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Paints and varnishes — Determination of water-vapour transmission properties — Cup method

Peintures et vernis — Détermination des propriétés de transmission de la vapeur d'eau — Méthode de la coupelle

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Foreword

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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 7783 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

This first edition of ISO 7783 cancels and replaces ISO 7783-1:1996 and ISO 7783-2:1999, which have been merged and technically revised. It also incorporates the Technical Corrigendum ISO 7783-1:1996/Cor.1:1998.

Introduction

ISO 7783 is one of a series of standards dealing with the sampling and testing of paints, varnishes and related products. It describes a method for determining the water-vapour transmission rate of self-supporting and non-self-supporting coatings.

The water-vapour transmission rate is not necessarily a linear function of film thickness, temperature or relative-humidity difference. A determination carried out under one set of conditions will not necessarily be comparable with one carried out under other conditions. Therefore, it is essential that the conditions of test are chosen to be as close as possible to the conditions of use.

Water-vapour transmission is of greatest interest under conditions of high humidity. For this reason, the wet-cup method has been adopted as the reference method. By agreement, other procedures and conditions, like the dry-cup method, may be used.

Paints and varnishes — Determination of water-vapour transmission properties — Cup method

1 Scope

This International Standard specifies a method for determining the water-vapour transmission properties of coatings of paints, varnishes and related products.

It supplements ISO 12572. As far as possible, the procedure, the definitions and the calculations have been taken over from ISO 12572. It is recommended that ISO 12572 be consulted, if necessary, to obtain a better understanding of the procedure specified in this International Standard.

Water-vapour transmission rates of more than 680 g/(m^2·d) (i.e. water-vapour diffusion-equivalent air layer thicknesses, s_d, of less than 0,03 m) will not be accurately quantified by the test method described in this International Standard.

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 1513, *Paints and varnishes — Examination and preparation of test samples*

ISO 2808, *Paints and varnishes — Determination of film thickness*

ISO 3233, *Paints and varnishes — Determination of percentage volume of non-volatile matter by measuring the density of a dried coating*

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 15528, *Paints, varnishes and raw materials for paints and varnishes — Sampling*

3 Terms and definitions

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

3.1
water-vapour transmission rate
V
mass of water vapour that is transmitted over a given period through a given surface area of a test piece under specified constant conditions of relative humidity at each face of the test piece

NOTE 1 It is measured in grams per square metre per day [g/(m^2·d)].

NOTE 2 A water-vapour transmission rate measured at atmospheric pressure, p, can be converted to the equivalent value at standard atmospheric pressure, p_0, by multiplying by p/p_0. This allows a linear correlation with the water-vapour diffusion-equivalent air layer thickness (s_d) value (see 3.3) by the factor 20,4.

NOTE 3 The term “water-vapour transmission” is often incorrectly used for water-vapour transmission rate.

3.2
rate of flow of water vapour through the test piece

G

mass of water vapour that is transmitted over a given period through a test piece under specified constant conditions of relative humidity at each face of the test piece

NOTE It is measured in grams per hour.

3.3
water-vapour diffusion-equivalent air layer thickness

s_d

thickness of a static air layer that has, under the same conditions of measurement, the same water-vapour transmission rate as the coating tested

NOTE It is measured in metres.

3.4
water-vapour resistance factor

μ

factor that indicates how many times greater the water-vapour resistance of a material is compared with a layer of static air of the same thickness at the same temperature and pressure

NOTE 1 It is dimensionless.

NOTE 2 The calculation and use of a water-vapour resistance factor is meaningful only if the water-vapour transmission rate of a particular material is a constant, i.e. independent of the thickness, which, however, is normally not the case for coatings.

3.5
test piece

⟨non-self-supporting coatings⟩ supporting substrate with the coating applied to it or ⟨self-supporting coatings⟩ the coating alone

3.6
wet-cup method

method of measuring water-vapour permeability in which the test piece is sealed to the rim of a cup containing a saturated aqueous solution of ammonium dihydrogen phosphate

NOTE This is the most convenient manner of carrying out determinations of water-vapour permeability under conditions of high relative humidity (between 93 % and 50 %).

