

# Protective clothing — Protection against heat and fire — Method of test: Evaluation of materials and material assemblies when exposed to a source of radiant heat

The European Standard EN ISO 6942:2002 has the status of a  
British Standard

ICS 13.340.10

## National foreword

This British Standard is the official English language version of EN ISO 6942:2002. It is identical with ISO 6942:2002. It supersedes BS EN 366:1993 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PH/3, Protective clothing, to Subcommittee PH/3/2, Clothing for protection against heat and flame, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

### Cross-references

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### Summary of pages

This document comprises a front cover, an inside front cover, the EN ISO title page, pages 2 to 15, and a back cover.

The BSI copyright date displayed in this document indicates when the document was last issued.

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Vêtements de protection - Protection contre la chaleur et le  
feu - Méthode d'essai: Evaluation des matériaux et  
assemblages des matériaux exposés à une source de  
chaleur radiante (ISO 6942:2002)

Schutzkleidung - Schutz gegen Hitze und Feuer -  
Prüfverfahren: Beurteilung von Materialien und  
Materialkombinationen, die einer Hitze-Strahlungsquelle  
ausgesetzt sind (ISO 6942:2002)

This European Standard was approved by CEN on 12 November 2001.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

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## Foreword

This document (ISO 6942:2002) has been prepared by Technical Committee ISO/TC 94 "Personal safety - Protective clothing and equipment" in collaboration with Technical Committee CEN/TC 162 "Protective clothing including hand and arm protection and lifejackets", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2002, and conflicting national standards shall be withdrawn at the latest by December 2002.

This document supersedes EN 366:1993.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative annex ZA, which is an integral part of this document.

Annex A is informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

## Introduction

Protective clothing against radiant heat is worn at different occasions and accordingly the radiation intensity (characterised by the heat flux density) acting on the clothing material extends over a wide range. This European Standard describes two test methods which can be applied to all sorts of materials, but, according to the intended use of the material, the heat flux density has to be chosen properly and the results have to be interpreted correctly,

Industrial workers or fire fighters may be exposed to a relatively low radiation intensity over a long period of time. On the other hand, industrial workers or fire fighters may be exposed to medium radiation intensities for relatively short periods of time or to high radiation intensities for very short periods of time. In the latter case, the clothing material may be changed or even destroyed.

The materials for the protective clothing should be tested at medium and high heat flux densities. The reaction on method A and the times  $t_{12}$  and  $t_{24}$  and transmission factor measured with method B characterise the material. Information of the precision of method B see annex A.

## 1 Scope

This European Standard specifies two complementary methods (method A and method B) for determining the behaviour of materials for heat protective clothing subjected to heat radiation.

These tests are carried out on representative single or multi-layer textiles or other materials intended for clothing for protection against heat. They are also applicable to assemblies, which correspond to the overall build up of a heat protective clothing assembly with or without underclothing,

Method A serves for visual assessment of any changes in the material after the action of heat radiation. With method B the protective effect of the materials is determined. The materials may be tested either by both methods or only by one of them.

The tests according to these two methods serve to classify materials; however, to be able to make a statement or prediction as to the suitability of a material for protective clothing additional criteria must be taken into account.

Since the tests are carried out at room temperature the results do not necessarily correspond to the behaviour of the materials at higher ambient temperatures and therefore are only to a limited extent suitable for predicting the performance of the protective clothing made from the materials under test.

## 2 Normative reference

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at appropriate places in the text and the publications are listed below. In the case of dated references, subsequent amendments to, or revisions of, any of these publications, apply to this European Standard only when incorporated into it by amendment or revision. In the case of undated references the latest edition of the publications referred to applies (including amendments).

