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Thermal insulating products for building applications — Conditioning to moisture equilibrium under specified temperature and humidity conditions

Produits isolants thermiques destinés aux applications du bâtiment — Conditionnement jusqu'à l'équilibre hygroscopique dans des conditions de température et d'humidité spécifiées

Reference number
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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 16544 was prepared by Technical Committee ISO/TC 163, *Thermal performance and energy use in the built environment*, Subcommittee SC 1, *Test and measurement methods*.

ISO 16544 includes the original EN 12429 prepared by Technical Committee CEN/TC 88 “Thermal insulating materials and products”, with the following clauses modified to reflect the conditions for tropical countries:

— Clause 6.5: Conditioning of test specimen in tropical countries;

— Clause 7.4: Test conditions in tropical countries;

— Clause 10: Test report.

Introduction

ISO 16544 is one of a series of existing European Standards on test methods which were adopted by ISO. This group of International Standards comprises the following group of interrelated standards:

ISO	Title	Respective EN standard
12344	Thermal insulating products for building applications — Determination of bending behaviour	EN 12089
12968	Thermal insulation products for building applications — Determination of the pull-off resistance of external thermal insulation composite systems (ETICS) (foam block test)	EN 13495
29465	Thermal insulating products for building applications — Determination of length and width	EN 822
29466	Thermal insulating products for building applications — Determination of thickness	EN 823
29467	Thermal insulating products for building applications — Determination of squareness	EN 824
29468	Thermal insulating products for building applications — Determination of flatness	EN 825
29469	Thermal insulating products for building applications — Determination of compression behaviour	EN 826
29470	Thermal insulating products for building applications — Determination of the apparent density	EN 1602
29471	Thermal insulating products for building applications — Determination of dimensional stability under constant normal laboratory conditions (23 degrees C/50 % relative humidity)	EN 1603
29472	Thermal insulating products for building applications — Determination of dimensional stability under specified temperature and humidity conditions	EN 1604
29764	Thermal insulating products for building applications — Determination of deformation under specified compressive load and temperature conditions	EN 1605
29765	Thermal insulating products for building applications — Determination of tensile strength perpendicular to faces	EN 1607
29766	Thermal insulating products for building applications — Determination of tensile strength parallel to faces	EN 1608
29767	Thermal insulating products for building applications — Determination of short-term water absorption by partial immersion	EN 1609
29768	Thermal insulating products for building applications — Determination of linear dimensions of test specimens	EN 12085
29769	Thermal insulating products for building applications — Determination of behaviour under point load	EN 12430
29770	Thermal insulating products for building applications — Determination of thickness for floating-floor insulating products	EN 12431

29771	Thermal insulating materials for building applications — Determination of organic content	EN 13820
29803	Thermal insulation products for building applications — Determination of the resistance to impact of external thermal insulation composite systems (ETICS)	EN 13497
29804	Thermal insulation products for building applications — Determination of the tensile bond strength of the adhesive and of the base coat to the thermal insulation material	EN 13494
29805	Thermal insulation products for building applications — Determination of the mechanical properties of glass fibre meshes	EN 13496
16534	Thermal insulating products for building applications — Determination of compressive creep	EN 1606
16535	Thermal insulating products for building applications — Determination of long-term water absorption by immersion	EN 12087
16536	Thermal insulating products for building applications — Determination of long-term water absorption by diffusion	EN 12088
16537	Thermal insulating products for building applications — Determination of shear behaviour	EN 12090
16546	Thermal insulating products for building applications —Determination of freeze-thaw resistance	EN 12091
16544	Thermal insulating products for building applications — Conditioning to moisture equilibrium under specified temperature and humidity conditions	EN 12429
16545	Thermal insulating products for building applications — Determination of behaviour under cyclic loading	EN 13793

A further group of existing European Standards on test methods for products used to insulate building equipment and industrial installations comprises the following group of interrelated International Standards:

ISO 12623	Thermal insulating products for building equipment and industrial installations — Determination of short-term water absorption by partial immersion of preformed pipe insulation	EN 13472
ISO 12624	Thermal insulating products for building equipment and industrial installations — Determination of trace quantities of water soluble chloride, fluoride, silicate, sodium ions and pH	EN 13468
ISO 12628	Thermal insulating products for building equipment and industrial installations — Determination of dimensions, squareness and linearity of preformed pipe insulation	EN 13467
ISO 12629	Thermal insulating products for building equipment and industrial installations — Determination of water vapour transmission properties of preformed pipe insulation	EN 13469

Thermal insulating products for building applications — Conditioning to moisture equilibrium under specified temperature and humidity conditions

1 Scope

This International Standard specifies equipment and procedures to condition a thermal insulating product to equilibrium moisture content at (23 ± 2) °C and (50 ± 5) % relative humidity.

It is also applicable to thermal insulating products with moulded skins but is not normally relevant for faced products or for products with other surface treatments.

NOTE 1 The normally specified moisture content is the result of the equilibrium between the atmosphere and the product at (23 ± 2) °C and (50 ± 5) % relative humidity. This International Standard can also be used if a product has to be conditioned to other relative humidities.

NOTE 2 The moisture equilibrium may, due to hysteresis effects, differ depending on whether the equilibrium has been reached by absorption or by desorption. In addition, perfect equilibrium can require a very long time to be reached. Therefore, it is necessary to accept equilibrium within a certain accuracy.

NOTE 3 For products that do not absorb moisture, conditioning is not needed. It should, nevertheless, be ensured that there is no water on the surface before testing.

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 29768, *Thermal insulating products for building applications — Determination of linear dimensions of test specimens*

ISO 12571, *Hygrothermal performance of building materials — Determination of hygroscopic sorption properties*

3 Terms and definitions

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

3.1 Terms and definitions

3.1.1
atmosphere 23/50
controlled atmosphere at a temperature of (23 ± 2) °C and a relative humidity of (50 ± 5) %

3.1.2
hygroscopic range
moisture content in equilibrium with 98 % relative humidity or lower

3.1.3
equivalent time
Δt_e
d^2 hours, where d is the numerical value of the test specimen thickness, in centimetres

3.1.4
limiting value of moisture content change
Δw_1
change in moisture content during a specified period of equivalent time, Δt_e, at the upper limit of the hygroscopic range

3.1.5
conditioning time factor
γ
factor by which the equivalent time, Δt_e, has to be multiplied to determine the required conditioning period in the hygroscopic range

3.2 Abbreviations

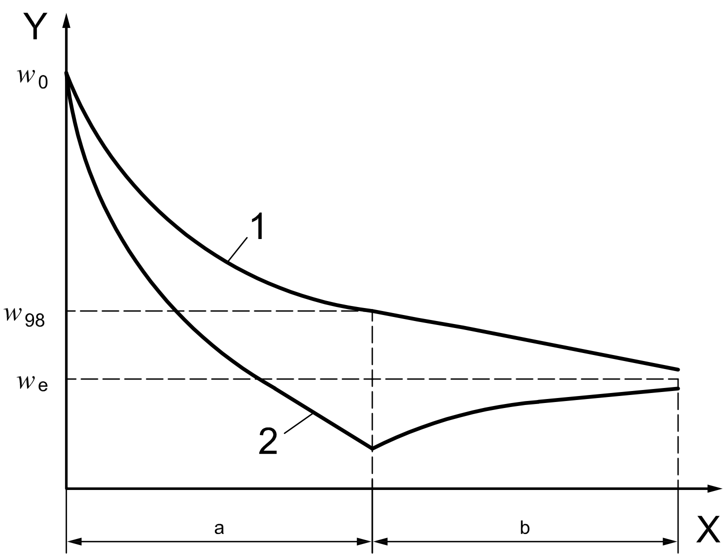
EPS	expanded polystyrene
ICB	insulation cork board
MW	mineral wool
PUR	polyurethane foam
XPS	extruded polystyrene foam