3.7
dry-cup method

method of measuring water-vapour permeability in which the test piece is sealed to the rim of a cup containing a desiccant

NOTE This is the most convenient manner of carrying out determinations of water-vapour permeability under conditions of low relative humidity (between 50 % and 3 %).

3.8
test assembly

assembly consisting of a test piece sealed to the rim of a test cup containing saturated ammonium dihydrogen phosphate solution in contact with undissolved ammonium dihydrogen phosphate crystals (wet-cup method) or containing desiccant (dry-cup method)

3.9
test area

area of the face of the test piece through which the water vapour flows during the test

NOTE It is measured in square metres.

4 Principle

A test assembly consisting of a self-supporting coating, or a non-self-supporting coating on porous substrate, sealed to the rim of a cup is placed in a test enclosure kept at a specified temperature (e.g. 23 °C) and relative humidity (e.g. 50 %). The relative humidity in the cup is maintained at a constant level — either at 93 % by means of a saturated salt solution (wet-cup method) or at 3 % by means of a desiccant (dry-cup method). Because of the difference between the partial pressure of the water vapour inside the test cup and the partial pressure of the water vapour in the test enclosure, water vapour diffuses through the coating under test. By weighing the test assembly at suitable time intervals, the change in mass of the test assembly is followed. From the change in mass and the test area, the water-vapour transmission rate and the water-vapour diffusion-equivalent air layer thickness are calculated.

5 Apparatus and materials

5.1 Substrate for non-self-supporting coatings

Any homogenous, porous material which has a water-vapour transmission rate above 240 g/(m^2·d) is suitable for use as the substrate for non-self-supporting coatings, for instance polyethylene frits, cellular-concrete discs, glass frits, unglazed ceramic tiles.

When using cellular-concrete substrates, the coating shall be applied on the smooth side.

If the coating system under test does not include a primer and it is necessary to use one before applying the coating system under test, do so, but the transmission rate of the primed substrate will have to be determined separately.

5.2 Test cup

Test cups are made of glass, plastic or metal. The test cup used shall be resistant to corrosion under the conditions of the test.

NOTE For aluminium test cups, a wall thickness of 1 mm has been found to be satisfactory.

The exact surface area of the test piece exposed is defined by the design of the cup. The area of the exposed surface shall be at least 50 cm^2 for non-self-supporting coatings and at least 10 cm^2 for self-supporting coatings.

The cup shall be so designed that an efficient seal is made between it and the test piece, using sealing material (see 5.5), if necessary.

When the saturated solution (5.3) or desiccant (5.4) has been placed in the cup, the area of the surface of the saturated solution or desiccant shall be similar to that of the exposed surface of the test piece. The air gap between the test piece and the surface of the solution or desiccant shall be between 10 mm and 30 mm.

5.3 Ammonium dihydrogen phosphate ($NH_4H_2PO_4$) solution for wet-cup method

Prepare a saturated solution of ammonium dihydrogen phosphate (analytical grade) in contact with undissolved crystals, using water of at least grade 3 purity as defined in ISO 3696.

In the wet-cup method, which is the reference method, the relative humidity in a cup containing this saturated solution will be 93 %. The resulting water vapour pressure difference relative to the test enclosure, in which the relative humidity is maintained at 50 %, is 1 207 Pa at standard temperature (23 °C) and pressure (101 325 Pa).

5.4 Desiccant for dry-cup method

The desiccant shall be either dried silica gel in the form of granules passing a 4 mm sieve but retained on a 1,6 mm sieve, or anhydrous calcium chloride which has been dried at 200 °C.

It shall be possible to complete the test before the efficiency of the desiccant is reduced appreciably.

In the dry-cup method, the relative humidity in the cup shall be 3 %. The resulting water-vapour pressure difference relative to the test enclosure, in which the relative humidity is maintained at 50 %, is 1 400 Pa at standard temperature (23 °C) and pressure (101 325 Pa).

