Technical Specification No.2

Determination of thermal resistance

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ASSOCIATION POUR LA CERTIFICATION DES MATERIAUX ISOLANTS
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1 Preamble

The thermal resistance *R* of a product is determined based on the thermal conductivity λ of the material of which it is composed and its thickness *e*, according to the following ratio:

$$R = \frac{e}{\lambda}$$

With:

- *R* in m².K/W
- *e* in m
- λ in W/(m.K)

The certified thermal resistance values are rounded down to 0.05 m².K/W.

The certified thermal resistance takes into account the possible settling of the product over time in bulk products.

2 Methods of determination

The methods described in this paragraph are based on two principles linked to the nature of the target in question.

For products in panels or rolls and for bulk products in a closed cavity, where the thickness of product used is a nominal characteristic, the thermal resistance is determined based on the thermal conductivity and this nominal thickness.

For bulk products in an open cavity, the thickness of the product to apply is established according to the thermal resistance to be achieved and the measured thermal conductivity. The thicknesses to be applied according to the thermal resistance are therefore given in the form of a table.

2.1 Products in panels or rolls

The certified thermal resistance is established based on the thermal conductivity of reference for the material it is composed of and its nominal thickness. The thermal conductivity of reference may be:

- The thermal conductivity at fractile 90/90 ($\lambda_{90/90}$)
- The declared thermal conductivity (λ_D)

The thermal conductivity used to calculate the thermal resistance is used to verify conformity of the characteristics according to the procedures in Technical Specifications E.

The certified thermal resistance values are rounded to 0.05 m².K/W by default and presented in a table according to the nominal thicknesses of the product range in question.

Thickness				
Thermal resistance				

For products coming under harmonised European standards NF EN 13162 to 13171, these procedures can be found in these standards.

2.2 Reflective products or products for which emissivity is certified

In the case of these products, there is no thermal conductivity measurement. The thermal resistance is measured directly according to the prescriptions in standard NF EN 16012, § 5.5 and 5.6.

The intrinsic thermal resistance *R* is expressed at 10°C based on a calculation at fractile 90/90. This calculation is performed according to paragraph 4 of Technical Specification No.1 adapting the formula so that:

$$R_{90/90} = R_{moyen} - k.s_R$$

For products which do not contain a hygroscopic layer, the measurement is performed at laboratory temperature.

For products containing hygroscopic layers, the measurement is performed adapting paragraphs 1.2, 2 and 3 of Technical Specification No1.

The moisture conversion factors are determined in accordance with paragraph 5 of Technical Specification No.1. The thermal resistance is then determined based on the value of $R_{10,dry,90/90}$, corrected by the moisture conversion factor:

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

Or $$R_{90/90} = R_{10,sec,90/90} \times e^{-f_{u,2}(u_{23,80} - u_{sec})}$$

In complement to §1 when the resistance $R_{90/90}$ is less than 0.05 m².K/W, the certified thermal resistance is 0.01 m².K/W.

Particular conditions

For products for which the thickness is insufficient with regard to the measuring devices, several test specimens should be piled or superimposed to measure the thermal resistance according to standard NF EN 12667.

2.3 Bulk products coming under by a harmonised European standard

The methods for determination of the thermal resistance and for construction of the performance table in the harmonised standard currently in force apply.

2.4 Bulk products which do not come under a harmonised European standard

2.4.1 Blown material

The thermal resistance values are based on the following information:

- density range,
- thermal conductivity of reference per density range
- level of humidity by weight (in %) depending on the stabilisation and application conditions (drying, duration, etc.),
- possible settling

The thermal resistance values are expressed based on the thermal conductivity value of reference λ_{ref} and are each associated with a minimum installed thickness and a minimum number of bags for 100 m².

1. The certified thermal resistance R is expressed in (m².K)/W in intervals of 0.5 (m².K)/W or 1 m².K/W, based on a minimum certified value of 2 (m².K)/W.