EN 20139

Textiles - standard atmospheres for conditioning and testing (ISO 139:1973)

IEC 60584-1

Thermocouples. Part 1: Reference table

### 3 Terms and definitions

For the purposes of this standard, the following terms and definitions apply,

#### 3.1 heat transfer levels

Time $t_{12}$	The time in seconds expressed to one decimal place, to achieve a calorimeter temperature rise of $(12 \pm 0,1)$ °C
Time $t_{24}$	The time in seconds expressed to one decimal place, to achieve a calorimeter temperature rise of $(24 \pm 0,2)$ °C

#### 3.2 heat transmission factor (TF)

A measure of the fraction of heat transmitted through a specimen exposed to a source of radiant heat. It is numerically equal to the ratio of the transmitted to the incident heat flux density.

#### 3.3 test specimen

All the layers of fabric or other material arranged in the order and orientation as used in practice and including undergarments if appropriate.

#### 3.4 incident heat flux density:

The amount of energy incident per unit time on the exposed face of the calorimeter, expressed in kW/m<sup>2</sup>.

#### 3.5 radiant heat transfer index (RHTI)

A number, to one decimal place calculated from the mean time (measured in seconds, to one decimal place) to achieve a temperature rise of  $(24 \pm 0,2)$  °C in the calorimeter when testing by this method with a specified incident heat flux density.

#### 3.6 change in appearance of the specimen

All changes in appearance of the material (shrinkage, formation of char, discoloration, scorching, glowing melting etc.).

#### 3.7 multi-layer clothing assembly

series of layers in garments arranged in the order as worn

NOTE It may contain multi-layer materials, material combinations or separate layers of clothing material in single layers.

### 4 Principle

#### 4.1 Method A

A specimen is supported in a free-standing frame (specimen holder) and is exposed to a specific level of radiant heat for a specific time. The level of radiant heat is set by adjustment of the distance between the specimen and the thermal radiation source. Following the exposure, the specimen and its individual layers, are examined for visible changes.

#### 4.2 Method B

A specimen is supported in a free-standing frame (specimen holder) and is exposed to a specific level of radiant heat. The times for temperature rises of 12 °C and 24 °C in the calorimeter are recorded and are expressed as radiant heat transfer indexes. The percentage heat transmission factor is calculated from the temperature rise data and is also reported.

## 5 Apparatus

### 5.1 General

The test apparatus consists of the following items, which are used for both test methods:

- source of radiation (5.2);
- test frame (5.3);
- specimen holder (5.3).

For method B, the following are also required:

- calorimeter (5.4);
- temperature measuring and recording device (5.5).

### 5.2 Source of radiation

The radiation source consists of six silicon carbide (SiC) heating rods, with the following characteristics:

- total length:  $(356 \pm 2)$  mm;
- length of heating part:  $(178 \pm 2)$  mm;
- diameter:  $(7,9 \pm 0,1)$  mm;
- electrical resistance:  $3,6 \Omega \pm 10 \%$  at  $1070 \text{ }^\circ\text{C}$ .

These rods are placed in a U-shaped support made of insulating, flame resistant material so that they are arranged horizontally and in the same vertical plane. Figure 1 shows the constructional details of the support and the arrangement of the heating rods, which, are loosely mounted in the grooves of the support to avoid mechanical stress.