5.5 Sealing material

It shall be ensured that the test assembly is fully sealed, with the exception of the test area. The sealing material shall be impermeable and free from cracks. For sealing, mechanical clamps, wax or two-component sealing materials have been found suitable. The use of molten wax for sealing the test assembly is described in Annex B.

The sealing material shall not contain solvents or other volatile constituents which could cause any change in the coating or lead to weighing errors caused by the evaporation of solvent.

NOTE The most usual way of sealing the cup is to fit the cup with a mechanical clamp or screw device which can incorporate a sealing ring made of a suitable polymeric material. Mechanical sealing might not be suitable if the test piece has a rough surface or if it is very fragile. In such cases, the use of molten wax is more satisfactory.

5.6 Test enclosure

The test enclosure shall be of a design such that both the temperature and the relative humidity in the enclosure can be controlled at the levels required for the test. Thus, for the reference method, the enclosure shall be capable of maintaining the temperature at (23 ± 2) °C and the relative humidity at (50 ± 5) % (standard conditions as defined in ISO 3270). To ensure uniform conditions during the test, the air shall be caused to flow over the outer surface of the test piece at a speed between 0,02 m/s and 0,3 m/s. The ambient air pressure shall be corrected to standard pressure (1 013,25 hPa) as described in 8.1.

NOTE Maintaining the air speed at the correct level is the second most important source of error after preparation of the test pieces.

When cups have to be removed from the test enclosure for weighing, the specified conditions shall be re-established not more than 15 min after the door of the enclosure has been closed. The door shall remain open for the shortest possible time. This is especially important with materials having a high permeability.

5.7 Balance

The balance used shall be suitable for determining the change in mass of the test assembly with an accuracy of 1 mg or better for cups giving a test area of 50 cm^2 or less, or 10 mg for cups giving a test area greater than 50 cm^2.

The most suitable arrangement is to have the balance located in the test enclosure. If this is not possible, care shall be taken that no loss in mass occurs during the transport of the test assembly to the balance.

6 Preparation for the test

6.1 Sampling of coating material

Take a representative sample of the product to be tested (or of each product in the case of a multi-coat system), as described in ISO 15528.

Examine and prepare each sample for testing, as described in ISO 1513.

6.2 Preparation of test pieces

6.2.1 Preparation of non-self-supporting coatings on a porous substrate

The substrate shall be clean and dry.

Apply the coating material to be tested to the substrate in accordance with the manufacturer's application instructions. Do not apply less than the amount indicated by the manufacturer and not more than 50 % more, e.g. by applying a larger number of coats or by applying the first coat as a primer coat after dilution. It is essential that the coating be complete, continuous, homogeneous and free from visible imperfections. If the amount necessary to produce such a coating is more than 50 % greater than the amount indicated by the manufacturer, use another substrate or another test method.

Dry the test pieces for 7 days in freely circulating air at (23 ± 2) °C and (50 ± 5) % relative humidity.

6.2.2 Preparation of self-supporting coatings

Use a substrate from which the coating can be easily detached when dry/hard. The most suitable substrates are glass plates coated with high-density polyethylene or polytetrafluoroethylene which is free from surface defects. Other techniques may be used, for example precoating a substrate with a soluble material such as poly(vinyl alcohol) which will permit the coating to be removed easily by soaking in water. This method should be used with caution, however, since water-soluble material can affect the water-vapour permeability of the coating.

Coat the substrate by the method specified by the manufacturer and dry it for 7 days in freely circulating air at (23 ± 2) °C and (50 ± 5) % relative humidity (if stoving is required, care shall be taken to ensure that the substrate chosen is not affected at the relevant temperature).

Remove the coating carefully from the substrate.

Use a cutting template (see Figure B.1) to cut out specimens of a size suitable for the cup. Examine the test pieces visually and discard any which appear to have pinholes.