4 Principle

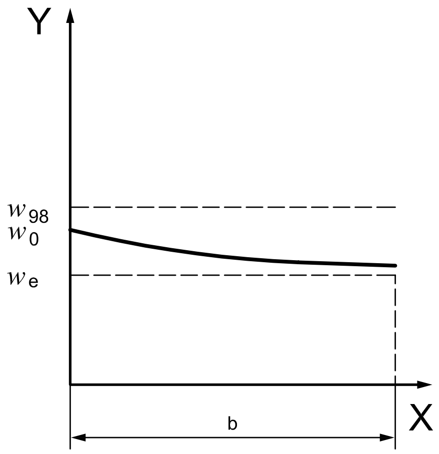
The conditioning is carried out using one or two steps (see Figure 1).

Step 1 is conditioning the test specimen to a moisture content within the hygroscopic range. This conditioning may take place in an atmosphere 23/50 or in a ventilated oven. The choice of condition depends on the type of material. Alternative I shows drying in atmosphere 23/50 and alternative II drying in a heated oven.

Step 2 is conditioning the test specimen to equilibrium with an atmosphere 23/50, after the moisture content has reached the hygroscopic range.



a)



b)

Key

X time
Y moisture content
1 alternative I
2 alternative II
w_0 is the initial moisture content
w_{98} is the moisture content at upper limit of hygroscopic range
w_e is the moisture content in equilibrium with atmosphere 23/50

Figure 1 — Moisture content versus time during Step 1 and Step 2

5 Apparatus

5.1 Temperature and humidity controlled chamber, capable of maintaining the atmosphere 23/50.

5.2 Temperature controlled ventilated oven, that takes the air from an environment of 23/50. The oven shall be capable of maintaining a temperature of (40 ± 5) °C or (70 ± 5) °C or (105 ± 5) °C as specified in the relevant product standard or any other European technical specification.

5.3 Measuring instruments, capable of measuring the linear dimensions of test specimens in accordance with ISO 29768, with an accuracy of 1 %.

6 Test specimens

6.1 Dimensions of test specimens

The thickness of the test specimens shall be the original product thickness.

The test specimens shall be squarely cut and square having sides of (200 ± 1) mm.

6.2 Number of test specimens

The number of test specimens shall be as specified in the relevant product standard. If the number is not specified, then at least three test specimens shall be conditioned.

NOTE In the absence of a product standard or any other European technical specification, the number of test specimens may be agreed between parties.

6.3 Preparation of test specimens

The test specimens shall be cut so that they are representative of the full size product. Any surface skins, facings and/or coatings shall be retained.

6.4 Preconditioning of test specimens

If the procedure shown in Figure 1a) is used, ensure that the test specimens have a moisture content well above the hygroscopic range. If, in this case, the hygroscopic sorption curve for the product is not known, it shall be determined in accordance with ISO 12571.

NOTE To increase the moisture content to above the hygroscopic range, it may be necessary to immerse the test specimens in water, expose them to the exterior climate or expose them to water vapour in accordance with ISO 16536.

6.5 Conditioning of test specimen in tropical countries

In tropical countries, different conditioning and testing conditions can be relevant. In this case, the moisture content shall be in equilibrium with atmosphere (27 ± 5) °C and (65 ± 5) % RH, and this shall be stated clearly in the test report.

7 Procedure

7.1 General

Determine the linear dimensions in accordance with ISO 29768 with an accuracy of 1 %. Calculate the volume, V, of each test specimen.

The conditioning is carried out using either of the alternative procedures shown in Figure 1a) (Steps 1 and 2) or the procedure shown in Figure 1b) (Step 2 alone).

The test specimens shall be installed in the chamber or ventilated oven such that substantially free air circulation occurs around them.

In some cases, the moisture content will be within the hygroscopic range before the conditioning starts. In this case, Step 1 shall be omitted and only Step 2, in accordance with Figure 1b), shall be followed.

7.2 Conditioning Step 1

Place the test specimens in an atmosphere 23/50, or in a ventilated oven at an elevated temperature. The temperature shall be as specified in the relevant product.

NOTE 1 In the absence of a product standard or any other technical specification, the temperature may be agreed between parties.