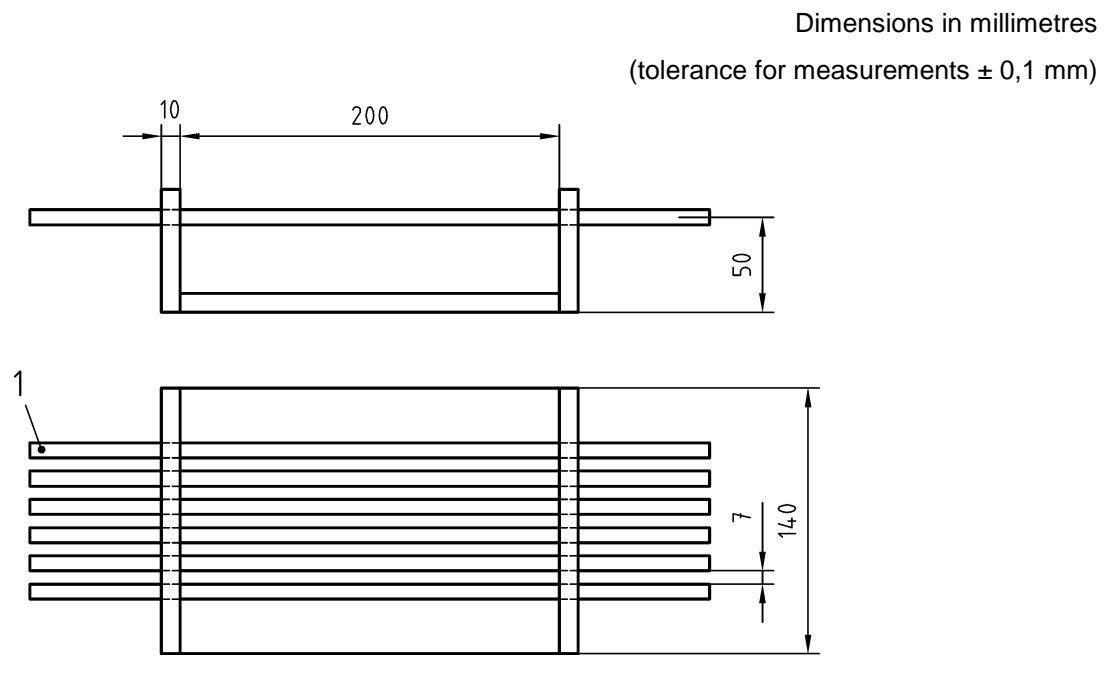
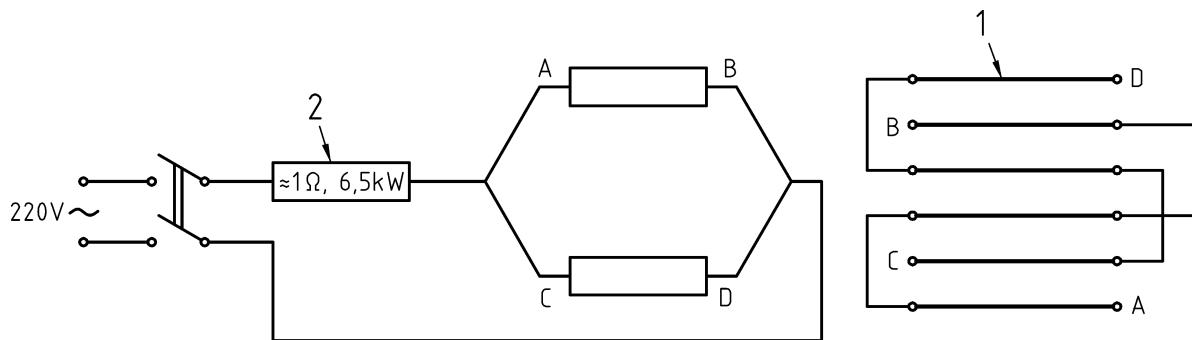


Figure 1: Source of radiation



A diagram of a possible power supply for the radiation source is shown in figure 2. The six rods are arranged into two groups of three, placed in series. The two groups are connected in parallel and are wired to the 220 V supply through a pre-resistance of 1  $\Omega$ . For other supply voltages, the circuit has to be changed accordingly. If the supply voltage fluctuates by more than  $\pm 1\%$  during a measurement, stabilisation has to be provided.



- 1 Silicon carbide rod  
2 Pre-resistance

**Figure 2: Circuit diagram for heating rods**

The electrical connections of the heating rods shall be made carefully (e.g. by means of a stranded aluminium band), taking into consideration that the rods become very hot. Precautions shall be taken to avoid short circuits between the rods.

The correct operation of the radiation source can be checked by using an infrared thermometer to measure the temperature of the silicon carbide rods. After allowing the radiation source to warm up for about five minutes, the rods should have reached a temperature of about 1100 °C.