6.2.3 Conditioning

Method A

For coatings which, in use, will not be exposed to rain, e.g. coatings for interior use or for arid places, condition the test pieces at (23 ± 2) °C and (50 ± 5) % relative humidity for 28 days or until the difference in mass between two consecutive weighings, carried out at 24 h intervals, is less than 1 %.

Method B

Since, in use, the volatile and/or water-soluble constituents of a coating can be removed by the influence of the weather (in particular, water-soluble constituents can be leached out by rainwater), coatings which are affected by rain shall be conditioned prior to the determination of the water-vapour transmission rate by subjecting the test pieces to 3 cycles under the following conditions:

— 24 h in water (tap water) at (23 ± 2) °C;

— 24 h drying at (50 ± 2) °C.

During the weekend or any interruption of the conditioning for other reasons, store the test pieces at (23 ± 2) °C and (50 ± 5) % relative humidity.

After the last cycle, continue to dry the test pieces at (50 ± 2) °C for at least another 24 h. Then condition the test pieces at (23 ± 2) °C and (50 ± 5) % relative humidity for at least 24 h before carrying out the test.

6.3 Determination of the thickness of the coating

6.3.1 General

The thickness, d, of the coating is required for the calculation of the water-vapour resistance factor, μ. It may be determined by calculation or by optical, mechanical or other suitable methods.

NOTE Optical determination of the thickness of the coating can also be used to check the test piece for pores, holes, etc., and to determine the depth of penetration of the coating material into the substrate.

6.3.2 Determination of the thickness of the coating by calculation

Calculate the dry-film thickness, d, in micrometres, from the application rate (the amount of coating material applied), using the following equation:

$$d = \frac{C \times \mathrm{NV_V}}{100} \tag{1}$$

where

C is the application rate, in millilitres per square metre;

$\mathrm{NV_V}$ is the non-volatile-matter content, expressed as a percentage by volume, determined in accordance with ISO 3233.

6.3.3 Determination of the thickness of the coating by optical, mechanical or other suitable methods

Determine the mean thickness of the coating by a suitable method selected from those specified in ISO 2808.

6.4 Preparation of the test assemblies

Clean and dry the cups, together with any ancillary fittings.

Into each cup introduce a quantity of saturated ammonium dihydrogen phosphate solution (5.3) and additional ammonium dihydrogen phosphate crystals (for the wet-cup method) or desiccant (5.4) (for the dry-cup method) such that there will be an air gap of at least 10 mm below the test piece. An air gap larger than 10 mm, but not larger than 30 mm, is better if ammonium dihydrogen phosphate solution is used, to make handling of the test assembly during weighing easier.

Seal each test piece to a cup with a vapour-tight seal.

If a non-self-supporting coating is being tested, the coated side of the test piece shall face the atmosphere in the test enclosure (50 % relative humidity). It is important that the air gap remain the same throughout the test (see 8.2.1).

NOTE If the test assemblies are removed from the enclosure for weighing, it might be helpful to cover each assembly with a lid marked to indicate the identification of the test assembly.

7 Procedure

Carry out the determination using at least three test pieces.

Weigh the test assemblies on the balance (5.7) and place them in the test enclosure maintained at the conditions of the test. Ensure, in particular, that the speed of the air flow over the outer surface of the test pieces is between 0,02 m/s and 0,3 m/s as this has a significant influence on the rate of flow of water vapour through the test piece (see 5.6).

Determine the loss in mass at appropriate time intervals. The interval between successive weighings should preferably be 24 h, 48 h or 96 h, but shorter time intervals (for example 3 h, 4 h or 8 h) might be necessary for coatings with a high transmission rate. Use a time interval which will give a change in mass between two successive weighings which is at least 5 mg if a balance with an accuracy of 1 mg is used or at least 50 mg if a balance with an accuracy of 10 mg is used. If the first two weighings show a change in mass which is too large or too small, adjust the time interval for subsequent weighings.

Carry out the weighings in a way which will avoid, to the greatest possible extent, any interference in the transmission of the water vapour by the test piece.

Continue the weighings until the change in mass per unit time becomes constant.

