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Technical Specification No.1

Determination of thermal conductivity

ASSOCIATION POUR LA CERTIFICATION DES MATERIAUX ISOLANTS

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1 Measurement principle

Measurement of thermal conductivity is performed according to standard NF EN 12667 or NF EN 12939.

The thickness of the test specimens and the test conditions are determined in accordance with the technical guidelines for the relevant product.

The thermal conductivity used to calculate thermal resistance is expressed at 10°C for an insulating product stabilised at equilibrium moisture content at 23°C, 50% RH.

1.1 Products coming under a harmonised European standard

The thermal conductivity is determined after ageing of the test specimens if applicable, in accordance with the methodologies defined in the harmonised European standards currently in force, and the corresponding product guideline. Measurement at a temperature other than 10°C involves determining a curve showing the variation of thermal conductivity according to the temperature. If the measurement is made in another state to that stabilised at 23°C, 50% RH, the moisture conversion factor must be determined.

1.2 Products based on plant or animal fibres

Thermal conductivity is determined in the following manner:

1. measurement of the thermal conductivity of the specimens in the dry state at 10°C.
2. measurement of the thermal conductivity of specimens stabilised at 23°C/50% HR. Expression of the result at the mean temperature of 10°C.
3. determination of the moisture conversion factor based on the thermal conductivity measurements.

1.3 Bulk products

Test specimens are prepared according to the procedures in Technical Specification No.8.

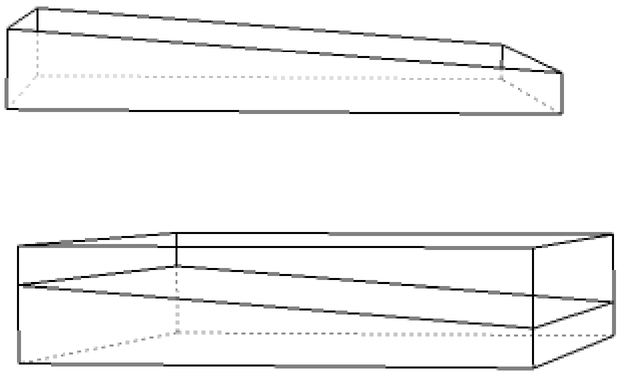
1.4 Sloped products

This paragraph deals with the thermal characteristics of rigid insulation boards with a variable thickness traditionally called "sloped".

The slope of these panels according to the rules Thbat-THU 4/5 can not be greater than 5%.

1.4.1 Détermination of thermal conductivity

The thermal conductivity of the sloped panel is measured according to the head to tail method



The measurements must cover the slope range (min-max) and the thickness range (min-max)

1.4.2 Thermal Calculation

2 The thermal conductivities of the sloped panels are those measured according to the head to tail method (above).Measurement of thermal conductivity in dry state

Unless otherwise specified in the product guideline, "dry state" is defined as being the following stabilised state: the specimens are initially dried in a ventilated oven set to 70°C±3°C until a difference of less than 0.1% by weight is observed between 3 measurements 24 hours apart (according to standards NF EN ISO 12570 and 12571), the air being taken from an air conditioned chamber at 23 ± 6°C. Thermal conductivity measurements are performed on dry specimens at 10°C ($\lambda_{10,dry}$) and at 23°C ($\lambda_{23,dry}$).

Measurement of thermal conductivity at 23°C is performed in order to determine the temperature conversion factor. A single test specimen of each sample is measured at 23°C.

When the specimens are removed from the drying oven, laboratory precautions are taken to reduce the influence of the ambient humidity on the measurement as far as possible, by enclosing the specimens in water vapour tight envelopes using e.g. sufficiently sealed plastic materials (e.g. 150 µm polyane). The test specimens are then cooled, weighed and inserted into the measuring devices.

3 Measurement of thermal conductivity in wet specimens

Measurement of thermal conductivity on wet specimens is performed in order to determine the moisture conversion factor according to §5.

Unless otherwise specified in the product guideline, "wet state" is defined as being the following stabilised state: the specimens are conditioned in an atmosphere at (23±2)°C and (50±5)% relative humidity for a minimum of one week until a difference in weight of less than 0.05% is obtained between 2 measurements made 24 hours apart (according to standard NF EN 12429).

Thermal conductivity measurements are performed on wet specimens at a temperature of 23°C ($\lambda_{23,(23/50)}$) and are then transferred by calculation to 10°C, or are directly performed at 10°C ($\lambda_{10,(23/50)}$).

Identical laboratory precautions are taken to those mentioned in § 2 to reduce the influence of the ambient humidity on the thermal conductivity as much as possible.

