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Thermal insulating products for industrial installations — Determination of the coefficient of linear thermal expansion at sub-ambient temperatures

Produits isolants thermiques pour les installations industrielles — Détermination du coefficient de dilatation thermique linéique à des températures inférieures à la température ambiante

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Foreword

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Thermal insulating products for industrial installations — Determination of the coefficient of linear thermal expansion at sub-ambient temperatures

1 Scope

This document specifies the equipment and procedures for determining the coefficient of linear thermal expansion at sub-ambient temperatures (−196 °C to 25 °C), subject to the possible temperature limitation of the test specimens. It is not applicable to products which experience dimensional changes during the test due to the loss of hydration water or which undergo other phase changes.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 9229, *Thermal insulation — Vocabulary*

ISO 18099, *Thermal insulating products for building equipment and industrial installations — Determination of the coefficient of thermal expansion*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9229, ISO 18099 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

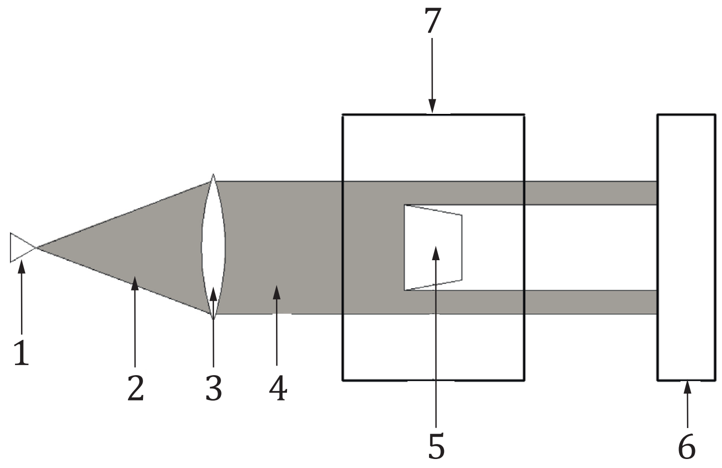
— IEC Electropedia: available at https://www.electropedia.org/

3.1
sub-ambient temperature
temperature from −196 °C to 25 °C at which the thermal insulation product is used to reduce heat flow

4 Method A — Optical method

4.1 Principle

The changes in a product's linear dimensions, as its temperature is changed, are measured and characterized by the optical measurement method (See Figure 1 for an example).



Key

1 light source
2 light
3 collimator lens
4 parallel light beam, wider than the test specimen
5 test specimen, with dimension of 10 mm to 30 mm
6 detector, wider than the light beam
7 test chamber

Figure 1 — Example of an apparatus for optical method

4.2 Apparatus

4.2.1 Light source system

An InGaN-based light source which can project a broad-width planar parallel light beam onto the sample and detector. The collimator lens should be used to keep the light beam parallel within 2" (≈ 0,009 696 mrad).

4.2.2 Light detector system

The light beam with the shadow of the sample is detected by a sensor. The signal is then evaluated by a digital edge-detection processor which provides a sensitive and precise measurement of the dimensions of the sample before and after expansion. It shall be calibrated over the required range to within $2 \times 10^{-5} \times l_0$ for the length.

4.2.3 Test chamber and cooling system

Capable of maintaining the mean temperature of the test specimen to within ± 0,5 K of the desired test temperature.

The test chamber shall be capable of limiting the rate of temperature change to 1 °C/min during the change from one test temperature to another. The disk-shaped chamber with liquid nitrogen cooling system above and heating elements below the sample is usually fit to optical dilatometry. There should be two holes on the test chamber to let the light beam go through. The dimension is fit to the sample and light beam to ensure good temperature distribution.

NOTE Liquid nitrogen has been found in practice to be the most satisfactory coolant. The cooling system can consist of pressure-controlled valve and nitrogen source (e.g. a dewar) feeds liquid nitrogen to a heat exchanger.

4.2.4 Temperature-measuring instruments

Calibrated thermocouples suitable for the test with an accuracy of ± 0,5 K.