### 5.3 Specimen holder

Different specimen holders are used for tests A and B. They are constructed from 2 mm thick steel sheets fixed to a 10 mm thick aluminium plate. The specimen holder for test A has wider side plates than the specimen holder for test B. The specimen holder for test B also holds the calorimeter in position.

The specimen holders are fastened so that they fit concentrically into the opening of the vertical of the test frame. When fixed in position, the specimen holder for tests A hold the back of the specimen 10 mm behind the sheet metal cover at the front of the test frame. The specimen holder for test B holds the vertical centre line of the calorimeter 10 mm behind the sheet metal cover at the front of the test frame.

### 5.4 Calorimeter

The curved copper plate calorimeter is constructed as follows.

A rectangle (50 mm by 50,3 mm) is cut from a copper sheet of at least 99 % purity and 1,6 mm thick. This copper plate is bent in the longer direction into an arc with a radius of 130 mm. The chord across this arc should be approx. 50 mm. The copper plate should be accurately weighed before assembly and should have a mass of 35,9 to 36 g.

A copper constantan thermocouple, with an output in millivolts complying with IEC 60584-1, is mounted on the back of the copper plate. Both wires should be attached to the centre of the plate using the minimum amount of solder. The diameter of both wires should be 0,26 mm or less and only the length attached to the plate should be bared.

The calorimeter is located in a mounting block which shall consist of a 90 mm by 90 mm square piece of asbestos-free non-combustible, heat insulation board of nominal thickness 25 mm. The thermal characteristics of the board should comply with the following specification:

## EN ISO 6942:2002 (E)

- density  $(750 \pm 50) \text{ kg/m}^3$
- thermal conductivity  $0,18 \text{ W/(m.k)} \pm 10 \%$

A triangular wedge is removed from two opposite sides of the top of this block, so that the two sides are reduced to a height of 21 mm. Two further triangular wedges are removed from 20 mm in from each of the lowered sides, to further reduce them to a height of 17 mm. This gives a top surface with four flat faces, which corresponds very closely to the curved surface which would be obtained by grinding the top surface into an arc of 130 mm radius (see figure 3).

A rectangular hole is cut in the centre of the top of the board. The hole shall be 50 mm across parallel to the lowered sides and 46 mm across parallel to the shaped sides. The hole shall have a flat bottom and shall be 10 mm deep along the lower edges and approx. 12 mm deep in the centre. An edge, 1 mm deep by 2 mm wide, is cut along the two lower edges of the rectangular hole for mounting the curved copper plate. A 3 mm diameter circular hole is cut in the centre of the rectangular hole for passing the thermocouple wires.

The curved copper plate is bonded to the mounting block around its edges using an adhesive capable of withstanding temperatures of about 200 °C. The top of the copper plate should be 0,6 mm higher than the mounting block along the two straight edges and higher than the mounting block along the two curved edges. The mounting block should be higher than the bottom of the copper plate along its curved edges.

The calorimeter is mounted into the combined specimen/calorimeter holder B.

The face of the calorimeter shall be coated with a thin film of an optically black paint having a coefficient of absorption,  $\alpha$ , greater than 0,9.

Dimensions in millimetres  
(tolerance for measurements  $\pm 0,1$  mm)

