INTERNATIONAL STANDARD

**ISO 16534**

First edition
2012-05-15

# Thermal insulating products for building applications — Determination of compressive creep

*Produits isolants thermiques destinés aux applications du bâtiment — Détermination du fluage en compression*

Reference number
ISO 16534:2012(E)

# Contents

Page





Copyrighted material licensed to Dublin Institute of Technology by SAI Global (www.saiglobal.com), downloaded on 12 Jul 12 by Ann McSweeney.
No further reproduction or distribution is permitted. Uncontrolled when printed.

# 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 16534 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 16534 includes the original EN 1606 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 specimens;

— Clause 7.1: Test conditions;

— Clause 10: Test report.

# Introduction

ISO 16534 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 |



Copyrighted material licensed to Dublin Institute of Technology by SAI Global (www.saiglobal.com), downloaded on 12 Jul 12 by Ann McSweeney.
No further reproduction or distribution is permitted. Uncontrolled when printed.

| | | |
|---|---|---|
| 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 |



Copyrighted material licensed to Dublin Institute of Technology by SAI Global (www.saiglobal.com), downloaded on 12 Jul 12 by Ann McSweeney.
No further reproduction or distribution is permitted. Uncontrolled when printed.

# Thermal insulating products for building applications — Determination of compressive creep

## 1 Scope

This International Standard specifies the equipment and procedures for determining the compressive creep of specimens under various conditions of stress. It is applicable to thermal insulating products.

## 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 29469, *Thermal insulating products for building applications — Determination of compression behaviour*

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

ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

## 3 Terms and definitions

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

**3.1**
**thickness**
linear dimension measured perpendicular to the length and width plane

**3.1.1**
**thickness**
$d$
original product thickness

**3.1.2**
**thickness**
$d_{\mathrm{S}}$
initial thickness of the test specimen

**3.1.3**
**thickness**
$d_{\mathrm{L}}$
thickness of the test specimen under the basic compressive stress of the loading device ('dead weight')

**3.1.4**
**thickness**
$d_0$
thickness of the test specimen 60 s after the beginning of the loading process

**3.1.5**
**thickness**
$d_{\mathrm{t}}$
thickness of the test specimen at a given time, $t$

**3.2**
**compressive stress**
$\sigma_c$
ratio of the compressive force to the initial surface area of the cross-section of the test specimen

**3.3**
**deformation**
$X$
reduction in thickness of the test specimen

**3.4**
**relative deformation**
$\varepsilon$
ratio of the deformation of the test specimen $X$, and its thickness $d_s$, measured in the direction of loading

**3.5**
**compressive creep**
$X_{ct}$
increase in deformation of the test specimen under a constant stress with time under specified conditions of temperature and humidity

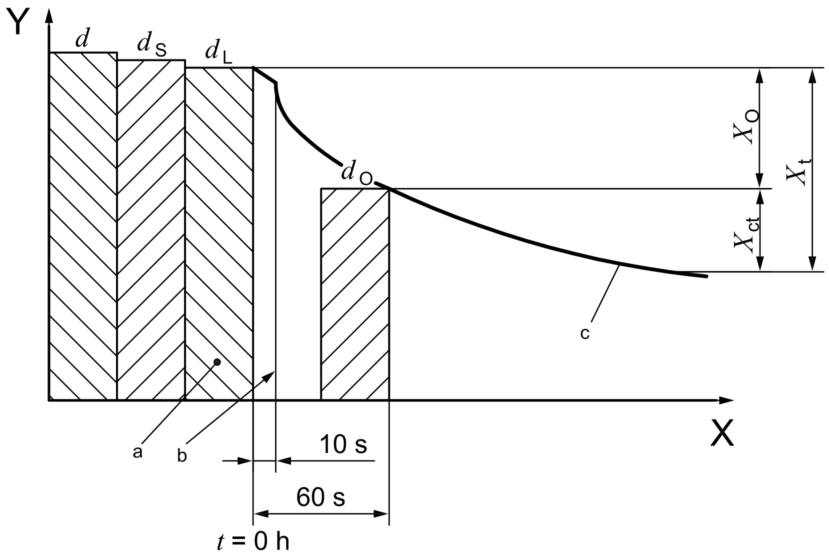
$$X_{ct} = X_t - X_0$$

where

$X_t$ is the deformation at time $t$;

$X_0$ is the initial deformation (after 60 s from the beginning of loading).

An illustration of the different thicknesses and deformations is given in Figure 1.




**Key**

a thickness

b time, $t$

c deformation curve

$d_L$ reference value for deformation measurements

1 'Dead weight' of the loading device (<10 % of the smallest stress chosen for the creep test).

2 Load applied in the compressive creep test.

NOTE In the illustration, $d_L$ is used as a reference value for deformation measurements. If $d_S$ is used as the reference value, the illustration can be used, omitting the column for $d_L$ (see 7.3).