The thermocouples are connected to a stepwise recording device. If only the mean coefficient of linear thermal expansion, α_m, between two temperatures is needed, the measurements shall only be carried out at these temperatures. If the full curve over a temperature range is needed, it shall be done in a continuous way.

4.2.5 Equipment to prepare the test specimen

Suitable saw or thin-walled steel tube to prepare the test specimen. The thin-walled steel tube is a steel tube with a thin wall, and one side is sharp, which can be used to cut a cylinder-shaped specimen.

4.3 Test specimen

4.3.1 Dimensions of test specimens

The dimensions shall be appropriate for the dimensions of the apparatus and smaller than the width of the light beam, usually 10 mm to 30 mm. Because of its small dimensions, the test specimen should be carefully selected to be representative of the product being tested.

The shape of the specimen can be a cylinder or cuboid. If a cuboid is used, the trapezoidal transversal surface is in favour of avoiding the influence of deviation of the position, where the topline will not influence the measurement of baseline. For anisotropic materials, the direction should be marked and recorded.

The material tested can be rigid or flexible material, except the transparent materials.

4.3.2 Preparation of test specimens

Any skins, facings, and/or coatings shall be removed.

Test specimens shall be sawn or cut from the product with a thin-walled steel tube in the direction in which the measurement of the coefficient of linear thermal expansion shall be made and in which the linear dimensions are to be recorded.

Special requirements for preparation such as annealing or drying under specified conditions shall be indicated where relevant in the product standard.

For anisotropic products, the measurements shall be carried out both in the direction of the length and of the width.

4.3.3 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 two test specimens shall be used.

4.4 Conditioning of test specimens

The test specimens shall be stored for at least 6 h at (23 ± 5) °C. In case of dispute, they shall be stored at (23 ± 2) °C and (50 ± 5) % relative humidity (RH) for the time specified in the relevant product standard.

In tropical climates, different conditioning and testing conditions can be relevant. In this case, the conditions shall be (27 ± 5) °C and (65 ± 5) % RH.

4.5 Procedure

Clean the test specimen and position it in the centre of the light beam area in the chamber, making sure that the end surfaces are perpendicular to the light beam. Measure its length at (23 ± 2) °C which shall be considered as the reference temperature.

Place the thermocouples in a hole, which is on the backside of the light beam of the specimen, or in good contact with the test specimen in which emissivity of the test specimen and thermocouples should be matched. Close the test chamber and cool the system to the lowest temperature needed. Then heat the chamber, making sure that the temperature gradient given in the relevant product standard is respected. If no information is available, do not exceed 3 K/min and 1 K/min for the last 50 °C interval to target temperature.

Stabilize the temperature at temperature intervals over a time sufficient to obtain a uniform temperature within the test specimen. Usually, 30 min is sufficient.

Measure the temperature and the test specimen length when stable temperature is recorded (±1 K). Record the length variation/temperature curves continuously.

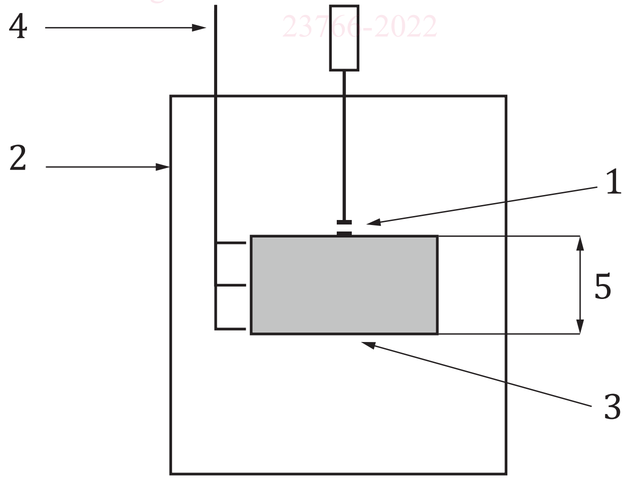
When the temperature returns to the reference value, remeasure the length. If irreversible changes have occurred, repeat the cycles until only reversible changes occur, and the irreversible changes should be reported as a whole for information.

The result shall be calculated from the readings of the reversible changes.