It is essential that wetting of the test pieces by the ammonium dihydrogen phosphate solution is avoided. If wetting takes place, repeat the test.

8 Expression of results

8.1 Water-vapour transmission rate, V, of self-supporting coatings

8.1.1 Rate of flow of water vapour, G, through the test piece

For each test assembly, plot the change in mass, in grams, against time, in hours. The test is considered to be complete when three or more points lie in a straight line.

In the linear part of the plot, determine the best-fit straight line through at least three measurement points. The slope of this straight line is the rate of flow of water vapour, G, in grams per hour, through the test piece.

8.1.2 Water-vapour transmission rate, V, of the coating

The water-vapour transmission rate, V, in grams per square metre per day, of the coating, at standard atmospheric pressure, p_0 (i.e. the pressure at mean sea level), is given by Equation (2):

$$V = 24 \times \frac{p}{p_0} \times \frac{G}{A} \tag{2}$$

where

G is the rate of flow of water vapour, in grams per hour, through the test piece;

A is the area, in square metres, of the test piece through which the water vapour flows;

the factor $\frac{p}{p_0}$ corrects the water-vapour transmission rate, V, to standard atmospheric pressure;

the factor 24 converts G from grams per hour to grams per day.

The atmospheric pressure, p, in pascals, at the place of measurement during the test can be calculated with sufficient accuracy from the equation:

$$p = p_0 - \frac{h}{8,5} \tag{3}$$

where

h is the height above sea level, in metres, of the test laboratory;

p_0 is the standard atmospheric pressure, in pascals ($p_0 = 101\,325$ Pa).

NOTE In the calculation of the water-vapour transmission rate, V, in Equation (2), the air gap below the coating is not taken into account because its influence on the water-vapour transmission rate of self-supporting coatings is negligible.

Take as the result the mean value of at least three individual determinations, but include in the calculation of the mean every individual value of V above 680 g/(m^2·d). If all the individual values of V are above 680 g/(m^2·d), the mean value shall be reported as "$V > 680$ g/(m^2·d)" (see Clause 1).

8.2 Water-vapour transmission rate, V, of non-self-supporting coatings

8.2.1 General

When calculating the water-vapour transmission rate of a non-self-supporting coating, the water-vapour transmission rate of the substrate has to be taken into account. The air gap between the ammonium dihydrogen phosphate solution or the desiccant and the test piece will not need to be taken into account since the water-vapour transmission rate of the coating is obtained by subtracting that for the substrate plus coating from that for the substrate alone, so the influence of the air gap therefore disappears provided the air gap remains the same throughout the test.

8.2.2 Rate of flow of water vapour through the substrate, G_S, and through the substrate plus coating, G_CS

For each test assembly, plot the change in mass, in grams, against time, in hours. The test is considered to be complete when three or more points lie in a straight line.

In the linear part of the plot, determine the best-fit straight line through at least three measurement points. The slope of this straight line is the rate of flow of water vapour, in grams per hour, through the substrate plus coating, G_CS.

If separate measurements were made on the substrate alone, calculate, in the same way, the rate of flow of water vapour, in grams per hour, through the substrate, G_S.

If the substrate used is sufficiently similar to substrates previously used under the same conditions, a representative mean value may be used as the value of G_S. If this is not the case, the value of G_S will have to be measured prior to the determination.

8.2.3 Water-vapour transmission rate, V_S, of the substrate

The water-vapour transmission rate, V_S, in grams per square metre per day, of the substrate is given by Equation (4):

$$V_\mathrm{S} = 24 \times \frac{p}{p_0} \times \frac{G_\mathrm{S}}{A_\mathrm{S}} \quad (4)$$

where

G_S is the rate of flow of water vapour, in grams per hour, through the substrate;

A_S is the area, in square metres, of the test piece through which the water vapour flows;

the factor $\frac{p}{p_0}$ corrects the water-vapour transmission rate, V_S, to standard atmospheric pressure;

the factor 24 converts G_S from grams per hour to grams per day.

