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Hygrothermal performance of building materials and products — Determination of water-vapour transmission properties — Box method

Performance hydrothermique des matériaux et produits pour le bâtiment — Détermination des propriétés de transmission de la vapeur d'eau — Méthode de box

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ISO 21129:2007(E)

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Foreword

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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 21129 was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 1, *Test and measurement methods*.

Introduction

The general principles are applicable to all hygroscopic and non hygroscopic building materials and products.

It is required to search for hygrothermal performance and thermal performance of building materials in order to solve the condensation phenomenon of building walls and to establish the condensation-preventive measures.

In the box method, a specimen is fixed to a measurement box. The mass of saturated salt solutions contained in two pans hanging on the two side boxes of a specimen is measured. The amount of water vapour penetrating through a specimen is calculated from change of the mass of the saturated salt solutions in the two pans.

In a cup method, the mass of the saturated salt solution is measured together with that of the specimen; however, in the box method, it is not necessary to measure the mass of the specimen.

The reason that the box method is more accurate than the cup method is that there are thick materials and/or heavy materials in building materials or products.

If the principle of the box method is applied, it is possible to measure the water-vapour transmission properties of not only materials but also some building products with good accuracy.

INTERNATIONAL STANDARD **ISO 21129:2007(E)**

Hygrothermal performance of building materials and products — Determination of water-vapour transmission properties — Box method

1 Scope

This International Standard specifies a box method for determining the water-vapour permeability of building materials. The box method is used primarily to measure the water-vapour permeance of materials that have low water-vapour resistance, in which the influence of the surface-humidity transmission-resistance cannot be ignored.

NOTE Materials with low water-vapour resistance includes those with no greater than $1,8 \times 10^9 \cdot \text{m}^2 \cdot \text{s} \cdot \text{Pa/kg}$ of resistance [water vapour permeability coefficient of $5,5 \times 10^{-8}$kg/($\text{m}^2 \cdot \text{s} \cdot$ Pa or above)].

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 9346, *Hygrothermal performance of buildings and building materials — Mass transfer — Physical quantities and definitions*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the definitions given in ISO 9346 and the following apply.

3.1.1
density of water vapour flow rate
mass of water vapour transferred through per unit area per unit time under specified conditions of temperature, humidity and thickness

3.1.2
water vapour permeance
density of water vapour flow rate divided by the water vapour pressure difference between the two surfaces of the specimen

3.1.3
water vapour conductivity
water vapour permeance per unit thickness

3.1.4
water vapour resistance
reciprocal of water vapour permeance

3.1.5
water vapour permeability
product of the water vapour permeance and the thickness of a homogeneous specimen

3.2 Symbols and units

Symbol	Quantity	Unit
W_p	Water-vapour permeance of specimen	kg/(m^2·s·Pa)
Z_p	Water-vapour resistance of specimen	m^2·s·Pa/kg
G	Water-vapour flow rate through specimen	kg/h
A	Area of specimen	m^2
P	Water-vapour pressure in box or room	Pa
φ	Relative humidity	
$1/\beta$	Water-vapour surfaces resistance	m^2·s·Pa/kg
β	Surface coefficient of water-vapour transfer	kg/(m^2·s·Pa)
δ_p	Water-vapour permeability of specimen	kg/(m·s·Pa)
d	Thickness of specimen	m
Subscripts: High — High water vapour pressure side. Low — Low water vapour pressure side.		

See References [1] to [5] for further details.

4 Principle

Install a box (called the water-vapour-permeability test box) for measuring the amount of permeated water vapour in a room maintained at a constant temperature and humidity. To create a difference in water vapour pressure, i.e., a difference in humidity, between the two sides of the specimen, attach the test box to one face (opening) and then place a high- or low-density aqueous salt solution into the box and maintain the box at a constant humidity. During this time, water vapour flows from the box to the room or from the room to the box by permeating the specimen. The amount of vapour flow can be determined by measuring the change in mass of the dish containing the aqueous salt solution by taking measurements at constant intervals using a scale (electronic balance); see Figure 1. In this way, the total water-vapour resistance, including the surface-transmission-resistance of the material, can be calculated by measuring the vapour-pressure difference on both sides of the specimen at a steady state and a constant water-vapour permeance. The water-vapour resistance of the material can be calculated by subtracting the surface-humidity transmission-resistance on both sides of the specimen, obtained according to Annex B, from the total water vapour resistance.