5 Method B — Displacement method

5.1 Principle

The changes in a product's linear dimensions, as its temperature is changed, are measured and characterized by the displacement method (See Figure 2 for an example).



Key

1 displacement sensor
2 test chamber
3 test specimen
4 temperature sensor
5 relevant dimension / length

Figure 2 — Example of an apparatus for displacement method

5.2 Apparatus

5.2.1 Sensor for distance

A displacement measurement sensor reading to the nearest 1 µm, with a load less than 50 Pa, shall be used for the measurement of the relevant dimension / length of rigid specimen. For soft insulation products, the required load for the determination of the thickness according to the product standard shall be taken into account. If no product standard exists, the load should be agreed between the involved parties.

5.2.2 Test chamber and cooling system

Capable of maintaining the mean temperature of the test specimen to within ±1 K of the desired test temperature below ambient temperature with the possibility to adjust the cooling down rate.

NOTE The chamber can be cooled down with liquid nitrogen to reach the cryogenic area.

5.2.3 Temperature-measuring instruments

Calibrated temperature-measuring devices suitable for the test with an accuracy of ±0,5 K to determine the mean temperature of the specimen (minimum three sensors over the specimen length in the direction of the displacement measurement).

The temperature-measuring devices are connected to a continuous recording device. If only the mean coefficient of linear thermal expansion, α_m, between two temperatures is needed, the measurements shall only be carried out at these temperatures. If the full curve over a temperature range is needed, it shall be done in a stepwise way.

5.2.4 Equipment to prepare the test specimen

Suitable saw to prepare the test specimen.

5.3 Test specimen

5.3.1 Dimensions of test specimens

The dimensions shall be appropriate for the dimensions of the apparatus.

Specimens of the dimension 50 mm × 50 mm × thickness (minimum 10 mm to maximum 50 mm) shall be used. Larger dimensions are also possible.

The test specimen should be carefully selected to be representative of the product being tested.

5.3.2 Preparation of test specimens

Any skins, facings, and/or coatings shall be removed.

Test specimens shall be sawn from the product in the direction in which the measurement of the coefficient of linear thermal expansion shall be made and in which the linear dimensions are to be recorded.

Special requirements for preparation such as annealing or drying under specified conditions shall be indicated where relevant in the product standard.

For anisotropic products, the measurements shall be carried out in all relevant directions.

5.3.3 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 two test specimens shall be used.

5.4 Conditioning of test specimens

The test specimens shall be stored for at least 6 h at (23 ± 5) °C. In case of dispute, they shall be stored at (23 ± 2) °C and (50 ± 5) % relative humidity (RH) for the time specified in the relevant product standard.

In tropical climates, different conditioning and testing conditions can be relevant. In this case, the conditions shall be (27 ± 5) °C and (65 ± 5) % RH.

5.5 Procedure

Clean the test specimen and the chamber. Measure the relevant dimension under the used test load at (23 ± 2) °C or (27 ± 5) °C which then shall be considered as the reference temperature.

Position the specimen in the chamber.

Close the test chamber and cool the system to the lowest temperature needed, making sure that the temperature gradient given in the relevant product standard is respected. If no information is available, the temperature gradient shall be agreed between the involved parties.

Stabilize the temperature at temperature intervals over a time sufficient to obtain a uniform temperature within the test specimen. Usually, 30 min is sufficient.

Measure the temperature and the test specimen relevant dimension when stable temperature is recorded (±1 K).

When the temperature returns to the reference value, remeasure the length. If irreversible changes have occurred, repeat the cycles until only reversible changes occur, and the irreversible changes should be reported as a whole for information.

The result shall be calculated from the readings of the dimensional changes and the associated mean temperatures of the specimen.

6 Calculation and expression of results

Calculate the mean coefficient of linear thermal expansion, α_m, in K^{-1} between the temperatures T_1 and T_2 using the following formula:

$$\alpha_m = \frac{1}{l_0} \times \frac{l_2 - l_1}{T_2 - T_1}$$

where

l_0 is the length of the test specimen, at the reference temperature T_0, in millimetres;

l_1 is the length of the test specimen, at the temperature T_1, in millimetres;

l_2 is the length of the test specimen, at the temperature T_2, in millimetres.