4 Calculation of fractile 90/90

4.1 Values used for the calculation

In the context of the application of standard NF EN ISO 10456, some values for k for a unilateral tolerance interval of 90% with a level of confidence of 90% are given below:

Number of samples measured	k
10	2.07
12	1.97
14	1.90
16	1.84
18	1.80
20	1.77
25	1.70
30	1.66
35	1.62
40	1.60
45	1.58
50	1.56
100	1.47
300	1.39
500	1.36
2000	1.32

For other numbers of samples, the value of k is obtained by linear interpolation or taken from standard ISO 12491.

4.2 Direct calculation based on thermal conductivity

Knowledge of the mean thermal conductivity and the standard deviation allows a value corresponding to the 90% fractile to be established with a confidence of 90% according to the principles of standard ISO 10456 summarised below:

$$\lambda_{90/90} = \lambda_{ave} + k.s_{\lambda}$$

$$s_{\lambda} = \sqrt{\frac{\sum_{i=1}^{n}\left(\lambda_i - \lambda_{dry}\right)^2}{n-1}}$$

with:

	$\lambda_{90/90}$	: thermal conductivity at fractile 90/90
	λ_{dry}	: mean thermal conductivity for the range in question
	s_{λ}	: estimator of the standard deviation of thermal conductivity
	k	: factor dependant on the number of samples measured
	n	: number of samples measured

A total of 10 samples (1 sample per batch) is a strict minimum.

If the product is manufactured in several factories, the mean thermal conductivity and the standard deviation must be determined for each of them.

4.3 Calculation based on the density

This calculation method is based on the relationship between the thermal conductivity and the density established by a curve $\lambda = f(\rho)$.

4.3.1 Fractile based on density

Based on the density results supplied by the manufacturer, the density value corresponding to the 90% fractile with a confidence level of 90% is calculated according to the following formula, then rounded to the nearest 0.1kg/m^3:

$$\rho_{90/90} = \rho_{ave} - k \times s_{\rho}$$

$$s_{\rho} = \sqrt{\frac{\sum_{i=1}^{n}(\rho_i - \rho_{ave})^2}{n-1}}$$

with:

	$\rho_{90/90}$	: density at fractile 90/90
	ρ_{ave}	: average density for the range in question
	s_{ρ}	: estimator of the standard deviation of the density

k : factor dependant on the number of samples measured

n : number of samples measured

A total of 10 samples is a strict minimum.

4.3.2 Thermal conductivity of reference

Based on the value of this density ($\rho_{90/90}$) and the modelling curve λ_{mod} = f (ρ_{mod}), we can calculate the value of the thermal conductivity of reference λ_{ref}.

This value λ_{ref} is defined by the thermal conductivity value corresponding on the curve λ_{mod} = f (ρ_{mod}), to the density value ($\rho_{90/90}$), then rounded up to the nearest 1 mW/(m.K).

5 Moisture conversion factors

For the declaration of the thermal value, the moisture conversion factors $f_{u,1}$ and $f_{u,2}$ are determined in two stages described below.

5.1 Factor $f_{u,1}$

The moisture factor is calculated on *N* test specimens. Unless specified otherwise in a product guideline, the number of test specimens *N* is equal to 2.

Stage 1: conditioning of the *N* test specimens in the dry state according to § 2 then measurement of the weight and thermal conductivity. The mean values are recorded as follows:

m_{dry} : mean value of the weight in kg,

$\lambda_{10,\ dry}$: mean thermal conductivity value of dry specimens at 10°C, in W/(m.K).

Stage 2: conditioning of the *N* specimens at (23 ± 2)°C and (50 ± 5)% RH according to §3 then measurement of the weight and thermal conductivity. The mean values are recorded as follows:

$m_{23,50}$: mean value of the weight in kg,

$\lambda_{10,\ (23,50)}$: mean thermal conductivity value on specimens in the wet state

Calculation of coefficient $u_{23,50}$ based on the formula:

$$u_{23,50} = \frac{m_{23,50} - m_{dry}}{m_{dry}}$$

Calculation of the moisture conversion factor $f_{u,1}$ (according to ISO 10456):

$$f_{u,1} = \frac{\ln \dfrac{\lambda_{10,(23,50)}}{\lambda_{10,dry}}}{u_{23,50} - u_{dry}}$$

6 Determination of the declared thermal conductivity

6.1 Products coming under a harmonised European standard

The thermal conductivity is declared according to the procedures described in the harmonised European standards currently in force.

6.2 Products which do not come under a harmonised European standard

6.2.1 For hygroscopic products

The declared thermal conductivity λ_D according to the formula:

$$\lambda_D = \lambda_{10,dry,90/90} \times e^{f_{u,1}(u_{23,50} - u_{dry})}$$

6.2.2 Other products

The declared thermal conductivity λ_D according to the formula:

$$\lambda_D = \lambda_{10,dry,90/90}$$

6.3 Rounding rule

The declared thermal conductivity value, λ_D, must be rounded up to 0.001 W/(m K).