5 Apparatus

NOTE See Figure 1.

5.1 Room, in which the temperature can be freely set within a range of 10 °C to 30 °C to an accuracy of at least ± 0,5 °C and the relative humidity of the room can be freely set within a range of (30 ± 3) % to (90 ± 3) %.

5.2 Water-vapour permeability test box, having the standard dimensions of 600 mm × 600 mm × 600 mm.

The measuring box should be made of material such as metal, glass or hard plastic that is impermeable to water vapour and, under the measurement criteria, it should be resistant to corrosion (anti-moisture material). The box joint shall be properly sealed to prevent water-vapour leakage. The box shall be constructed to provide sufficient strength for usage. The part connected to the sample installation frame at the opening (flange) shall be made of anti-moisture rubber packing or other material to enable air tightness.

5.3 Mixing fan, capable of blowing air along the surface of the specimen as uniformly as possible.

Average velocity of the air movement at a distance of 50 mm from the surface shall be adjusted to be 0,5 m/s.

5.4 Saturated-aqueous-salt solution dish, having an area at least equal to the area of the specimen.

The dish shall be resistant to corrosion from the salt solution and be of a construction to enable mass measurement by a balance.

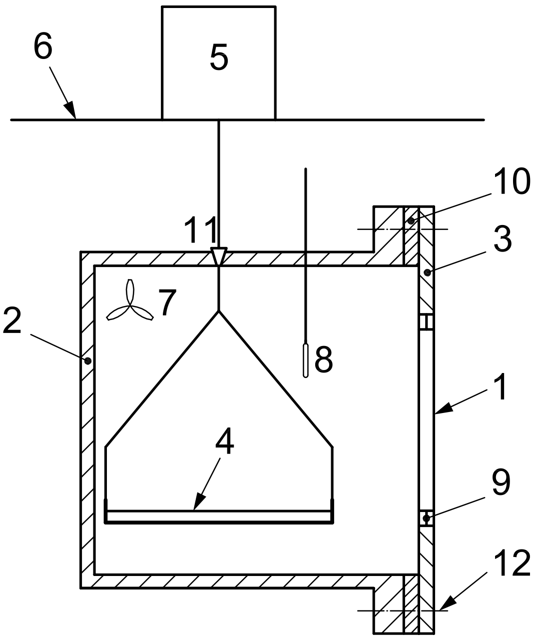
5.5 Balance, capable of weighing the pan with a precision of ± 10 mg.

5.6 Specimen installation frame, made of non-distorting, anti-moisture material.

It shall be constructed with an opening in the centre where the specimen can be placed, and enable secure air-tight attachment of the frame to the flange of the water-vapour test box. The opening dimensions shall be 300 mm × 300 mm. It shall have a flange-type shape to keep in thick specimens and have gaps to enable the sealing of small surface holes in the specimen.

5.7 Thermometers, two, capable of measuring the air temperature on both sides of the specimen to an accuracy of ± 0,1 °C.

5.8 Hygrometers, two, capable of measuring the relative humidity of both sides of the specimen to an accuracy of ± 2 %.



Key

1	specimen	7	mixing fan
2	measuring box	8	thermometer and hygrometer
3	frame for specimen	9	sealant
4	suspended weighing pan	10	rubber gasket
5	balance	11	rubber plug
6	room at constant temperature and humidity	12	clamp

Figure 1 — Test apparatus

6 Test specimen

6.1 Size and thickness of specimen

The standard size of the test specimen shall be 300 mm × 300 mm. The thickness shall be the thickness of the product. If the thickness of homogenous material exceeds 100 mm, it may be thinly sliced.