   E.g. R = 2.5; 3.5 and 4 m².K/W

2. The thickness (e_i) for each resistance R_i is determined based on:
   - the thermal conductivity of reference λ_{ref} in mW/(m.K), rounded up to the nearest 1 mW/(m.K),
   - a settling coefficient S determined according to Technical Specification No.4.

   $$e_i = R_i \times \lambda_{ref} \times \left(\frac{1}{1-S}\right)$$

   This thickness e_i in mm is rounded to the nearest 1 mm.

3. The number of bags (n_i) for 100 m² surface area is obtained by:

   $$n_i = e_i \times \rho_{min}/m_{sac} \times 10^{-1}$$

   with m_{sac} nominal weight indicated on the bags to the nearest 0.1 kg and ρ_{min} the minimum density for the range in question.

   n_i is rounded up to the nearest bag.

4. Table of results:

Based on the values of e_i and n_i, the following roundings are performed:

- minimum installed thickness (e) to the nearest 5 mm,
- minimum number of bags (n) for 100 m² rounded up to the next full bag.

The certified thermal resistances are presented in a table in the following form:

Certified thermal resistance (m²K/W)	Thickness after settling mm)	Minimum installed thickness (mm)	Minimum number of bags for 100 m²

The certified thermal resistance R can only be obtained by strictly respecting both the thickness and minimum number of bags for 100 m² of surface of roof space flooring covered and the prescriptions laid out in the valid Technical Assessment or the Technical Application Document (list

of Technical Assessments and Technical Application Documents available on the website www.cstb.fr).

2.4.2 Application by injection or wet spraying

The thermal resistance values are based on the following information:

- density range,
- thermal conductivity per density range
- level of humidity by weight (in %) depending on the stabilisation and application conditions (drying, duration, etc.),

The thermal resistance values are expressed based on the thermal conductivity value of reference λ_{ref} and are each associated with a minimum installed thickness depending on the depth of the cavity and a minimum number of bags for 100 m^2.

1. The thickness is expressed in mm in 10 mm intervals.

   E.g. e = 30; 40; …; 140 mm

2. For each thickness e_i, the certified thermal resistance R_i is expressed in (m^2.K)/W and determined based on:
   - the thermal conductivity of reference λ_{ref} in mW/(m.K), rounded up to the nearest 1 mW/(m.K),
   - the thickness e_i in mm

$$R_i = \frac{e_i}{\lambda_{ref}}$$

3. The number of bags (n_i) for 100 m² surface area is obtained by:

$$n_i = e_i \times \rho_{min}/m_{sac} \times 10^{-1}$$

   with m_{sac} nominal weight indicated on the bags to the nearest 0.1 kg and ρ_{min} the minimum density for the range in question.

   n_i is rounded up to the nearest bag.

4. Table of results:

Based on the values of R_i and n_i, the following roundings are performed:

- Thermal resistance (R) to 0.05 m².K/W by default,
- minimum number of bags (n) for 100 m² rounded up to the next full bag.

The certified thermal resistances are presented in a table in the following form:

Thickness to be installed = Thickness of the cavity (mm)	Certified thermal resistance (m²K/W)	Minimum number of bags for 100 m²

The certified thermal resistance R can only be obtained by strictly respecting both the thickness and minimum number of bags for 100 m² of surface area and the prescriptions laid out in the valid Technical Assessment or the Technical Application Document (list of Technical Assessments and Technical Application Documents available on the website www.cstb.fr).

2.5 Bulk sprayed mineral wool-based products

The thermal resistance values are based on the following information:

- density range,
- thermal conductivity per density range,
- level of humidity by weight (in %) depending on the stabilisation and application conditions (drying, duration, etc.).

The thermal resistance values are expressed based on the thermal conductivity value of reference λ_{ref} and are each associated with a minimum installed thickness and a minimum number of bags for 100 m^2.

The thermal conductivity measurements of reference λ_{ref} are performed according to the measures in Technical Specification No.1 and on specimens prepared in the top end of each density range covered [ρ_{max}- 20 ≤ ρ (kg/m^3) ≤ ρ_{max}].

1. The certified thermal resistance R is expressed in (m^2.K)/W in intervals of 0.5 (m^2.K)/W or 1 m^2.K/W, based on a minimum certified value of 2 (m^2.K)/W.

