
**Ageing of thermal insulation materials —
Determination of the long-term change in
thermal resistance of closed-cell plastics
(accelerated laboratory test methods)**

*Vieillissement des matériaux isolants thermiques — Détermination du
changement à long terme de la résistance thermique des plastiques
alvéolaires à cellules fermées (méthodes d'essai de laboratoire accélérées)*



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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 3.

Draft International Standards adopted by 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.

International Standard ISO 11561 was prepared by Technical Committee ISO/TC 163, *Thermal insulation*, Subcommittee SC 1, *Test and measurement methods*.

Annexes A and B of this International Standard are for information only.

Introduction

The purpose of this International Standard is to determine the ageing (long-term decrease in thermal resistance) of closed-cell cellular plastic materials and products which have properties that, due to diffusion of contained gases, change with time. The thermal resistance and its rate of change will vary with product variability, temperature and thickness, and also within the thickness due to cross-sectional variability and the effects of natural or applied surface skins or protective facings.

The long-term thermal resistance is one property required for establishing design thermal performance under service conditions and for determining life-time energy requirements.

This International Standard contains two procedures based on the conditioning of thin slices at room temperature, since conditioning at elevated temperatures can induce changes in a material other than those due to diffusion processes. The first, method A, relates to the core material only. An alternative, method B, is a simplified test to determine a conservative value of a design life-time thermal performance of a product. Two informative annexes provide essential background information on the ageing process and on the factors to be considered when measurements are required on faced products.

The phenomenon and mechanisms of ageing have been known and understood for many years. The use of a blowing agent produces a relatively uniform cell size and initial high thermal resistivity. However, during the subsequent life of the foam, the principle component gases in the air diffuse into the cells and this increases the cell gas pressure, effectively increasing the thermal conductivity of the gas mixtures. In addition, some of the blowing agent is absorbed by or dissolved into the polymer matrix, saturating it, while the remainder diffuses out. This inward diffusion is influenced by appropriate diffusion coefficients. These in turn are influenced by the temperature, effective cell diameter in the direction of movement of air components, and the nature of the polymer matrix.

Since the diffusion of nitrogen and oxygen molecules into the cells is very much faster than the outward diffusion of the generally used larger molecule (the blowing agent), the whole ageing process is a combination of two stages:

- a) a primary stage (thermal drift) due to the significant rate of change of cell gas composition (usually complete within 5 years);
- b) a secondary stage where air diffusion is complete but there is still very slow outward diffusion of the blowing agent (a period much greater than 10 years and estimated in some cases to be over 100 years).

Ageing of thermal insulation materials — Determination of the long-term change in thermal resistance of closed-cell plastics (accelerated laboratory test methods)

1 Scope

This International Standard specifies two laboratory test methods, based on slicing and scaling techniques, to determine the long-term changes in the thermal resistance of closed-cell (normally 90 %) cellular plastic materials that contain gases which, through diffusion processes, affect the properties of a foam with time.

Using standard methods for the measurement of thermal resistance, method A consists of periodic measurements performed over a short time interval on thin specimens conditioned in a controlled ambient temperature environment. The results of relative change with time are used in conjunction with a mathematical technique to derive the thermal resistance of greater thicknesses of the material as a function of time.

Method B describes a simple test to determine a conservative design life-time value (25 years and longer) for an unfaced, closed-cell, cellular plastic product. This method is limited currently to unfaced homogeneous materials. For this method, multiple specimens of the core and surfaces of materials with variations in the slope of the primary stage thermal resistivity and a time relationship of less than 10 % within a sample are considered to be homogeneous. Generally, products with natural skins or with density deviations normally found with such products may be considered acceptable for test by this technique.

2 Normative references

The following normative document contains provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 7345, *Thermal insulation — Physical quantities and definitions*.

ISO 8301, *Thermal insulation — Determination of steady-state specific thermal resistance and related properties — Heat flow meter apparatus*.

ISO 8302, *Thermal insulation — Determination of steady-state thermal resistance and related properties — Guarded hot plate apparatus*.

ISO 9346, *Thermal insulation — Mass transfer — Physical quantities and definitions*.

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 7345 and ISO 9346, and the following apply.

NOTE A list of symbols is given in Table 1.

3.1 ageing

process by which the physical, mechanical and thermal properties of a material, product, or system change with time

NOTE 1 Accelerated tests can introduce effects that will not occur during natural ageing. Care should be taken when developing such test methods and methods of evaluation of test results.

NOTE 2 Examples of ageing processes are the settling of some low-density fibrous materials and gas diffusion in cellular plastics.

NOTE 3 Whatever the process, ageing is always strongly related to the environmental or service conditions to which the material, product or system is exposed and to its shape, size and finish. Accurate prediction of ageing effects should always consider these items.

3.2 aged value

value of a property of a material, product or system after exposure to known environmental conditions for a specified time

3.3 accelerated aged value

aged value obtained through laboratory test or through reproducible prediction models for a specified time interval and specified environmental conditions aimed at reproducing frequently encountered service conditions

NOTE The actual size, working environment and expected life-time should be compared carefully with those implied in the definition of an aged value.

3.4 design life-time

time interval during which an installed material, product or system should maintain its design performance

NOTE Life-time depends upon the serviceability of the installation, for example, the design life-time for a thermal insulation material, product or system used in a building might be at least 25 years.