6.2 Preconditioning of test specimen

Before testing, the test specimen shall be stored at (23 ± 5) °C, (50 ± 10) % relative humidity for a period long enough to stabilize its mass.

Here, constant mass refers to a change in weight over three consecutive days of no greater than 5 %.

7 Procedure

7.1 Set-up of saturated aqueous salt solution dish — Saturated aqueous salt solution preparation and humidity difference setting

Select an aqueous saturated salt solution from Table 1 and set the humidity in a temperature-controlled room so that the humidity difference is 20 % to 40 %.

Dissolve the salt crystals in distilled water and pour the salt solution into the pan to a depth of 10 mm to 20 mm.

Further details of suitable salts can be found in ISO 12571:2000, Annexes A and B.

It is necessary to assure that enough crystal remain in the solution until measurement is finished.

Table 1 — Aqueous solution

Aqueous solution	Relative humidity %
KNO_3	94
NaCl	75
$Mg(NO_3)_2$	53
$MgCl_2$	33
LiCl	11
NOTE Temperature is 23 °C.	

7.2 Installation of specimen

Mask the edge of the specimen with aluminium foil using epoxy resin adhesive. Attach the specimen to the specimen installation frame and seal the joint part. At this time, sealant shall not run onto the surface of the specimen because it is necessary that the specimen area be equal to the permeance area. The installation frame shall be airtight using rubber packing and a clamp at the opening of the measuring box.

7.3 Calibration of the measuring box

The amount of water-vapour leakage from the measuring box is calibrated beforehand as a characteristic of the measurement device. Calibration shall be made at every temperature and humidity according to the procedure of 7.4 by installing a metal plate in the frame. The leakage of water vapour is the mass change of a pan per hour.

7.4 Measuring the permeated water vapour amount

Measure the mass of the aqueous solution dish at appropriate time intervals. The time interval shall be determined so that a change in the mass of the specimen due to water-vapour permeance is within a range of 0,02 g to 2 g. Continue the measurements at the appropriate intervals, for at least five points in succession, until the change in mass (increase or decrease) at five consecutive points is constant to within ± 5 %. The amount of permeated water-vapour is calculated by adjusting the amount of water-vapour leaking from the test box in which the mass increase (or decrease) in permeated water-vapour amount per hour was corrected by the calibration as described in 7.3.

The amount of change in permeated water vapour can be the linear slope of the change in mass of at least five points calculated by the least square method.

7.5 Measuring of temperature and humidity

The temperature and relative humidity within the box or the conditioned room shall be recorded continuously during weighing of the mass. Water-vapour pressures can be derived from the air temperature and relative humidity; see Annex A.

7.6 Measurement of surface-humidity transmission-resistance

The surface-humidity transmission-resistance on both sides of the specimen shall be pre-determined as described in Annex B.

8 Calculation and expression of results

The water-vapour flow rate is determined by a least-squares method from the measurement of the mass change. Water-vapour permeance, W_p, water-vapour resistance, Z_p, and water-vapour permeability, δ_p, are calculated from Equations (1) to (3), respectively:

$$Z_\mathrm{p} = \frac{\left(P_\mathrm{high} - P_\mathrm{low}\right) \times A}{G} - 1/\beta \tag{1}$$

where $1/\beta$, *the* water-vapour surface resistance, is calculated as given in Annex B.

$$W_\mathrm{p} = \frac{1}{Z_\mathrm{p}} \tag{2}$$

$$\delta_\mathrm{p} = W_\mathrm{p} \times d \tag{3}$$

9 Measurement accuracy

Some of the factors that affect the accuracy of the measurement results are given in 9.1 to 9.4, so each can be examined where necessary to improve accuracy.