8.2.4 Water-vapour transmission rate, V_CS, of the substrate plus coating

The water-vapour transmission rate, V_CS, in grams per square metre per day, of the substrate plus coating is given by Equation (5):

$$V_\mathrm{CS} = 24 \times \frac{p}{p_0} \times \frac{G_\mathrm{CS}}{A_\mathrm{CS}} \quad (5)$$

where

G_CS is the rate of flow of water vapour, in grams per hour, through the substrate plus coating;

A_CS is the area, in square metres, of the substrate plus coating through which the water vapour flows;

the factor $\frac{p}{p_0}$ corrects the water-vapour transmission rate, V_CS, to standard atmospheric pressure;

the factor 24 converts G_CS from grams per hour to grams per day.

8.2.5 Water-vapour transmission rate, V, of the coating

The water-vapour transmission rate, V, of the coating is calculated, in grams per square metre per day, from the difference between the water-vapour transmission rate of the substrate, V_s, and that of the substrate plus coating, V_cs, as shown in Equation (7), which is derived from Equation (6):

$$\frac{1}{V} = \frac{1}{V_\mathrm{cs}} - \frac{1}{V_\mathrm{s}} \tag{6}$$

$$V = \frac{V_\mathrm{cs} \times V_\mathrm{s}}{V_\mathrm{s} - V_\mathrm{cs}} \tag{7}$$

Take as the result the mean value of at least three individual determinations, but include in the calculation every individual value of V above 680 g/(m^2·d). If all the individual values of V are above 680 g/(m^2·d), the mean value shall be reported as "$V > 680$ g/(m^2·d)" (see Clause 1).

8.3 Water-vapour diffusion-equivalent air layer thickness, s_d

If required, the water-vapour diffusion-equivalent air layer thickness, s_d, in metres, is also calculated. This is given by Equation (8) (for the derivation of this equation, see Annex A):

$$s_\mathrm{d} = \frac{\delta_\mathrm{a} \times \Delta p_\mathrm{V}}{V} \tag{8}$$

where

δ_a is the water-vapour permeation coefficient of air at standard temperature and pressure, in grams per metre per day per pascal [at 23 °C (= 296 K) and standard pressure (= 101 325 Pa), the value of δ_a is 0,016 9 g/(m·d·Pa)];

Δp_V is the difference between the partial water-vapour pressure in the test cup and that in the test enclosure (i.e. between the two sides of the coating), in pascals.

For the wet-cup method, for which $\Delta p_\mathrm{V} = 1\,207$ Pa, the diffusion-equivalent air layer thickness is calculated using Equation (9):

$$s_\mathrm{d} = \frac{20{,}4}{V} \tag{9}$$

For the dry-cup method, for which $\Delta p_\mathrm{V} = 1\,400$ Pa, the diffusion-equivalent air layer thickness is calculated using Equation (10):

$$s_\mathrm{d} = \frac{23{,}7}{V} \tag{10}$$

8.4 Water-vapour resistance factor, μ

If required, the water-vapour resistance factor, μ, may be calculated using Equation (11):

$$\mu = \frac{s_\mathrm{d}}{d} \times 10^6 \tag{11}$$

where d is the dry-film thickness, in micrometres (see 6.3).

In the case of textured products like rendering, the particle size of the material may be taken instead of the measured or calculated film thickness.

When calculating values of s_d for different dry-film thicknesses of a particular material, using the equation $s_d = \mu \times d \times 10^{-6}$, μ shall not be treated as a constant for that material. As can be seen from Equation (8), μ depends on Δp_V and therefore changes with ambient temperature and relative humidity.

9 Precision

9.1 Repeatability, (r)

The repeatability is the value below which the absolute difference between two test results (each the mean of three valid determinations) may be expected to lie when using the standardized test method under repeatability conditions, i.e. when the test results are obtained on identical material by one operator in one laboratory within a short interval of time using the standardized test method.

For the method specified in this International Standard, (r) is 40 % (relative to the mean of two test results), with a 95 % probability.