At preselected intervals of time, depending on the product tested and the atmosphere used, remove and weigh the test specimens to determine any mass changes. Continue until the change in moisture content is less than the limiting value, i.e.

$$\Delta w < \Delta w_1$$

where

Δw is the change in moisture content during a period of d^2 hours (d being the numerical value of the test specimen thickness in centimetres), in kg/m^3;

Δw_1 is the appropriate limiting value of moisture content change, determined in accordance with Annex A, in kg/m^3.

NOTE 2 The limiting value of moisture content change may be determined following the procedures in Annex B.

A suitable time interval is normally 24 h. Constant mass is considered to have been established when the change in the mass of the test specimen over a 24 h period is less than 0,05 % of the total mass.

NOTE 3 For products with a thickness greater than 10 cm, extra drying out time may be required. The acceptable rate of drying is inversely proportional to the square of the thickness, i.e. a 20 cm product would require a change in mass less than 0,013 % per 24 h.

A temperature as high as possible is desirable because this will minimize the conditioning period, but the temperature should not be so high as to cause changes in the material properties.

The effect of moulded skins should be taken into account by increasing the thickness, d, in the expression "d^2 hours". The increase should be the thickness of a slice of homogeneous material with the same vapour resistance as the moulded skins, e.g. for XPS the thickness should be increased by one centimetre for each surface skin of the product.

7.3 Conditioning Step 2

Place the test specimens in an atmosphere 23/50 until equilibrium is reached. Equilibrium is deemed to be reached if during the drying process, in two subsequent weighings using a 24 h interval, the change of mass between the two determinations is less than 0,05 % of the total mass.

NOTE 1 An approximation of the conditioning time may be estimated from $\gamma \times d^2$ hours, where γ is the conditioning time factor and d is the test specimen thickness, in centimetres. For values of γ, see Annexes A and C.

The effect of moulded skins should be taken into account by increasing the thickness, d, in the expression "d^2 hours". The increase should be the thickness of a slice of homogeneous material with the same vapour resistance as the moulded skins, e.g. for XPS the thickness should be increased by one centimetre for each surface skin of the product.

Products with a thickness greater than 10 cm and almost impermeable products require longer conditioning periods than specified by the equilibrium criterion and should be dealt with accordingly by the laboratory.

7.4 Test conditions in tropical countries

In tropical countries, different conditioning and testing conditions can be relevant. In this case, the conditions shall be (27 ± 2) °C and (65 ± 5) % RH instead of 23/50.

8 Calculation and expression of results

The limiting value of moisture content change and the conditioning time factor by experiment shall be calculated in accordance with Annex A.

9 Accuracy

NOTE It has not been possible to include a statement on the accuracy of the measurements in this edition of this International Standard, but it is intended to include such a statement when the standard is next revised.

10 Test report

Information on the conditioning procedure shall be included in the relevant test report.

Conditioning and testing conditions in tropical countries shall be included, if applicable.

Annex A
(normative)

Determination of limiting value of moisture content change and conditioning time factor by experiment

A.1 Calculation based on conditioning at atmosphere 23/50

Find the moisture content at equilibrium, w_{50}, from the hygroscopic sorption curve.

Calculate the moisture content at time t, w_t, in kilogrammes per cubic metre using Equation (A.1):

$$w_t = \frac{m_t - m_e + w_{50} \times V}{V} \tag{A.1}$$

where

m_t is the mass of the moist test specimen at time t, in kg;

m_e is the mass of the test specimen in equilibrium with atmosphere 23/50, in kg;

w_{50} is the moisture content at equilibrium with atmosphere 23/50, in kg/m^3;

V is the test specimen volume, in m^3.

Plot the relationship between moisture content and time for each test specimen.

Find for each test specimen the slope of the drying curve, dw/dt, in kilogrammes per cubic metre per hour, at a moisture content corresponding to the upper limit of the hygroscopic range, 98 % RH (w_{98}).