9.1 Specimen area

The dimensions of the test specimen are measured to an accuracy of ± 0,5 mm, so the likely error in specimen area of standard size is ± 0,3 %.

9.2 Specimen thickness

If permeated water-vapour resistance is measured, the thickness of the specimen does not affect the measurement accuracy, but if the water-vapour permeance of a uniform material is measured, the results of the measurement of specimen thickness directly affects the measurement accuracy. The thickness of a rigid specimen can be measured to within an accuracy of 0,5 % or better using a micrometer.

9.3 Seal

Errors can occur if the finish on the seal that holds the specimen in the fixing frame causes leakage of water vapour from that part. If this area is properly sealed, the errors from leaking have little effect on the measurement results for material with a high water-vapour permeance.

9.4 Humidity control

Water vapour permeates due to a difference in air humidity between the two sides of the specimen, so the precision with which the humidity difference is set affects the measurement results. The relative humidity of the saturated aqueous salt solution is considered to be accurate to ± 0,5 % of the value of the humidity given in Table 1 if care is taken in the preparation; see ISO 12572:2001, 9.6. The humidity of the constant-temperature and constant-humidity room is measured with a hygrometer that is accurate to at least ± 2 %, so the error in the setting of the humidity difference when the humidity difference between each side of the specimen is 20 % to 40 % is about ± 6 % to 12 % of the value of the relative humidity.

10 Test report

The test report shall contain the following:

a) product identification: product name, type, size, thickness, density, etc.;

b) test procedure:

    1) number of this International Standard,

    2) mean temperature and relative humidity in the room or boxes,

    3) date of the test,

    4) information concerning the apparatus, etc.;

c) results:

    1) water-vapour transmission properties (resistance, permeance, permeability),

    2) individual test results;

d) laboratory and person responsible for testing.

Annex A
(normative)

Conversion of water-vapour pressure

Water-vapour pressure, P, expressed in pascal, in air on both sides of the specimen, can be calculated as given by Equation (A.1), after measuring the temperature and relative humidity. The saturated water-vapour pressure in air is given in Table A.1 as a function of temperature.

NOTE The saturated water vapour pressure, P_{sat}, is a variable that is a function of temperature. In ISO 12572, $P_{\text{sat}} = 610{,}5 \exp [17{,}269 \cdot \theta/(237{,}3 + \theta)]$, which results in values slightly different from those given in Table A.1.

$$P = \varphi \cdot P_{\text{sat}} \tag{A.1}$$

where

P_{sat} is saturated water vapour pressure, expressed in pascal;

φ is the relative humidity, expressed as a fraction.

Table A.1 — Saturated water vapour pressure as a function of temperature and relative humidity[2]