**Figure 1 — Illustration of the different thicknesses and deformations**

## 4 Principle

The compressive creep is determined by measuring the increase in deformation of a specimen under constant compressive stress and specified conditions of temperature, humidity and time.

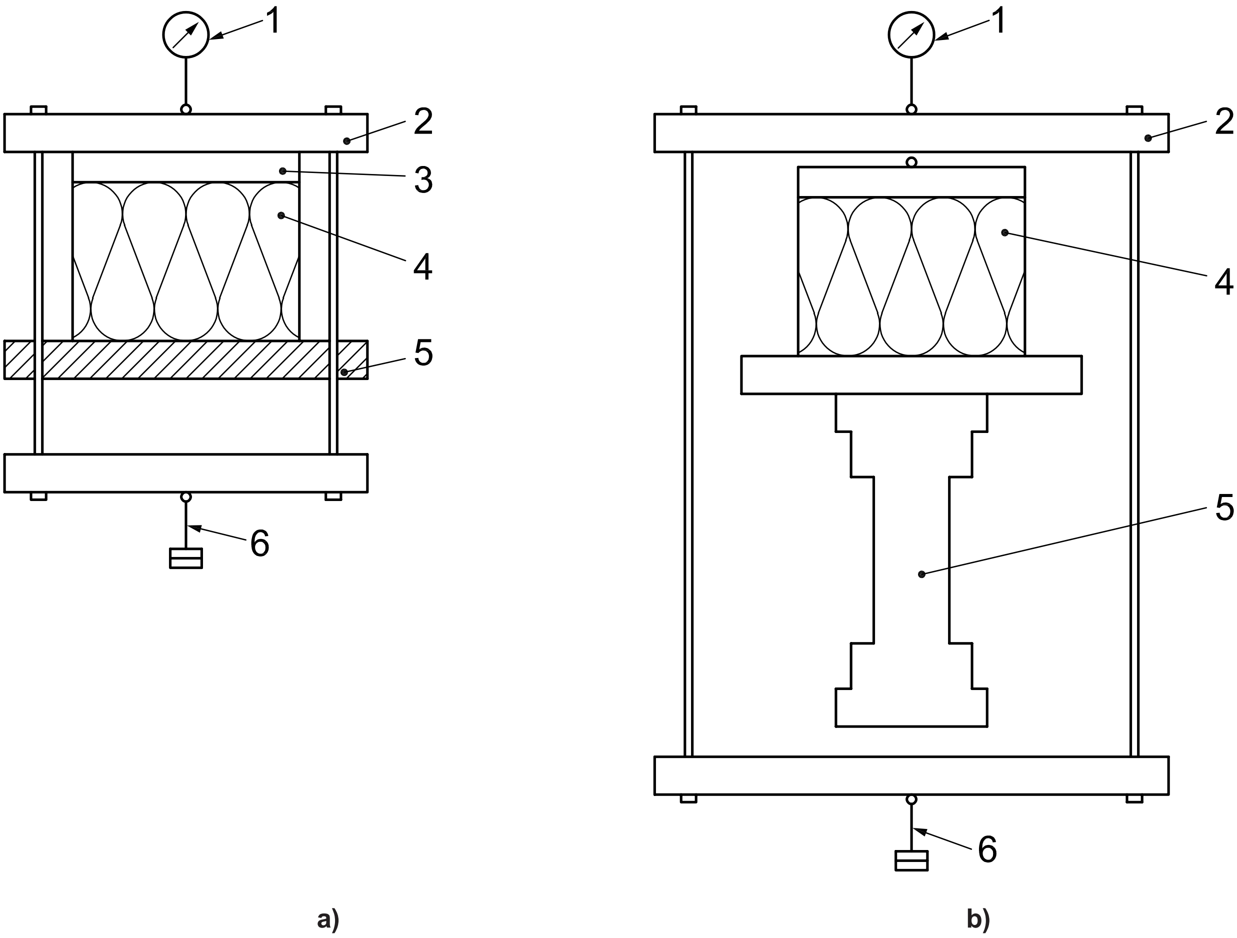
## 5 Apparatus

**5.1 Loading device,** consisting of two flat platens, one of which shall be movable, arranged so that they compress the specimen in a vertical direction. The movable platen shall be guided in such a manner as to be self-aligning. The platens shall be capable of being loaded smoothly and without distortion so that, during the test, the static stress does not change by more than ± 5 %.

**5.2 Measuring device** (e.g. dial gauge), capable of determining the distance between the two platens, i.e. the deformation of the specimen, to an accuracy of 0,01 mm.

**5.3 Suitable damping measures,** to minimize the effects of external vibration (e.g. substantial foundation of the apparatus support).

Examples of the testing apparatus are given in Figure 2.




**Key**

1 displacement transducer or dial gauge
2 loading bridge
3 load distribution plate (movable, self-aligning)
4 test specimen
5 support beam
6 loading by weights

**Figure 2 — Examples of test apparatus**

# 6 Test specimens

## 6.1 Selection of test specimens

The specimens for determining the compressive creep shall be taken from the same sample, with the same preparation as the specimens used for the compression test as specified in EN 826.