   E.g. R = 2.5; 3.5 and 4 m^2.K/W

2. The thickness (e_i) for each resistance R_i is determined based on the thermal conductivity of reference λ_{ref} in mW/(m.K), rounded up to the nearest 1 mW/(m.K).

   $$e_i = R_i \times \lambda_{ref}$$

   This thickness e_i in mm is rounded to the nearest 1 mm.

3. The number of bags (n^i) for 100 m² surface area is obtained by:

   $$n_i = e_i \times \rho_{min}/m_{sac} \times 10^{-1}$$

   with m_{sac} nominal weight indicated on the bags to the nearest 0.1 kg and ρ_{min} the minimum density for the range in question.

   n_i is rounded up to the nearest bag.

4. Table of results:

Based on the values of e_i and n_i, the following roundings are performed:

- minimum installed thickness (e) to the nearest 5 mm,
- minimum number of bags (n) for 100 m² rounded up to the next full bag.

The certified thermal resistances are presented in a table in the following form:

Certified thermal	Minimum installed	Minimum

resistance (m²K/W)	thickness (mm)	number of bags for 100 m²

The certified thermal resistance R for each density range can only be obtained by strictly respecting both the thickness and prescriptions laid out in the DTU guideline 27.1. The thermal impact of the impregnation product injected during finishing operations shall be taken into account. This impact shall be assessed by each of the industrialists concerned.

3 Particular measures

3.1 Determination of the thermal resistances of very thick insulation

For reference laboratories and the manufacturers' laboratories, "very thick" corresponds to the lack of means for direct measurement of the thermal resistance of insulation at the thickness produced. The product is thicker than the limit provided for in Appendix A of standard NF EN 12667. In this case, the thermal resistance is determined according to standard NF EN 12939.

A specific examination is required for each product with regard to the phenomenon of radiation and the variations of the material according to the thickness with regard to the characteristics of the material it is composed of and any specific features of the manufacturing process.

Insofar as the effect due to radiation according to the thickness is limited, the test is conducted in accordance with the measures of Technical Specifications No.1 on *n* sub-sized specimens obtained by slicing (*n* is generally equal to 2 but may be higher for very thick products). The thermal resistance of the initial test specimen is therefore determined by adding the thermal resistances of each of the *n* sub-specimens:

$$R = \sum_{i=1}^{n} R_i$$

For materials that are not homogeneous and/or with a radiation effect, a specific study must be carried out for each product, or even for each thickness.

If a certificate concerns a range of thicknesses containing one or more very thick products, and for an industrial manufacturer who is not equipped to measure the full thickness, a sample of the very thick product is systematically verified by determining the thermal resistance in two parts.

3.2 Determination of the thermal resistances of multi-layer products

For products for which one of the layers cannot be certified due to its low thickness, the manufacturer's controls and tests must concern either the entire product or each of its layers, upon the proposal of the lead member and after consulting the Certification Committee.

3.3 Rules for certification of products of variable density according to the thickness

It is permitted:

- that a certified product may, for a range of thicknesses, have a variable density;
- for each specific case, the acceptable limits for density variation according to the thickness are assessed and fixed by agreement between the lead member and the manufacturer;
- the cases presented to the Certification Committee must include the elements necessary to assess this specific situation;
- in agreement with the manufacturer, the lead member proposes the internal and external controls and tests to the Certification Committee according to the density ranges.

3.4 Rules for certification of slabs having surface treatment obtained by machining or thermoforming

3.4.1 Production concerned

The method for calculation of certified thermal resistance described below can only be applied to products having surface treatment of limited thickness and area (see the following paragraphs).

For thicker treatments over an extended area, the rules must be modified and verified on a case by case basis to take into account the complexity of the heat transfer.

Only products resulting from production of slabs meeting the minimum criteria required for a request for certification by the ACERMI may be the object of certification by applying the rules defined below.

3.4.2 Surface treatment by machining

Products are produced from flat panels by removing surface material using means such as grooving or pitting[1] which lead to a repetitive or non-repetitive localised reduction in the initial thickness (figure 1). The surfaces may also be planed before machining in order to rectify the initial flatness of the panels.