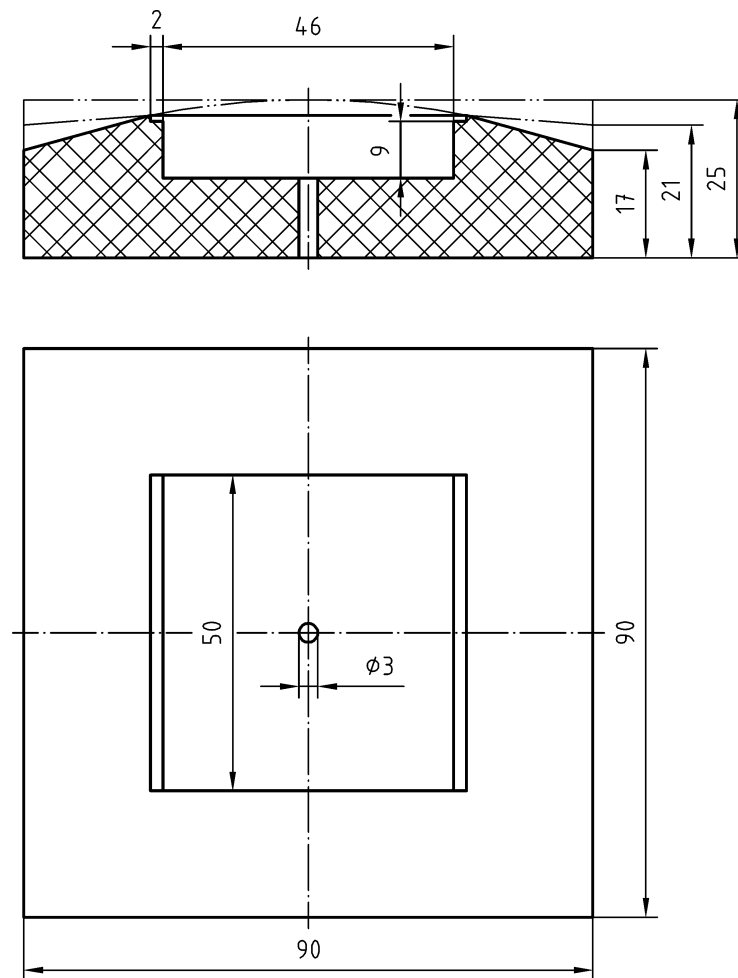


Figure 3: Calorimeter mounting block

### 5.5 Temperature recorder

To enable the absolute temperature of the copper plate to be determined, the thermocouple should be connected to either an ice junction or a commercial reference junction. The voltage signals from the thermocouple should be connected to either a suitable potentiometric chart recorder or programmable data recorder. The recorder should enable voltages to be read to  $10 \mu\text{V}$  and times to 0,1 s. A computer can also be used.

### 5.6 Apparatus location

Locate the apparatus where it will be shielded from air currents or place baffles or shields to limit the effect of air movement at the apparatus location.”

## 6 Sampling

The tests according to method A should be performed using one specimen and the tests according to method B using at least three specimens per heat flux level. If the tested material is very inhomogeneous, at least three specimens by method A and five specimens by method B should be tested,

The specimens shall have dimensions (230 x 80) mm and shall be taken from points more than 20 mm from the edge of the piece of material, in an area free from defects. Composite specimens shall reproduce the arrangement in which the layers are used in practice.

Should the supplier of the material fail to indicate which is the external surface, the tests shall be performed on each side.

## 7 Test conditions

### 7.1 Conditioning atmosphere

Before testing, the specimens shall be conditioned for at least 24 h at a temperature of  $(20 \pm 2)$  °C and a relative humidity of  $(65 \pm 2)$  % . The test shall begin no more than 3 min. after the specimen has been taken from the conditioning atmosphere.

NOTE: As the test results depend very strongly on the humidity of the specimens, the conditioning atmosphere should be very carefully controlled.

### 7.2 Testing atmosphere

The tests shall be carried out in a room free of air currents and protected from any system that is capable of producing stray heat radiation that could be recorded by the calorimeter.

The temperature in the test room shall be between 15 °C and 35 °C and the calorimeter has to be cooled to the room temperature  $\pm 2$  °C before each test.

### 7.3 Heat flux density

The levels of incident heat flux density should be chosen from the following levels:

Low levels:	5 and 10 kW/m <sup>2</sup>
Medium levels:	20 and 40 kW/m <sup>2</sup>
High level:	80 kW/m <sup>2</sup>

taking into account the intended use of the material under test. Other levels of incident heat flux density may optionally be chosen.

Methods A and B are carried out independently of each other,

NOTE: If both methods are used, it is recommended that method A is carried out first, in order to select the appropriate levels of incident heat flux density.