Calculate the limiting value of moisture content change, Δw_1, in kilogrammes per cubic metre using Formula (A.2):

$$\Delta w_1 = dw/dt \cdot d^2 \tag{A.2}$$

where

d is the test specimen thickness, in cm;

d^2 is the equivalent time, Δt_e, in hours.

The limiting value of the moisture content change is the mean value of the individual results and shall be expressed to two significant figures.

Estimate the time period, t_{step2}, from the plot using moisture content w_{98} to w_{50}, in hours.

Calculate the conditioning time factor, γ, using Equation (A.3):

$$\gamma = \frac{t_{step\,2}}{d^2} \tag{A.3}$$

where

d is the test specimen thickness, in cm;

d^2 is the equivalent time, Δt_e, in hours.

A.1.1 Calculation based on conditioning in a ventilated oven

Calculate the moisture content at time t, w_t, in kilogrammes per cubic metre using Equation (A.4):

$$w_t = \frac{m_t - m_{dry}}{V} \tag{A.4}$$

where

- m_t is the mass of the moist test specimen at time t, in kg;
- m_{dry} is the mass of the oven-dried test specimen, in kg;
- V is the test specimen volume, in m^3.

Plot the relationship between moisture content and time for each test specimen.

Find for each test specimen the slope of the drying curve, dw/dt, in kilogrammes per cubic metre per hour, at a moisture content corresponding to the upper limit of the hygroscopic range, 98 % RH, w_{98}.

Calculate the limiting value of moisture content change, Δw_1, in kilogrammes per cubic metre using Equation (A.5):

$$\Delta w_1 = dw/dt \cdot d^2 \tag{A.5}$$

where

- d is the test specimen thickness, in cm;
- d^2 is the equivalent time, Δt_e, in hours.

The limiting value of the moisture content change is the mean value of the individual results and shall be expressed to two significant figures.

Annex B
(informative)

Computer calculations to determine the limiting value of moisture content change

Computer calculations, modelling the drying out process, have been carried out for five different products. The materials are: high density MW, EPS, XPS with moulded skins, ICB and PUR. Conditioning atmospheres are assumed to be either a controlled atmosphere 23/50 or a ventilated oven that takes the air from an environment at 23/50 at either 40 °C, 70 °C or 105 °C. Test specimen thickness is assumed to be 10 cm.

One-dimensional, isothermal conditions are assumed. Moisture flow is described by a diffusion Equation (B.1) or (B.2):

$$g = \delta_{\mathrm{v}} \cdot dv/dx \qquad \text{(B.1)}$$

or

$$g = \delta_{\mathrm{p}} \cdot dp_{\mathrm{v}}/dx \qquad \text{(B.2)}$$

where

g is the density of moisture flow rate, in kilogrammes per square metre per second;

δ_{v} is the permeability with regard to humidity by volume, in square metres per second;

δ_{p} is the permeability with regard to partial vapour pressure, in kilogrammes per metre per second per pascal;

v is the humidity by volume, in kilogrammes per cubic metre;

p_{v} is the partial water vapour pressure, in pascals;

x is the coordinate in thickness direction, in metres.

δ_{v} and δ_{p} are assumed constant and are determined by a wet cup method in accordance with EN 12086.

NOTE The assumption of one-dimensional conditions may give results on the safe side if the test specimen is allowed to dry out in all directions (no sealed surfaces).

The time (in days) needed to reach the hygroscopic range from an initial moisture content of 10 kg/m^3 (ICB: 50 kg/m^3) is given in Table B.1. If the initial amount of moisture is below 10 kg/m^3, the time needed can be estimated by proportion from the figures given in Table B.1.

Table B.1 — Time to reach the hygroscopic range for different materials at different temperatures

Material	Time in days at quoted temperature			
	23 °C	40 °C	70 °C	105 °C
MW, high density	2	< 1	< 1	–
EPS	18	5	1	–
XPS	> 60	17	4	–
ICB	31	7	2	2
PUR	18	4	1	–

The criterion to check that the hygroscopic range is reached is that the change in moisture content, Δw, during a specified period of equivalent time, Δt_e, is less than a limit value of Δw_1.