[1] Pitting is assimilated to this case when the size of the perforations is small.

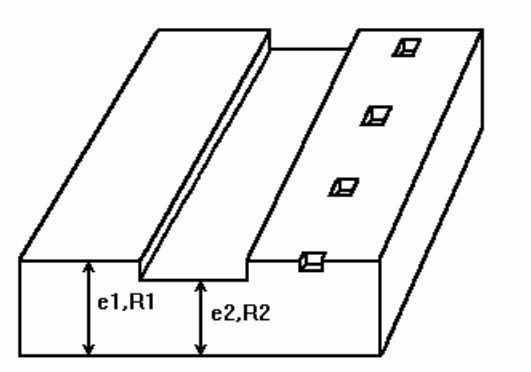


Figure 1
With the symbols defined in paragraph 3.4.4 below, only productions simultaneously satisfying both the following conditions are certifiable by applying this rule:

- (e1 - e2) ≤ 5 mm
- s2/s1 ≤ 0.10

3.4.3 Surface treatment by thermoforming

The target products are those for which the surface treatment is obtained by thermoforming leading to repetitive or non-repetitive localised reduction of the initial thickness. The surfaces may also be planed before this surface treatment is performed in order to rectify the initial flatness of the panels.

With the symbols defined in paragraph 3.4.4 below, only productions simultaneously satisfying both the following conditions are certifiable by applying this rule:

- (e1 - e2) ≤ 2 mm
- s2/s1 ≤ 0.50

3.4.4 Method

Let:

e_1 the total thickness of the panel

e_2 the thickness at the bottom of the marking

s_1 the proportion of the area having thickness e_1

s_2 the proportion of the surface such that $s_2 = 1 - s_1$

R_1 the initial thermal resistance of the panel

R_2 the thermal resistance determined with e_2.

The initial thermal resistance R_1 taken into account is that of the initial product before the surface treatment is applied.

If the product is already certified in this state, the resistance R1 is that of the ACERMI certificate before applying the rounding rule.

If the product is already certified but is planed before the final machining, the effect of planing on the thermal resistance is studied prior to applying the calculation rule.

If the product is not certified, the thermal resistance R1 is determined under the conditions applicable to examination of an application for ACERMI certification. The value taken into account for calculation is that obtained before application of the rounding rule.

For the thickness e_2, the thermal resistance R_2 is determined under the conditions applicable to examination of an application for ACERMI certification. The value taken into account for calculation is that obtained before application of the rounding rule.

Thermal resistances R_1 and R_2 are considered in parallel, and the thermal resistance R of the machined panel is given by the ratio:

$$\frac{1}{R} = \frac{e_1}{R_1} + \frac{e_2}{R_2}$$

3.4.5 Follow-up after certification

Follow-up after certification can cover either the initial product before any machining, or the product with thickness e_1 before final machining is performed, or after appropriate cutting on the part corresponding to thickness e_2 at the lowest point of the machining.

The appropriate follow-up method, depending on the effect of the surface treatment on the certified characteristics, and its conditions of application are defined between the applicant and the lead member during the study prior to certification, and are an integral part of the technical file for the product.

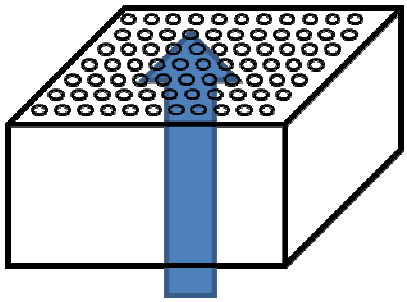
If the surface treatment has a significant effect on the thermal characteristics, inspection of the products before and after treatment may be requested

4 Sloped products

For the sloped panel, only the certified thermal conductivity of the sloped panel will appear. (see modality on the CT01).

5 Perforated products

Panels having been perforated from side to side in the direction of the heat flow. During their implementation the perforations are blocked by a coating or a wall.



Only products meeting the flowing conditions may be certfied

- Diameter of perforations ≤ 6 mm
- Number de perforations ≤ 1250/m2

The products as described can be measured directly. No correction ont the thermal resistance values is to be applied.