The method of selecting the specimens shall be as specified in the relevant product standard.

NOTE In the absence of a product standard or any other technical specification, the method of selection of the test specimens can be agreed between parties.

## 6.2 Dimensions of test specimens

The thickness of specimens shall be equal to the original product thickness. The width of the specimens shall not be less than their thickness. Products with facings or integrally moulded skins which are retained in use shall be tested with these faces or skins intact.

Test specimens shall not be layered to produce a greater thickness for testing.

The specimens shall be cut squarely and have sides with the following recommended dimensions:

— 50 mm × 50 mm; or

— 100 mm × 100 mm; or

— 150 mm × 150 mm; or

— 200 mm × 200 mm or

— 300 mm × 300 mm.

The dimensions of specimens shall be the same as used in the compression test as described in ISO 29469. These are specified in the relevant product standard or agreed between parties.

The linear dimensions shall be determined in accordance with ISO 29768, to an accuracy of 0,5 %.

The tolerance and parallelism and flatness between the upper and lower face of the specimen shall not be greater than 0,5 % of its side length, with a maximum of 0,5 mm.

If the specimen is not flat, it shall be ground flat or an adequate coating shall be applied to prepare the surface for the test. Where it is coated, no significant creep should occur in the coating or it shall be taken into account by deducting the creep of the coating.

### 6.3 Number of test specimens

The number of specimens shall be as specified in the relevant product standard. If the number is not specified, then at least three specimens shall be used for each compressive stress selected from 7.2.

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

### 6.4 Preparation of test specimens

The specimens shall be cut so that the direction of loading applied to the product will correspond to the direction in which the compressive forces are applied to the product in use.

The specimens shall be cut by methods that do not change the original structure of the product.

For products with non-parallel faces, the parallelism of the upper and lower face of the specimen shall be in accordance with 6.2.

NOTE Special methods of preparation, when needed, may be given in the relevant product standard.

### 6.5 Conditioning of test specimens

The specimens shall be conditioned for at least 24 h under the test conditions. In case of dispute, the time for conditioning (equilibrium of moisture content) shall be as specified in the relevant product standard.

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

## 7 Procedure

### 7.1 Test conditions

The test shall be carried out at (23 ± 2) °C and (50 ± 5) % RH.

NOTE Other conditions can be given in the relevant product standard or can be agreed between parties.

In tropical countries, different conditioning and testing conditions may be relevant. In this case, the conditions shall be (27 ± 2) °C and (65 ± 5) % RH.

## 7.2 Stress selection

The test shall be carried out at three or more different stresses.

To verify one defined level of stress only this level shall be used.

The alternative stresses for the creep test, $\sigma_c$, shall be based on either the compressive strength, $\sigma_m$, or the compressive stress, $\sigma_{10}$, at 10 % strain measured in accordance with ISO 29469, and shall be calculated as follows:

$\sigma_c = 0,15 \times \sigma_m$ or $\sigma_c = 0,15 \times \sigma_{10}$

$\sigma_c = 0,20 \times \sigma_m$ or $\sigma_c = 0,20 \times \sigma_{10}$

$\sigma_c = 0,25 \times \sigma_m$ or $\sigma_c = 0,25 \times \sigma_{10}$

$\sigma_c = 0,30 \times \sigma_m$ or $\sigma_c = 0,30 \times \sigma_{10}$

$\sigma_c = 0,35 \times \sigma_m$ or $\sigma_c = 0,35 \times \sigma_{10}$

NOTE If appropriate, other values of $\sigma_c$ may be chosen.

## 7.3 Test procedure

If the thickness of a specimen, $d_s$, is to be determined without using the loading device, it shall be measured to an accuracy of 0,1 mm, in accordance with ISO 29768.

Place the specimen carefully in the loading device, under the ‘dead weight’ of the loading device. The thickness under this load, $d_L$, is to be considered the reference value for the deformation measurements. Determine $d_L$ to the nearest 0,01 mm.

The stress imposed by the ‘dead weight’ shall be less than 10 % of the minimum stress selected for the test.

If the thickness of the specimen, $d_s$, is determined using the loading device, the specimen shall be preloaded by applying a pressure of (250 ± 10) Pa and the thickness measured to an accuracy of 0,01 mm. This value shall then be used as the reference value for the deformation measurements.

If a significant deformation occurs under the pressure of 250 Pa, then a load corresponding to 50 Pa may be used, assuming that such a load is specified in the relevant product standard. In this case, the thickness, $d_s$, should be determined under the same load.

Apply the selected stress uniformly to the specimen within (10 ± 5) s.

Determine the initial deformation, $X_0$, to the nearest 0,01 mm (60 ± 5) s after loading has started.

Determine the deformation, $X_t$, to the nearest 0,01 mm at the following times after loading:

0,1 h, 1 h, 5 h, and then at the following days after loading has started: 1, 2, 4, 7, 9, 11, 14, 18, 24, 32, 42, 53, 65 and 80 days, and once between 90 days and 100 days.