The assumption behind this type of criterion is that the rate of drying for a certain material of a certain thickness at a certain temperature is always the same at the upper limit of the hygroscopic range, regardless of the initial moisture content.

From the slope of the drying curves, the rate of drying at the upper limit of the hygroscopic range is determined. The limiting values Δw_1 are determined as the rate of drying multiplied by an interval of d^2 hours.

Table B.2 shows a summary of the results. This table can be used in the absence of experimental results determined according to Annex A.

Table B.2 — Limiting value of moisture content change, Δw_1

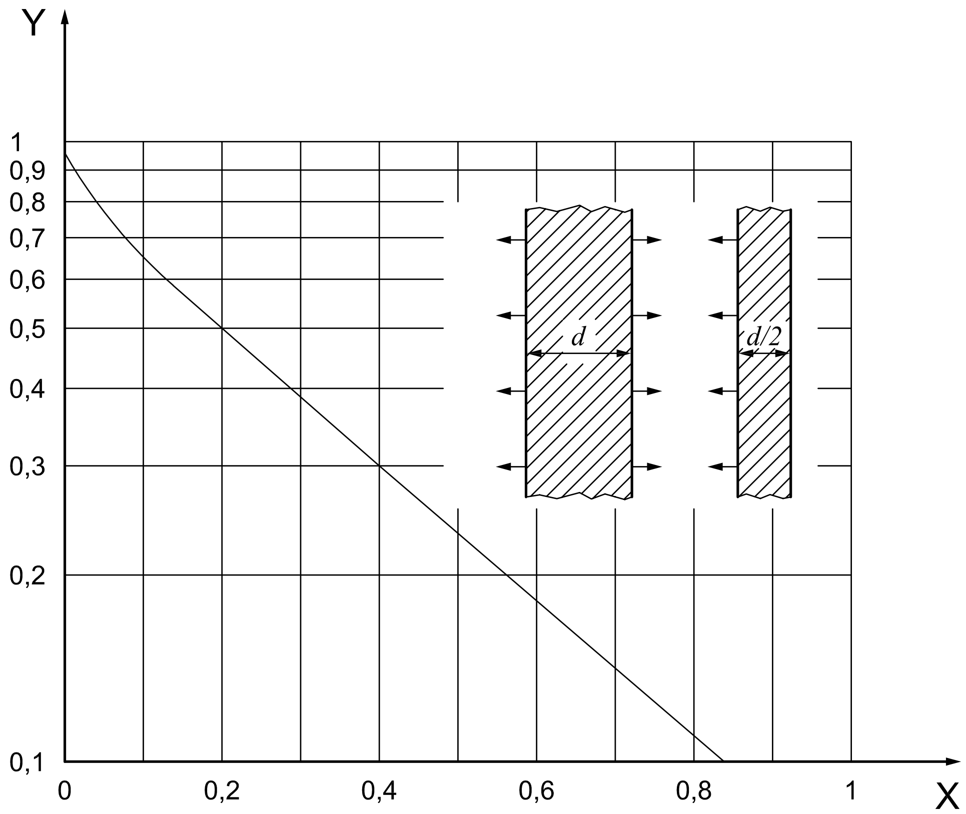
Material	Moisture content change in kg/m3 at quoted temperature			
	23 °C	40 °C	70 °C	105 °C
fibrous and granular materials	10	–	–	–
cellular plastics	0,4	1,5	4	–
cork	1,2	5	25	50

NOTE The values in Table B.2 are calculated under the assumption that the products are homogeneous and that there are no moulded skins, facings or other surface treatment.

Annex C
(informative)

Calculations of conditioning time to reach equilibrium using the Fourier number

The relationship between moisture content and time is described in Figure C.1 below (w_0 and w_e are respectively, the initial and equilibrium moisture contents). The initial moisture content is assumed to be uniformly distributed.