9.2 Reproducibility, (R)

The reproducibility is the value below which the absolute difference between two test results (each the mean of three valid determinations) may be expected to lie when using the standardized test method under repeatability conditions, i.e. when the test results are obtained on identical material by different operators in different laboratories using the standardized test method.

For the method specified in this International Standard, (R) is 100 % (relative to the mean of two test results), with a 95 % probability.

10 Test report

The test report shall contain at least the following information:

a) all information necessary for identification of the product tested;

b) a reference to this International Standard, together with its year of issue (i.e. ISO 7783:2011);

c) the number of test pieces tested;

d) the method of application of the coating, the application rate (amount of coating material applied), the number of coats and details of any dilution carried out;

e) the dry-film thickness, in micrometres, of the coating or coating system tested;

f) (for non-self-supporting coatings) the type of substrate (including the primer, if used) and its average thickness, in millimetres;

g) whether the dry-cup or the wet-cup method was used;

h) details of the test assembly used, including the method of preparation and sealing used and the size of the waxing template (B.2.2), if used;

i) the duration and conditions of drying (or stoving), ageing (if applicable) and conditioning (method A or method B — see 6.2.3) of the test pieces before testing;

j) the temperature and relative humidity in the test enclosure;

k) the results of the test, including the arithmetic mean of a valid set of values of the water-vapour transmission rate, V, and, if required, the value of the water-vapour diffusion-equivalent air layer thickness, s_d, for the thickness determined;

l) (if needed for calculations relating to construction applications) the value of the water-vapour resistance factor, μ, together with the associated film thickness, reported as a pair of values;

m) any particular observations;

n) details of any deviations from the test method specified;

o) the name of the test laboratory in which the test was carried out and the name of the person who actually carried out the test;

p) the date of the test.

Annex A
(informative)

Derivation of Equation (8) in Subclause 8.3 for the calculation of the water-vapour diffusion-equivalent air layer thickness, s_d

The calculation of the water-vapour diffusion-equivalent air layer thickness, s_d, from the measured water-vapour transmission rate, V [Equation (8) in Subclause 8.3], is based on the following equations and definitions:

$$\delta_a \times d_a = \delta_c \times s_d \tag{A.1}$$

s_d can therefore be expressed as follows:

$$s_d = \frac{\delta_a}{\delta_c} \times d_a \tag{A.2}$$

where

δ_a is the water-vapour permeation coefficient of air, in grams per metre per day per pascal;

d_a is the thickness of the air layer (in this case 1 m);

δ_c is the water-vapour permeation coefficient of the coating, in grams per metre per day per pascal;

s_d is the water-vapour diffusion-equivalent air layer thickness of the coating, in metres.

The water-vapour permeation coefficient of air, δ_a, is a function of the diffusion coefficient of water vapour in air, D, the gas constant for water vapour, R_V, and the temperature, T, as given by Equation (A.3):

$$\delta_a = \frac{D}{R_V \times T} \tag{A.3}$$

where

R_V is the gas constant for water vapour, in newton metres per gram per Kelvin [$R_V = 0{,}462$ N·m/(g·K)];

T is the mean value of the temperature, in kelvins, during the test [for the wet-cup (i.e. the reference) method, $T = 296$ K (= 23 °C)];

D is the diffusion coefficient of water vapour in air, in square metres per day.

The diffusion coefficient of water vapour in air, D, is a function of the air temperature, T, during the test and can be calculated from Equation (A.4):

$$D = D_0 \times \left(\frac{T}{T_0}\right)^{1{,}81} \tag{A.4}$$

where

T_0 is the standard temperature, in kelvins (= 273 K);

D_0 is the diffusion coefficient of water vapour in air at standard temperature and pressure [at 273 K and standard pressure (= 101 325 Pa), the value of D_0 is 1,996 m^2/d].