NOTE These times, expressed in hours, are equidistant time increments in a logarithmic time scale.

If the test is continued after 90 days (see 7.4), readings shall be made at equidistant time increments (logarithmic scale). An example for appropriate reading time increments is given in Figure 3.

When the product to be tested incorporates a facing which is difficult to remove or if a coating is added for testing purposes, the compressive creep may be measured by the relative movement of the flat platens of the loading device. Alternatively, it may be measured from the relative movement of reference points placed on the edges of the material, if the intention is to access the material itself.

### 7.4 Duration of test

The compressive creep shall be measured at time intervals given in 7.3 over a period of at least 90 days. The duration of the test shall be as specified in the relevant product standard or shall be agreed between the parties. The total duration of testing depends on the required extrapolation time, which shall be determined in accordance with Annex A.

## 8 Calculation and expression of results

The deformation value, $X_t$, shall be tabled for each specimen.

Calculate the relative deformation, $\varepsilon_t$, as a percentage, for each specimen, using Equation (1):

$$\varepsilon_t = \frac{X_t}{d_s} \times 100 \qquad (1)$$

where

$X_t$ is the deformation at time $t$, in mm;

$d_s$ is the thickness of the specimen, in mm.

The relative deformation for each specimen and the mean value of the three relative deformations for each stress level shall be plotted in a semi-log (time) or a log/log diagram. The calculation of creep deformation and the equation for its extrapolation is given in Annex A.

## 9 Accuracy of measurement

Following the experience from a “round robin test” where comparable test equipment and test specimen preparation were used, the accuracy for compressive creep $\varepsilon_{ct}$ and total deformation $\varepsilon_t$ when measured under a static load can be estimated as given below:

— Repeatability limit $r$ with a probability of 95 %: Approximately 0,5 %;

— Reproducibility limit $R$ with a probability of 95 %: Approximately 1,2 %.

The above mentioned terms are applied as described in ISO 5725-2.

## 10 Test report

The test report shall include the following information:

a) Reference to this International Standard, i.e. ISO 16534:2012;

b) Product identification

   1) product name, factory, manufacturer or supplier;

   2) production code number;

   3) type of product;

   4) packaging;

   5) the form in which the product arrived at the laboratory;

   6) other information as appropriate (e.g. nominal thickness, nominal density);

c) Test procedure

   1) pre-test history and sampling (e.g. person taking the sample, place of sampling);

2) conditioning;

3) any deviations from Clauses 6 and 7;

4) date of testing;

5) conditioning and testing conditions in tropical countries, if applicable;

6) dimensions and number of specimens;

7) kind of surface treatment (grinding or type of coating);

8) general information relating to the test (strength, $\sigma_m$, or stress, $\sigma_{10}$, measured in accordance with EN 826 and the chosen stresses, $\sigma_c$);

9) events which may have affected the results;

d) Results

1) the tabled deformation values and the diagrams $X_t$ versus $t$ in semi-log or log/log form for each specimen, and the mean values for the chosen stresses:

2) results according to Annex A for each stress level, if any:

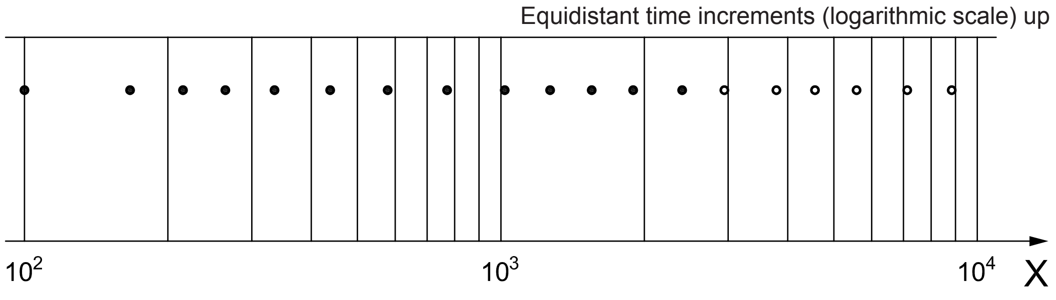
i) the statistical parameters $a$, $b$, and $r^2$;

ii) factors $m$ and $b$ of the Findley equation;

iii) the creep deformation, $X_{ct}$, together with the linear regression analysis in a log/log diagram;

iv) the relative deformation, $\varepsilon$, and the extrapolation curve in a semi-log diagram.

Information about the apparatus and identity of the person responsible for the test should be available in the laboratory, but it need not be recorded in the report.