Units in pascal

Temperature °C	Relative humidity									
	0,0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9
10	1 228,1	1 236,4	1 244,7	1 253,0	1 261,4	1 269,9	1 278,4	1 286,9	1 295,5	1 304,2
11	1 312,9	1 321,7	1 330,5	1 339,3	1 348,2	1 357,2	1 366,2	1 375,3	1 384,4	1 393,5
12	1 402,8	1 412,1	1 421,4	1 430,8	1 440,2	1 449,7	1 459,3	1 468,9	1 478,5	1 488,2
13	1 498,0	1 507,8	1 517,7	1 527,7	1 537,7	1 547,7	1 557,9	1 568,0	1 578,3	1 588,6
14	1 598,9	1 609,3	1 619,8	1 630,3	1 640,9	1 651,6	1 662,3	1 673,0	1 683,9	1 694,8
15	1 705,7	1 716,7	1 727,8	1 739,0	1 750,2	1 761,4	1 772,8	1 784,2	1 795,6	1 807,1
16	1 818,7	1 830,4	1 842,1	1 853,9	1 865,8	1 877,7	1 889,7	1 901,7	1 913,8	1 926,0
17	1 938,3	1 950,6	1 963,0	1 975,5	1 988,0	2 000,6	2 013,3	2 026,0	2 038,8	2 051,7
18	2 064,7	2 077,7	2 090,8	2 104,0	2 117,2	2 130,5	2 143,9	2 157,4	2 170,9	2 184,5
19	2 198,2	2 212,0	2 225,8	2 239,7	2 253,7	2 267,8	2 281,9	2 296,1	2 310,4	2 324,8
20	2 339,2	2 353,8	2 368,4	2 383,1	2 397,8	2 412,7	2 427,6	2 442,6	2 457,7	2 472,9
21	2 488,2	2 503,5	2 518,9	2 534,4	2 550,0	2 565,7	2 581,4	2 597,3	2 613,2	2 629,2
22	2 645,3	2 661,5	2 677,7	2 694,1	2 710,5	2 727,1	2 743,7	2 760,4	2 777,2	2 794,1
23	2 811,0	2 828,1	2 845,2	2 862,5	2 879,8	2 897,2	2 914,8	2 932,4	2 950,1	2 967,9
24	2 985,8	3 003,7	3 021,8	3 040,0	3 058,3	3 076,6	3 095,1	3 113,6	3 132,3	3 151,1
25	3 169,9	3 188,9	3 207,9	3 227,0	3 246,3	3 265,6	3 285,1	3 304,6	3 324,3	3 344,0
26	3 363,9	3 383,8	3 403,9	3 424,0	3 444,3	3 464,7	3 485,2	3 505,7	3 526,4	3 547,2
27	3 568,1	3 589,1	3 610,2	3 631,5	3 652,8	3 674,2	3 695,8	3 717,4	3 739,2	3 761,1
28	3 783,1	3 805,2	3 827,4	3 849,7	3 872,2	3 894,7	3 917,4	3 940,2	3 963,1	3 986,1
29	4 009,2	4 032,5	4 055,8	4 079,3	4 102,9	4 126,6	4 150,5	4 174,4	4 198,5	4 222,7
30	4 247,0	4 271,5	4 296,0	4 320,7	4 345,5	4 370,5	4 395,5	4 420,7	4 446,0	4 471,5

Annex B
(normative)

Method for calculating the water vapour surface resistance

The water-vapour surfaces resistance, $1/\beta$, discussed in Clause 8, can be calculated by the following method. First, in compliance with the procedures in Clause 7, one specimen is used to determine water-vapour resistance, Z_1, and then a second specimen, consisting of two overlaid sheets each equal in thickness to the specimen, is used to determine water vapour resistance, Z_2, in the same manner.

The water vapour resistances, Z_1 and Z_2, are calculated using Equations (B.1) and (B.2):

$$Z_1 = \frac{\left(P_{\text{high}} - P_{\text{low}}\right)}{G_1} \times A \qquad \text{(B.1)}$$

$$Z_2 = \frac{\left(P_{\text{high}} - P_{\text{low}}\right)}{G_2} \times A \qquad \text{(B.2)}$$

where the subscript numbers 1 and 2 represent the respective determined results of one sheet and two sheets, respectively, of the specimen.

While, Z_1 and Z_2 are expressed by Equations (B.3) and (B.4):

$$Z_1 = Z_{\text{p}} + 1/\beta \qquad \text{(B.3)}$$

$$Z_2 = 2Z_{\text{p}} + 1/\beta \qquad \text{(B.4)}$$

Wherefore, water-vapour surface resistance, $1/\beta$, can be calculated from Equation (B.5), which is derived from Equations (B.3) and (B.4).