The value of δ_a at $T = 296$ K and at standard pressure can be calculated from Equation (A.5):

$$\delta_a = \frac{D_0}{R_V \times T} \times \left(\frac{T}{T_0}\right)^{1,81} \tag{A.5}$$

Substituting 1,996 m^2/d for D_0,

0,462 N·m/(g·K) for R_V,

296 K for T and

1,158 for $\left(\frac{T}{T_0}\right)^{1,81}$

gives

$$\delta_a = \frac{1,996}{0,462 \times 296} \times 1,158 = 0,0169 \text{ g/(m·d·Pa)}$$

The water-vapour permeation coefficient of the coating, δ_c, is a function of the water-vapour transmission rate, V, and the water-vapour partial-pressure difference, Δp_V, as given by Equation (A.6):

$$\delta_c = \frac{V}{\Delta p_V} \times d_a \tag{A.6}$$

where

V is the water-vapour transmission rate of the coating, in grams per square metre per day;

Δp_V is the water-vapour partial-pressure difference between the two sides of the coating, in pascals;

d_a is the thickness of the air layer (in this case 1 m).

Combining Equation (A.6) with Equation (A.2) gives

$$s_d = \frac{\delta_a \times \Delta p_V}{V} \tag{A.7}$$

Substituting 0,016 9 g/(m·d·Pa) for δ_a at $T = 296$ K in Equation (A.7) gives

$$s_d = \frac{0,0169 \times \Delta p_V}{V} \tag{A.8}$$

For the dry-cup method, taking Δp_V as 1 400 Pa allows Equation (A.8) to be simplified to $s_d = \frac{23,7}{V}$.

For the wet-cup method, taking Δp_V as 1 207 Pa allows Equation (A.8) to be simplified to $s_d = \frac{20,4}{V}$.

Annex B
(normative)

Use of molten wax for sealing the test assembly

B.1 General

If wax is used as the sealing material, it is essential that it adhere strongly to both the cup and the test piece. In addition, it is important that it be not brittle at the test temperature, not hygroscopic and not susceptible to oxidation. A surface of 50 cm^2 of freshly melted wax, when exposed for 24 h at 38 °C and 90 % relative humidity, shall not give a variation in mass of more than 1 mg. Wax mixtures that attack the test piece shall not be used.

Suitable wax compositions are:

a) 60 % (by mass) microcrystalline wax and 40 % (by mass) refined crystalline paraffin wax;

b) 80 % (by mass) paraffin wax with a melting point of 50 °C to 52 °C and 20 % (by mass) viscous-consistency polyisobutene (relatively low degree of polymerization);

c) mixture of waxes melting over the range 60 °C to 75 °C and with an oil content of 1,5 % (by mass) to 3 % (by mass).

If the wax contains traces of water, these can be eliminated by heating to 105 °C to 110 °C and stirring.

The oil content of the microcrystalline wax shall be below 3 % (by mass) and that of the refined paraffin wax below 1 % (by mass).

It is advisable to use new wax to seal each test piece. However, if wax is reused, then care shall be taken to remove foreign bodies and impurities before use.

If the molten wax is allowed to spread on to the test area, this will reduce the effective area of the test piece and lead to erroneous results.

NOTE The apparatus and procedures used are similar to those described in ISO 2528.

B.2 Apparatus

The general requirements specified in 5.2 apply. Figure B.1 shows examples of apparatus which has proved satisfactory in use.

B.2.1 Circular non-porous cups, with a groove round the rim for sealing the test piece with wax. The groove shall have a profile such that the test piece can be sealed over the opening of the cup and that no water vapour can escape at or through the edges of the test piece.

The exact surface area to be exposed is defined by the diameter, D, of the waxing template (see B.2.2). The internal diameter of the rim of the cup on which the test piece rests shall be equal to or very slightly greater than the diameter, D.

B.2.2 Waxing templates, to control the application of the wax and to allow the test surface to be defined exactly. Their diameter, D, is the diameter of the exposed area of the test piece.

These templates may be

a) cover templates (see Figure B.1) which shall be taken off when the hot wax has been run in and has cooled (they comprise discs with central handles, drilled with a small hole at a suitable point and having the edge