**a) Time, $t$ in h**

**Key**

• Readings for the required test duration of 90 days (see 7.3)

○ Readings for a test duration longer than 90 days (see 7.4)

| Day | Time | Duration in h | Day of the week |
|---|---|---|---|
| 0 | 10:00 | 0 (loading) | Monday |
| 0 | 10:01 | 0,017 | Monday |
| 0 | 11:00 | 1,0 | Monday |
| 0 | 15:00 | 5,0 | Monday |
| 1 | 10:00 | 24 | Tuesday |
| 2 | 10:00 | 48 | Wednesday |
| 4 | 14:00 | 100 | Friday |
| 7 | 10:10 | 168 | Monday |
| 9 | 10:00 | 216 | Wednesday |
| 11 | 10:00 | 264 | Friday |
| 14 | 10:00 | 336 | Monday |
| 18 | 10:00 | 432 | Friday |
| 24 | 10:00 | 576 | Thursday |
| 32 | 10:00 | 768 | Friday |
| 42 | 10:00 | 1 008 | Monday |
| 53 | 10:00 | 1 272 | Friday |
| 65 | 10:00 | 1 560 | Wednesday |
| 80 | 10:00 | 1 920 | Thursday |
| 100 | 10:00 | 2 400 | Wednesday |
| 123 | 10:00 | 2 952 | Friday |
| 156 | 10:00 | 3 744 | Wednesday |
| 190 | 10:00 | 4 560 | Tuesday |
| 231 | 10:00 | 5 544 | Monday |
| 295 | 10:00 | 7 080 | Tuesday |
| 365 | 10:00 | 8 760 | Tuesday |

**Figure 3 — Reading times — Example of time intervals for deformation measurements**

# Annex A
(normative)

# Calculation method

## A.1 General

This Annex specifies a calculation method for the determination of a long-term deformation value of thermal insulating products due to compressive creep. In case of positive validation of another mathematical model, that model shall be incorporated by amendment or revision of this Annex.

This method may be used to define a permissible load in practical applications and/or to define the compressive behaviour of a certain product.

In order to make a reliable extrapolation of the behaviour of thermal insulating products with time, when tested in accordance with this International Standard, the results of many tests and experience are required. This experience is not yet available for all products. It has been well established and confirmed for different plastic foam products. For other products, tests are still running and no mathematical model has yet been validated.

A validation shall be based on measurements over a period of at least five years for different products within the same product family. Based on these measurements, different mathematical models shall be evaluated by using measured values from periods of up to two years and comparing the extrapolation with the data obtained over a period of five years.

This Annex gives a permissible extrapolation, with a maximum extrapolation up to 30 times the testing time.

To validate the characteristic form of a curve based on the mathematical model, it should be similar to that obtained by the measured values.

Even with an extrapolation up to 30 times the testing time, it is recommended that a safety factor should be applied for the determination of long-term allowable stress and the corresponding deformation.

## A.2 Principle

The calculation method is based on a mathematical function called the Findley equation [1] (A.1), which allows the description of the creep behaviour of thermal insulating products, provided that the linear regression analysis according to Equation (A.2) fits with a coefficient of determination $r^2 \geq 0,9$.

$$X_{\mathrm{t}} = X_0 + m \times t^{\mathrm{b}} \tag{A.1}$$

where $m$ and $b$ are material constants.

Equation (A.1) can be written in a logarithmic form, as follows:

$$\log (X_{\mathrm{t}} - X_0) = \log m + b \times \log t \tag{A.2}$$

Hence it follows that log $m$ is the intercept of the ordinate and $b$ is the slope of the straight line defined by this equation. These constants shall be calculated by a regression analysis based on the measured deformation as a function of time.

## A.3 Procedure

**A.3.1** Using the values for the thickness of the test specimens, $d_S$ and $d_L$, and deformation values, $X_0$ and $X_t$, at a time, $t$, measured in accordance with this International Standard, the terms log $t$, $X_{ct}$, log $X_{ct}$ shall be calculated starting with the value read after seven days ( = 168 h).

This period of seven days may be reduced if the measured data show a linear behaviour in a log/log diagram corresponding to Equation (A.2).

**A.3.2** For the linear regression analysis, the following statistical terms shall be determined.

General equation for the linear regression line:

$$y = a + b \times x \tag{A.3}$$

$$x_m = \Sigma x_t / n \tag{A.4}$$

$$y_m = \Sigma y_t / n \tag{A.5}$$

$$Q_x = \sum x_t^2 - \left[ \left( \sum x_t \right)^2 / n \right] \tag{A.6}$$

$$Q_y = \sum y_t^2 - \left[ \left( \sum y_t \right)^2 / n \right] \tag{A.7}$$

$$Q_{xy} = \sum x_t y_t - \left[ \left( \sum x_t \right) \times \left( \sum y_t \right) / n \right] \tag{A.8}$$

$$s_R^2 = \left[ Q_y - \left( Q_{xy}^2 / Q_x \right) \right] / (n - 2) \tag{A.9}$$

$$s_R = \sqrt{s_R^2} \tag{A.10}$$

$$r^2 = Q_{xy}^2 / \left( Q_x \times Q_y \right) \tag{A.11}$$

$$r = \sqrt{r^2} \tag{A.12}$$

$$b = Q_{xy} / Q_x \tag{A.13}$$



Copyrighted material licensed to Dublin Institute of Technology by SAI Global (www.saiglobal.com), downloaded on 12 Jul 12 by Ann McSweeney.
No further reproduction or distribution is permitted. Uncontrolled when printed.

