and can be derived from Figure B.1 or calculated from the following equation:

$$\delta_L = \frac{D}{R_D \times T} = \frac{0,083}{R_D \times T} \times \frac{p_0}{p} \left(\frac{T}{273} \right)^{1,81} \quad (\text{B.4})$$

where

D is the water vapour diffusion coefficient, in m^2/h ;

R_D is the gas constant for water vapour [462 J/(kg·K)];

T is the temperature in the climatic chamber, in K;

p is the mean atmospheric pressure in the climatic chamber, in kPa;

p_0 is the atmospheric pressure under standard conditions (101,325 kPa).

If the value of S_d is found to be $> 1\,500\text{ m}$, the material may be described as “virtually impervious to water vapour” in the thickness tested.

B.2 Simplified evaluation method

To determine the permeability to water vapour, the water vapour transmission rate g , in $\text{g}/(\text{m}^2\cdot\text{d})$, can be determined from the following equation:

$$g = \frac{24}{t_2 - t_1} \times \frac{m_2 - m_1}{A} \quad (\text{B.5})$$

where

$m_2 - m_1$ is the difference in mass between two weighings, in g;

$t_2 - t_1$ is the time interval between two weighings, in h;

A is the test area of the specimen, in m^2 .

Since $\frac{m_2 - m_1}{t_2 - t_1} = 1000 \times I$, Equations (B.3) and (B.5) can be combined to give

$$\mu = \frac{1}{s} \left(\delta_L \times \frac{24\,000 \times (p_1 - p_2)}{g} - S_L \right) \quad (\text{B.6})$$

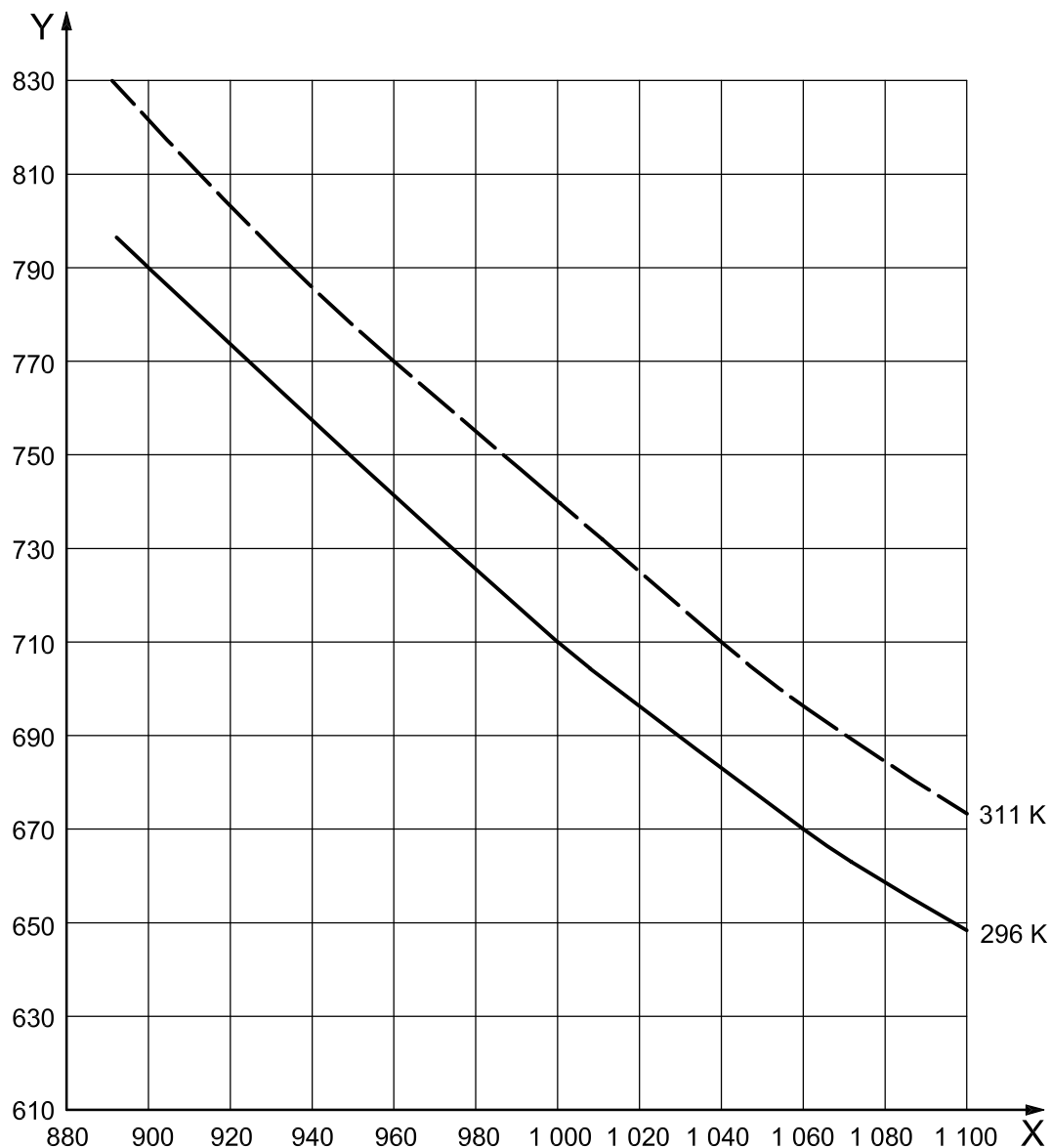
If S_L is neglected, the following simplified equation is obtained:

$$\mu = \delta_L \times \frac{24\,000 \times (p_1 - p_2)}{g \times s} \quad (\text{B.7})$$

To facilitate the calculation of the water vapour diffusion resistance index μ from Equation (B.7), the numerical values of the numerator $24\,000 \times \delta_L \times (p_1 - p_2)$ are represented by the symbol \bar{H} , and are given in Table 1 for all the test conditions for five different air pressures in each case.

Subclause 9.2 of this International Standard gives the water vapour transmission rate g in $\mu\text{g}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, whereas Equation (B.5) above gives g in $\text{g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$. Correcting for this difference in Equation (B.7) above and using the symbol \bar{H} yields

$$\mu = \frac{105}{24 \times 36} \times \frac{\bar{H}}{g \times s} = 115,74 \times \frac{\bar{H}}{g \times s} \quad (\text{B.8})$$



Key

X atmospheric pressure (kPa)

Y water vapour diffusion permeability in air [kg/(m·h·Pa)]

Figure B.1 — Water vapour diffusion permeability in air at 23 °C (296 K) and 38 °C (311 K) as a function of atmospheric pressure in accordance with Equation (B.4)