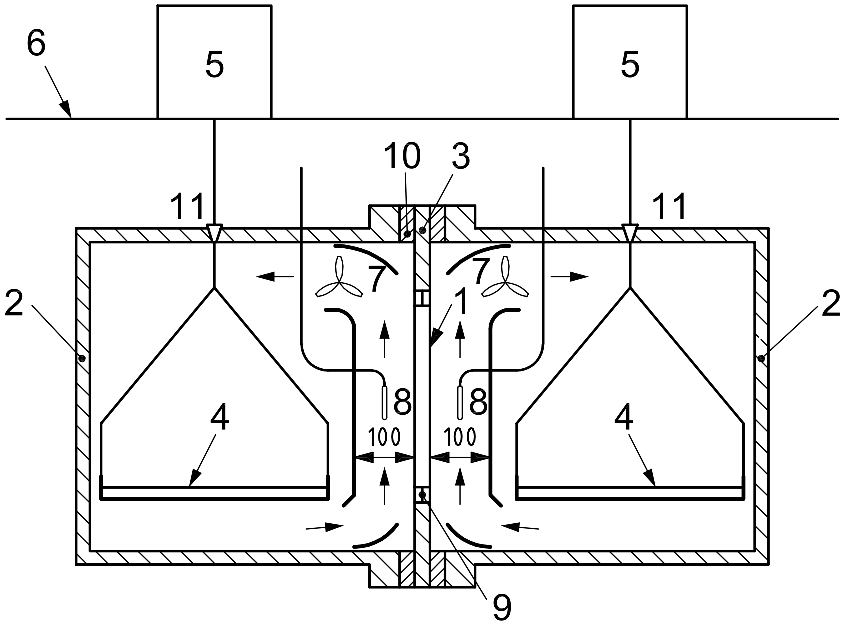
$$1/\beta = 2Z_1 - Z_2 \qquad \text{(B.5)}$$

Annex C
(informative)

Double-box method

In this test method, two measuring boxes are placed in a room controlled at a constant temperature. A test specimen is placed between the two measuring boxes; see Figure C.1. Because each box contains an aqueous saturated salt solution at a different concentration, water-vapour flow occurs through the specimen, the flow rate of water vapour can be measured and the water-vapour permeance determined by the same procedure as in Clause 7.

Dimensions in millimetres



Key

1	specimen
2	measuring box
3	frame for specimen
4	suspended weighing pan
5	balance
6	room at constant temperature
7	mixing fan
8	thermometer and hygrometer
9	sealant
10	rubber gasket
11	rubber plug

Figure C.1 — Test apparatus of double box method

To set up the suspended weighing pan, select the desired test environment from the sets of conditions given in Table C.1 or C.2.

The relative humidity in the measuring box shall be set by using the saturated aqueous salt solution given in the set of test conditions in Table C.1 or C.2. The ambient relative humidity shall be controlled by the air-conditioner, maintaining the room temperature at a constant 23 °C.

Prepare the saturated aqueous salt solution by dissolving the salt crystals in distilled water and pour the salt solution into the pan to a depth of 10 mm to 20 mm.

NOTE 1 Further details of suitable salts can be found in ISO 12571:2000, Annexes A and B.

NOTE 2 It is important that sufficient crystal remain in the solution until measurement is finished.

Table C.1 — Type A test conditions

Set	Conditions		High relative humidity			Low relative humidity		
	Temp. °C	**RH** %	**Aqueous solution**	**Temp.** °C	**RH** %	**Aqueous solution**	**Temp.** °C	**RH** %
A	23 to 94	75	KNO_3	23	94	NaCl	23	75
B	23 to 75	53	NaCl	23	75	$Mg(NO_3)_2$	23	53
C	23 to 53	33	$Mg(NO_3)_2$	23	53	$MgCl_2$	23	33
D	23 to 33	11	$MgCl_2$	23	33	LiCl	23	11

Table C.2 — Type B test conditions

Set	Conditions		High relative humidity			Low relative humidity		
	Temp. °C	**RH** %	**Aqueous solution**	**Temp.** °C	**RH** %	**Aqueous solution**	**Temp.** °C	**RH** %
A	23 to 94	55	KNO_3	23	94	$Mg(NO_3)_2$	23	53
B	23 to 75	33	NaCl	23	75	$MgCl_2$	23	33
C	23 to 53	11	$Mg(NO_3)_2$	23	53	LiCl	23	11

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