$$a = y_m - b \times x_m \tag{A.14}$$

where

$n$ is the number of values;

$x_t$ is the time, log $t$;

$y_t$ is the creep deformation, log $X_{ct}$;

$x_m$ is the mean value of $x_t$;

$y_m$ is the mean value of $y_t$;

$Q_x$ is the sum of squares of deviations, referring to $x$ values;

$Q_y$ is the sum of squares of deviations, referring to $y$ values;

$Q_{xy}$ is the sum of the deviations;

$s_R^2$ is the variance;

$s_R$ is the standard deviation;

$r^2$ is the coefficient of determination;

$r$ is the correlation coefficient;

$a$ is the intercept of the ordinate;

$b$ is the slope of the line.

## A.4 Calculation of long-term deformation

By using Equation (A.1), with $b$ from Equation (A.13), and by putting $m = 10^a$, a long-term deformation at any time, $t$, can be calculated. Extrapolation is permissible up to 30 times of the testing time, provided that $r^2 \geq 0,9$ (see example in Annex B).

# Annex B
(informative)

# Example of a linear regression analysis

Table B.1 gives the measured values for the deformation of three single specimens for one compressive stress. These are recorded after various time periods. In this example, the results are analysed using a linear regression technique, as described in Annex A, for the mean values of the specimens.

The calculated statistical values are:

$x_m = 3{,}238\ 72$

$y_m = -0{,}868\ 83$

$Q_x = 7{,}770\ 76$

$Q_y = 0{,}277\ 14$

$Q_{xy} = 1{,}444\ 65$

$s_R^2 = 0{,}000\ 41$

$s_R = 0{,}020\ 20$

$r^2 = 0{,}969\ 08\ (r^2 > 0{,}9)$

$r = 0{,}984\ 42$

$b = 0{,}185\ 91$

$a = -1{,}470\ 94$

Figure B.1 shows straight line regression analysis of the values of log $X_{ct}$ versus log $t$, with $m = 0{,}033\ 81$ and $b = 0{,}185\ 91$.

The long-term deformation value of the specimens for 10 years (about 87 600 h), for example, is to be calculated using Equation (A.1), with $m$ and $b$ as given above:

$$X_{87\ 600} = X_0 + 0{,}033\ 81 \times 87\ 600^{0{,}185\ 91}$$

$$X_{87\ 600} = 0{,}50 \text{ mm}$$

The relative deformation follows from (see Clause 8):

$$\varepsilon_t = \frac{X_t}{d_s} \times 100$$



Copyrighted material licensed to Dublin Institute of Technology by SAI Global (www.saiglobal.com), downloaded on 12 Jul 12 by Ann McSweeney.
No further reproduction or distribution is permitted. Uncontrolled when printed.

$$\varepsilon_{87\,600} = \frac{0{,}50}{50{,}2} \times 100$$

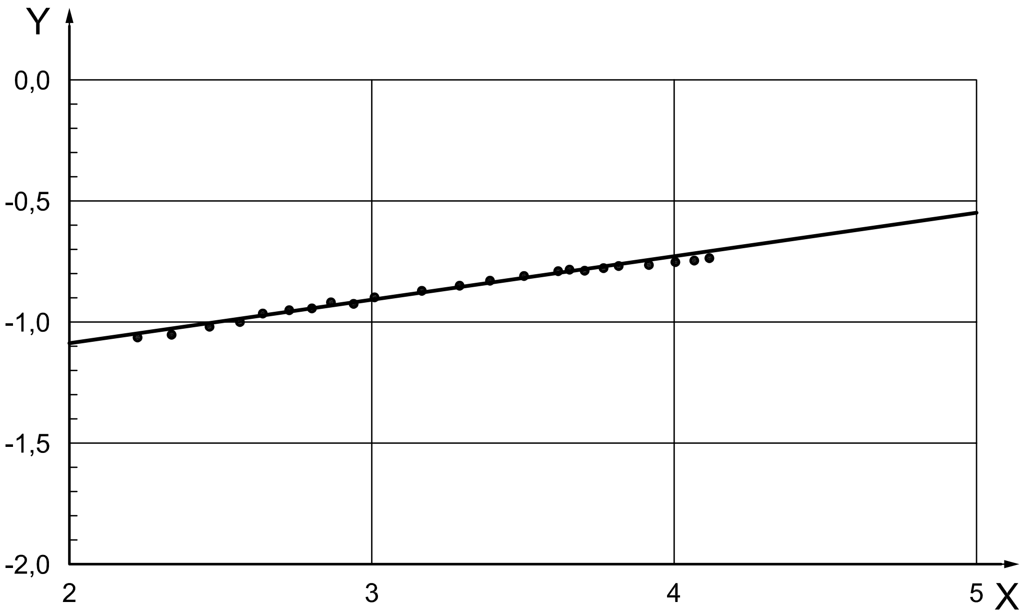
$$\varepsilon_{87\,600} = 1{,}0\ \%$$

In Figure B.2, the relative deformation, $\varepsilon_t$, shall be plotted against time in a semi-log diagram. In this plot, the measured values are depicted as points (●), and the curve is based on the mathematical calculation showing the extrapolation up to 100 000 h (about 11,4 years).