3.5 effective diffusion coefficient

material property which relates the rate of gas transport to the gas pressure difference across the material having a specific thickness at a specific temperature

3.6 primary stage

portion of the ageing process where changes in thermal properties are influenced primarily by diffusion of gaseous components such as nitrogen and oxygen into or out of the closed-cell material

3.7 scaling factor

ratio of the squares of the product and test specimen thicknesses

NOTE This ratio represents the acceleration rate being applied to the ageing process of a cellular plastic due to thickness differences.

3.8**secondary stage**

portion of the ageing process where changes in thermal properties are influenced primarily by the diffusion of blowing agents usually high molecular weight gases out of the closed-cell material

3.9**thickness of damaged surface layer (TDSL)**

average thickness of surface cells, on one surface, which are ruptured or otherwise damaged during preparation of the test specimen

3.10**transition point**

estimated age of a closed-cell cellular plastic when the ageing process changes from the primary to secondary stage

NOTE This is also called the transfer point.

Table 1 — Symbols

Symbol	Quantity	Unit
a	thermal diffusivity (thermal diffusion coefficient)	m^2/s
λ	thermal conductivity	$\text{W}/(\text{m}\cdot\text{K})$
ρ	density	kg/m^3
c_p	specific heat capacity at constant pressure	$\text{J}/(\text{kg}\cdot\text{K})$
D	effective gas diffusion coefficient	m^2/s
D_0	effective gas diffusion coefficient of a reference slab	m^2/s
d	thickness of specimen (slices)	m
d_0	thickness of a reference slab	m
F	numerical coefficient	
F_0	Fourier number	
i	day i of ageing period	day
n	ageing period	days
r	thermal resistivity	$\text{m}\cdot\text{K}/\text{W}$
r_0	initial thermal resistivity	$\text{m}\cdot\text{K}/\text{W}$
r_t	thermal resistivity of a test specimen after time t	$\text{m}\cdot\text{K}/\text{W}$
R	thermal resistance	$\text{m}^2\cdot\text{K}/\text{W}$
R_{av}	average thermal resistance during ageing period	$\text{m}^2\cdot\text{K}/\text{W}$
R_0	initial thermal resistance	$\text{m}^2\cdot\text{K}/\text{W}$
R_t	thermal resistance of a test specimen after time t	$\text{m}^2\cdot\text{K}/\text{W}$
R_n	thermal resistance on last day of ageing period	$\text{m}^2\cdot\text{K}/\text{W}$
S	scaling factor	
t	time	day
t_0	initial time	day
T	temperature	K
T_1, T_2	uniform surface temperatures of a heated or cooled slab	K
T_m	mean slab temperature	K
TDSL	thickness of damaged surface layer	m

4 Test methods — General

4.1 Conditions

A summary of the analytical model that serves as the basis for the slicing and scaling method is given in annex A. The experimental procedure is based on the assumption that the material characteristics of thin specimens are equivalent to those of the material being investigated, i.e. specimens of reduced thickness have the same effective diffusion coefficient and initial cell gas content as those of the full-thickness material and that one-dimensional diffusion is the dominating factor.

Conditioning of full-thickness samples to obtain a service life 25 years or longer value requires too long a period of testing.

4.2 Effects of influencing parameters

Annex A also contains brief details of other important factors which affect the ageing process:

- errors due to small thickness used;
- thickness of damaged surface layers;
- ageing prior to preparation of specimen;
- inhomogeneities in the material;
- high and/or inconsistent open-cell content.

5 Method A — Test to determine time-dependent change in thermal properties of core materials

5.1 Principle

Method A is a general procedure for determining change in thermal resistance at any time due to reduced conditioning time. Random samples of a cellular plastic product having a thickness greater than 25 mm are selected and, from each, separate thin test specimens are prepared having a uniform thickness of approximately 10 mm, but not less than 6 mm, with allowance being made for cell damage at each cut surface. In order to minimize the effects of preparation on resultant thermal performance, it is recommended that the specimen thickness be such that the TDSL is no greater than 5 % of the geometric thickness. Measurements of thermal resistance, of the specimens are made at regular time intervals from an initial starting time, as soon as possible after manufacture, until values of the ratio of the thermal resistance to that at time zero indicate that the specimen has passed from the primary into the secondary stage of the ageing process. A value for the aged thermal resistance of the product is then obtained by use of scaling factors.

5.2 Sampling

Select in conformance with appropriate standard sampling procedures. The pieces shall be prepared as soon as possible and practical after production (a recommended minimum of 3 days). This is to ensure that the cell gas content within the sample is stabilized and representative of the initial conditions.

5.3 Preparation of specimens

5.3.1 Condition the block, board, spray-applied or foamed-in-place samples at $(23 \pm 2) ^\circ\text{C}$ and $(50 \pm 5) \%$ relative humidity of air in a climate-controlled room (usually less than 2 days).

5.3.2 Depending upon the original thickness cut or otherwise, prepare each sample into separate thin slices of uniform thickness. Discard a surface slice if it is protected by any type of diffusion-tight membrane. The overall area should be not less than the equivalent minimum metering area of the test apparatus. To avoid undue warpage of a test specimen for large total area apparatus, it may be necessary to cut slices as two pieces: one to provide the central test section a little larger than the apparatus metering area, plus a second surrounding annular section of the same thickness.