Key

X Fourier number, Fo

Y moisture content $\frac{w - w_e}{w_0 - w_e}$

Figure C.1 — Mean moisture content, given as a dimensionless number between 0 and 1, shown as a function of the Fourier number, Fo, for a slab with the initial moisture content w_0 and equilibrium moisture content w_e

Assuming, for example, that 90 % of the equalisation has taken place, that is the moisture content will be in the range ± 10 % from equilibrium with atmosphere 23/50, then

$$\frac{w - w_e}{w_0 - w_e} = 0{,}10$$

and from the Figure C.1, $Fo = 0{,}84$. It is now possible to estimate the equalisation time from the definition of the Fourier number:

$$Fo = 4 \times \frac{D_w}{d^2} \times t \qquad \text{(C.1)}$$

or

$$t = \frac{Fo \times d^2}{4 \times D_w} \qquad \text{(C.2)}$$

where

D_w is the moisture diffusivity, in square metres per second;

t is the equalisation time, in seconds;

d is the test specimen thickness for two-sided drying, in metres.

The moisture diffusivity, D_w, in the hygroscopic range is a function of vapour permeability, temperature and slope of the sorption curve:

$$D_w = \frac{\delta_v \times v_{sat}}{\xi} \qquad \text{(C.3)}$$

where

δ_v is the permeability with regard to humidity by volume, in square metres per second;

v_{sat} is the saturation humidity by volume, in kilogrammes per cubic metre (at 23 °C, $v_{sat} = 0{,}021$ kg/m^3);

ξ is the moisture differential capacity, in kilogrammes per cubic metre.

The moisture differential capacity, ξ, is the slope of the hygroscopic sorption curve as determined by prEN ISO 12571, and in the calculations the value in the range 50 % to 98 % RH has been used

$$\xi = \frac{dw}{d\phi} \qquad \text{(C.4)}$$

where

w is the moisture content mass by volume, in kilogrammes per cubic metre;

φ is the relative humidity, in percentage.

Typical material properties for some products are given in Table C.1 below.

Table C.1 — Material properties

Material	δ_v m²/s	ξ kg/m³
MW, low density	20 · 10−6	0,5
MW, high density	8 · 10−6	2
EPS, 20 kg/m³	0,6 · 10−6	2
XPS, 30 kg/m³	0,3 · 10−6	1,5
ICB	0,6 · 10−6	30
PUR	0,5 · 10−6	3

Combining Equations (C.2) and (C.3) the equalisation time can now be calculated as:

$$t = \frac{Fo \times d^2}{4 \times D_w} = \frac{0{,}84 \times d^2 \times \xi}{4 \times \delta_v \times 0{,}021} = \frac{10 \times d^2 \times \xi}{\delta_v} \qquad \text{(C.5)}$$

If t is expressed in hours and d in centimetres:

$$t = \frac{2{,}8 \times 10^{-7} \times d^2 \times \xi}{\delta_v} \qquad \text{(C.6)}$$

The assumption of 90 % equalisation means roughly that the moisture content will be in the range ± 10 % from equilibrium with atmosphere 23/50.

The theory requires the initial moisture content to be uniformly distributed. This is not quite true in the procedure suggested here, but the non-uniform moisture distribution at the beginning of Step 2 in Figure 1 of this International Standard normally has no essential effect on the results.

Table C.2 shows a rough summary of the results. This table can be used in the absence of experimental results developed according to Annex A.

Table C.2 — Required conditioning period expressed as $\gamma \times d^2$, where γ is the conditioning time factor and d is the thickness of the product in centimetres

Material category	Conditioning period h
fibrous and granular materials	$0{,}2 \cdot d^2$
cellular plastics	$2 \cdot d^2$
cork	$20 \cdot d^2$

NOTE The same results would have been obtained with calculations using the vapour pressure (p_v) as a driving force for the diffusion and/or moisture content mass by mass (u).

Bibliography

[1] ISO 16536, *Thermal insulating products for building applications — Determination of long-term water absorption by diffusion*

[2] EN 12088, *Thermal insulating products for building applications — Determination of long term water absorption by diffusion*

[3] EN 12086 *Thermal insulating products for building applications — Determination of water vapour transmission properties*

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