**Table B.1 — Measured values for the deformation of three single specimens for one compressive stress**

| Test specimen | No. 1 | No. 2 | No. 3 |
|---|---|---|---|
| Thickness, $d_S$ mm | 50,2 | 50,2 | 50,2 |
| Thickness, $d_L$ mm | 50,19 | 50,24 | 50,24 |
| Deformation, $X_0$ mm | 0,22 | 0,23 | 0,21 |

| **Time** $t$ h | log $t$ | **Deformation** $X_t$ mm | | | **Relative deformation** $\varepsilon_t$ % | | | $\varepsilon_t$ **(mean)** % | **Compressive creep** $X_{ct}$ mm | | | $X_{ct}$ **(mean)** mm | log $X_{ct}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. 1 | No. 2 | No. 3 | No. 1 | No. 2 | No. 3 | | No. 1 | No. 2 | No. 3 | | |
| 167 | 2,222 72 | 0,31 | 0,31 | 0,29 | 0,61 | 0,61 | 0,58 | 0,601 | 0,09 | 0,08 | 0,08 | 0,082 | −1,086 19 |
| 215 | 2,332 44 | 0,31 | 0,31 | 0,30 | 0,61 | 0,63 | 0,59 | 0,608 | 0,09 | 0,08 | 0 09 | 0,085 | −1,068 88 |
| 287 | 2,457 88 | 0,31 | 0,32 | 0,30 | 0,62 | 0,64 | 0,60 | 0,621 | 0,09 | 0,09 | 0,09 | 0,092 | −1,036 21 |
| 357 | 2,552 67 | 0,32 | 0,33 | 0,31 | 0,64 | 0,65 | 0,62 | 0,637 | 0,10 | 0,10 | 0,10 | 0,100 | −1,000 00 |
| 431 | 2,634 48 | 0,33 | 0,33 | 0,32 | 0,66 | 0,66 | 0.63 | 0,652 | 0,11 | 0,10 | 0,11 | 0,107 | −0,969 27 |
| 527 | 2,721 81 | 0,33 | 0,34 | 0,32 | 0,66 | 0,67 | 0,64 | 0,657 | 0,11 | 0,11 | 0,11 | 0,110 | −0,958 61 |
| 623 | 2,794 49 | 0,34 | 0,34 | 0,32 | 0,67 | 0,68 | 0,64 | 0,663 | 0,12 | 0,11 | 0,11 | 0,113 | −0,946 92 |
| 719 | 2,856 73 | 0,34 | 0,35 | 0,33 | 0,68 | 0,69 | 0,66 | 0,677 | 0,12 | 0,12 | 0,12 | 0,120 | −0,920 82 |
| 863 | 2,936 01 | 0,34 | 0,35 | 0,32 | 0,67 | 0,70 | 0,64 | 0,672 | 0,12 | 0,12 | 0,11 | 0,118 | −0,929 35 |
| 1 007 | 3,003 03 | 0,35 | 0,36 | 0,34 | 0,70 | 0,71 | 0,67 | 0,692 | 0,13 | 0,13 | 0,13 | 0,127 | −0,895 06 |
| 1 439 | 3,158 06 | 0,36 | 0,37 | 0,35 | 0,72 | 0,73 | 0,69 | 0,715 | 0,14 | 0,14 | 0,14 | 0,139 | −0,855 94 |
| 1 943 | 3,288 47 | 0,36 | 0,38 | 0,35 | 0,73 | 0,75 | 0,70 | 0,725 | 0,14 | 0,15 | 0,14 | 0,144 | −0,841 64 |
| 2 447 | 3,388 63 | 0,37 | 0,38 | 0,36 | 0,74 | 0,76 | 0,72 | 0,740 | 0,15 | 0,15 | 0,15 | 0,152 | −0,819 11 |
| 3 215 | 3,507 18 | 0,38 | 0,39 | 0,37 | 0,75 | 0,78 | 0,73 | 0,752 | 0,16 | 0,16 | 0,16 | 0,158 | −0,802 26 |
| 4 127 | 3,615 63 | 0,38 | 0,40 | 0,37 | 0,77 | 0,79 | 0,74 | 0,765 | 0,16 | 0,17 | 0,16 | 0,164 | −0,784 27 |
| 4 487 | 3,651 96 | 0,39 | 0,40 | 0,37 | 0,77 | 0,80 | 0,74 | 0,771 | 0,17 | 0,17 | 0,16 | 0,167 | −0,777 28 |
| 5 015 | 3,700 27 | 0,39 | 0,40 | 0,38 | 0,78 | 0,80 | 0,75 | 0,775 | 0,17 | 0,17 | 0,17 | 0,169 | −0,772 11 |
| 5 855 | 3,767 53 | 0,39 | 0,40 | 0,38 | 0,78 | 0,80 | 0,76 | 0,780 | 0,17 | 0,17 | 0,17 | 0,172 | −0,765 31 |
| 6 527 | 3,814 71 | 0,40 | 0,41 | 0,38 | 0,79 | 0,81 | 0,76 | 0,787 | 0,18 | 0,18 | 0,17 | 0,175 | −0,756 14 |
| 8 159 | 3,911 64 | 0,40 | 0,40 | 0,38 | 0,79 | 0,80 | 0,76 | 0,783 | 0,18 | 0,17 | 0,17 | 0,173 | −0,761 12 |
| 10 007 | 4,000 30 | 0,40 | 0,41 | 0,39 | 0,80 | 0,81 | 0,77 | 0,792 | 0,18 | 0,18 | 0,18 | 0,178 | −0,749 58 |
| 11 519 | 4,061 41 | 0,40 | 0,41 | 0,39 | 0,80 | 0,81 | 0,77 | 0,794 | 0,18 | 0,18 | 0,18 | 0,179 | −0,747 15 |
| 12 959 | 4,112 57 | 0,41 | 0,41 | 0,39 | 0,81 | 0,82 | 0,78 | 0,800 | 0,19 | 0,18 | 0,18 | 0,182 | −0,739 93 |