## 8 Test method

### 8.1 Preliminary measures

The front surface of the calorimeter is blackened with a paint of a known, high (greater than 0,90) absorption factor  $\alpha$ . This blackening should be renewed before each calibration and after at least every 20 tests, or as soon as a deposit of char is visible. The blackening should be done after removing the previous layer of paint with a suitable solvent.

Before the start of the calibration and of every measurement the temperature of the copper calorimeter should be in a relatively steady state and within  $\pm 2$  °C of ambient temperature.

NOTE 1: On no account should the calorimeter be allowed to come into contact with water. If this occurs accidentally, the calorimeter should be dried thoroughly before further use.

Immediately before the start of the calibration and of every measurement

- a) the calorimeter is fixed in position in the opening, of the vertical plate of the test frame;
- b) the radiation source is positioned at a distance,  $d$ , from the vertical centre line of the front face of the calorimeter;
- c) the temperature measuring device is switched on ;
- d) the radiation source is switched on and allowed to heat up with the movable screen closed until the radiation is constant. This steady state is reached in about 5 min and can be checked, for example, by measuring the electrical heating current.

NOTE 2: The cooling of the frame's front plate and movable screen is sufficient if the temperature of the blackened calorimeter behind the closed movable screen does not rise by more than 3 °C per min. If this is not the case, the calorimeter can be put in position immediately before the start of the calibration and of every measurement

## 8.2 Calibration of the radiant source.

The movable screen is withdrawn and returned to position after a temperature rise of about 30 °C has been reached.

The recorded output should show a short non-linear temperature/time relationship just after the start of the exposure, followed by a linear region which continues until exposure ceases. Refer to standard thermocouple electromotive force tables to determine the rate of rise of temperature in this linear region,  $R$ , expressed in °C/s. The incident heat flux density,  $Q$ , in kW/m<sup>2</sup>, is then determined from the following equation:

$$Q_0 = \frac{M \cdot C_p \cdot R}{A \cdot \alpha}$$

$M$  is the mass of the copper plate in kg;

$C_p$  is the specific heat of copper 0,385 kJ/kg °C;

$R$  is the rate of rise of the calorimeter temperature in the linear region in °C/s;

$A$  is the area of the copper plate in m<sup>2</sup>.

$\alpha$  is the absorption coefficient of the painted surface of the calorimeter

The incident heat flux density is then adjusted to the required level  $\pm 2$  % by varying the distance,  $d$ , between the radiant source and the calorimeter.

## 8.3 Test A

One of the narrow sides of the test specimen (6) is fastened to one side plate of the specimen holder A (5.3), e.g. with a clamp. The other narrow side of the specimen is pulled over the other side plate and is held in tension under a force of 2 N by means of a suitable device (e.g. a weight, cord and pulley system). If the specimen to be tested consists of several layers, the narrow sides of the various layers shall be kept in alignment and the tensioning force of 2 N shall be applied to the assembly of all the layers.

The specimen holder is fastened into the vertical plate of the test frame so that the back of the specimen is at the same position as the vertical front centre line of the calorimeter face during the calibration. The radiation source, is fixed at the distance,  $d$ , which give the required incident heat flux density,  $Q_o$ . The radiant source is switched on and after it has reached the steady state the, movable screen is withdrawn for 3 min and then returned to its closed position. After the test the specimen is removed and, if it is a multi-layer specimen separated into its layers as far as possible.

#### 8.4 Evaluation A

After irradiation in accordance with 8.3 the specimen, or the individual layers of multi-layer specimens, are inspected. Any changes (e.g. discoloration, deposits, smouldering, charring, rupture, melting, shrinkage, sublimation) are noted, separately for each layer in the case of multi-layer specimens.

NOTE: A change in appearance of the specimen does not necessarily indicate that the thermal resistance of the material is insufficient. There are materials for which a change under the action of intense radiant heat actually increases their protective effect.

#### 8.5 Test B

The test specimen is fastened to one side plate of specimen holder B and held in contact with the face of the calorimeter, applying a force of 2 N. The preliminary, procedures of 8.1 are followed using the, distance  $d$ , which give the required incident heat flux density,  $Q_o$ . The movable screen is withdrawn and the starting point of the irradiation is recorded. The movable screen is returned to its closed position after a temperature rise of about 30 °C has been reached.