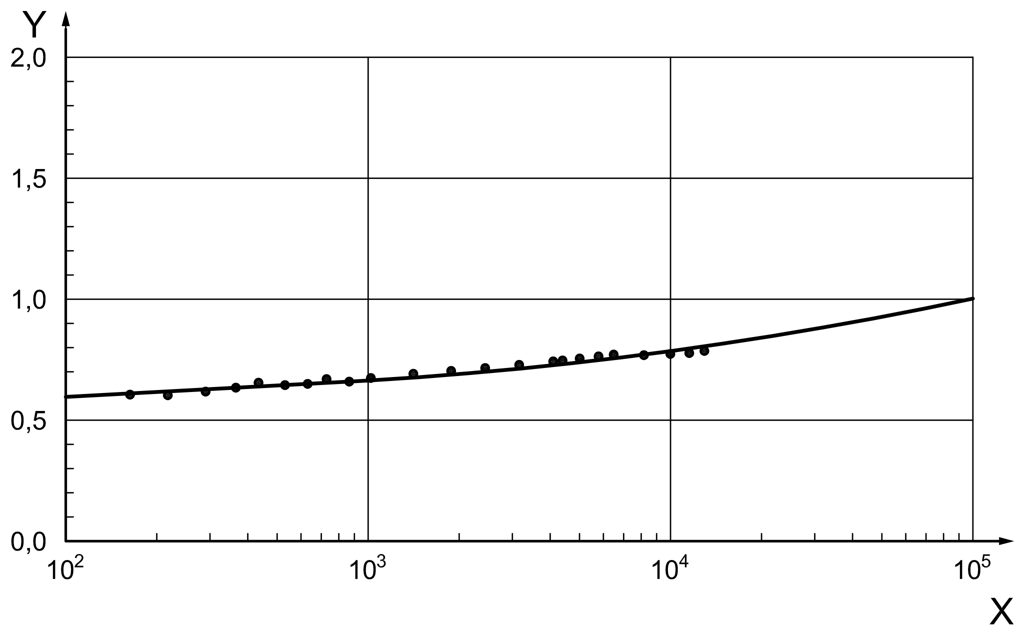



**Key**

X log $X_{ct}$ ($X_{ct}$ in millimetres)

Y log $t$ ($t$ in h)

**Figure B.1 — Creep deformation — Regression analysis**




**Key**

X deformation, $\varepsilon_t$, as a percentage

Y time, $t$, in h

**Figure B.2 — Long-term compressive creep behaviour — Measured values and calculated extrapolation**

# Bibliography

[1] FINDLEY, W.N. *Creep characteristics of plastics*. Symposium on plastics, American Society of Testing Materials, 1994, pp 118-34.




Copyrighted material licensed to Dublin Institute of Technology by SAI Global (www.saiglobal.com), downloaded on 12 Jul 12 by Ann McSweeney.
No further reproduction or distribution is permitted. Uncontrolled when printed.

Copyrighted material licensed to Dublin Institute of Technology by SAI Global (www.saiglobal.com), downloaded on 12 Jul 12 by Ann McSweeney.
No further reproduction or distribution is permitted. Uncontrolled when printed.

**ICS 91.100.60**

Price based on 16 pages



Copyrighted material licensed to Dublin Institute of Technology by SAI Global (www.saiglobal.com), downloaded on 12 Jul 12 by Ann McSweeney.
No further reproduction or distribution is permitted. Uncontrolled when printed.