The time  $t_{12}$ , expressed to one decimal place, to achieve a temperature rise of  $(12 \pm 0,1)$  °C and the time  $t_{24}$ , expressed to one decimal point, to achieve a temperature rise of  $(24 \pm 0,2)$  °C are determined. As required in the referencing standard, calculate and report the difference between  $t_{24}$  and  $t_{12}$ .

The test is repeated on the remaining specimen (see clause 6) after the necessary preliminary measures (see 8.1)

#### 8.6 Evaluation B

The transmitted heat flux density,  $Q_c$ , in kW/m<sup>2</sup>, is calculated from the equation

$$Q_c = \frac{M \cdot C_p \cdot 12}{A \cdot (t_{24} - t_{12})}$$

where

$M$  is the mass of the copper plate in kg;

$C_p$  is the specific heat of copper 0,385 (kJ/kg·°C);

$12/(t_{24} - t_{12})$  is the mean rate of rise of the calorimeter temperature in °C/s, in the region between a 12 °C and a 24 °C rise;

$A$  is the area of the copper plate in m<sup>2</sup>

The heat transmission factor, TF ( $Q_o$ ), for the incident heat flux density level  $Q_o$  is given by the equation

$$TF(Q_o) = \frac{Q_c}{Q_o}$$

The radiant heat transfer index, RHTI ( $Q_0$ ), for the incident heat flux density level  $Q_0$  is determined as the mean of  $t_{24}$ , the time in 0,1 seconds, for a temperature rise in the calorimeter of  $(24 \pm 0,2)$  °C.

## 9 Test report

The test report shall contain the following particulars:

- a) reference to this European Standard;
- b) a description of the material tested (including the color of the outermost material's surface), or of the individual layers and their arrangement, and their tradename(s), if known.
- c) the temperature and humidity of the testing atmosphere;
- d) levels of incident heat flux density chosen for the tests;
- e) the number of specimens tested at each level;
- f) the description of any change in appearance of the specimens during the test with method A;
- g) the individual values of the transmitted heat flux density  $Q_c$  or mean value and standard deviation if five or more specimens have been tested per level of incident heat flux density;
- h) the individual values of the heat transmission factor  $TF(Q_0)$  or mean value and standard deviation if five or more specimens have been tested per level of incident heat flux density;
- i) the individual values of the times  $t_{12}$  and  $t_{24}$  to reach the different heat transfer levels or mean value and standard deviation if five or more specimens have been tested per level of incident heat flux density;
- j) as required in the referencing standard, the individual time values of time,  $t_{12}$ , the time in seconds for a temperature rise in the calorimeter of  $(24 \pm 0,2)$  °C, and the difference between  $t_{24}$  and  $t_{12}$ .
- k) the date of testing;
- l) any deviations from this standard.
- m) the degree of uncertainty in each test measurement.

## Annex A (informative) Precision of method B

An interlaboratory test with five different materials conducted in nine laboratories at two levels of heat flux density (20, 40 kW/m<sup>2</sup>) gave the following mean variation:

	TF	t <sub>12</sub>	t <sub>24</sub>
-Repeatability	3,3%	0,9 s	1,3 s
-Reproducibility	10,3 %	2,6 s	4,3 s

The repeatability in the laboratories and the reproducibility between the laboratories has been judged satisfactory because the spread of the results is due to the non-uniformity of the material and of its reaction to the test and therefore cannot be improved



## Annex ZA (informative)

### **Clauses of this European Standard addressing essential requirements or other provisions of EU Directives.**

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association and supports relevant essential requirements of EU Directive 89/686/EEC.

WARNING : Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this European Standard.

The clauses of this European Standard specify test methods for the relevant requirements of protective clothing to support the essential requirements of Directive 89/686/EEC, Annex II, clause 3.6.

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