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

Vêtements de protection — Protection contre la chaleur et le feu — Méthode d'essai: Évaluation des matériaux et assemblages des matériaux exposés à une source de chaleur radiante

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 94, *Personal safety — Personal protective equipment*, Subcommittee SC 13, *Protective clothing*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 162, *Protective clothing including hand and arm protection and lifejackets,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fourth edition cancels and replaces the third edition (ISO 6942:2002), which has been technically revised.

The main changes are as follows:

— normative references have been updated (see Clause 2);

— the specified relative humidity range for the conditioning atmosphere has been changed (see 7.1);

— an example product for the optically black paint has been provided (see 5.4);

— the annex on ILT has been revised (Annex A).

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.

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 document 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 protective clothing are usually tested at medium and high heat flux densities. The response of materials to method A and the times t_{12} and t_{24} and transmission factor measured with method B characterise the material. For information on the precision of method B, see Annex A.

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

1   Scope

This document 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

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/TR 11610, *Protective clothing — Vocabulary*

3   Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 11610 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
Heat transfer levels

3.1.1
time t_{12}
time in seconds expressed to one decimal place, to achieve a calorimeter temperature rise of $(12 \pm 0,1)\,°C$ when tested according to method B

3.1.2
time t_{24}
time in seconds expressed to one decimal place, to achieve a calorimeter temperature rise of $(24 \pm 0,2)$ °C when tested according to method B

3.2
heat transmission factor
TF
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 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
amount of energy incident per unit time on the exposed face of the calorimeter

Note 1 to entry: The incident heat flux density is expressed in kW/m^2.

3.5
radiant heat transfer index
RHTI
number, calculated from the mean time (measured in seconds, to one decimal place) to achieve a specified temperature rise in the calorimeter when testing by this method with a specified *incident heat flux density* (3.4)

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 1 to entry: 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 (see 5.2);

— test frame (see 5.3);

— specimen holder (see 5.3).

For method B, the following are also required:

— calorimeter (see 5.4);

— temperature measuring and recording device (see 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 ± 2) mm;

— length of heating part: (178 ± 2) mm;

— diameter: (7,9 ± 0,1) mm;

— electrical resistance: 3,6 Ω ± 10 % at 1 070 °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.

Dimensions in millimetres
(tolerance for measurements ±0,1 mm)

Key

1   silicon carbide rod
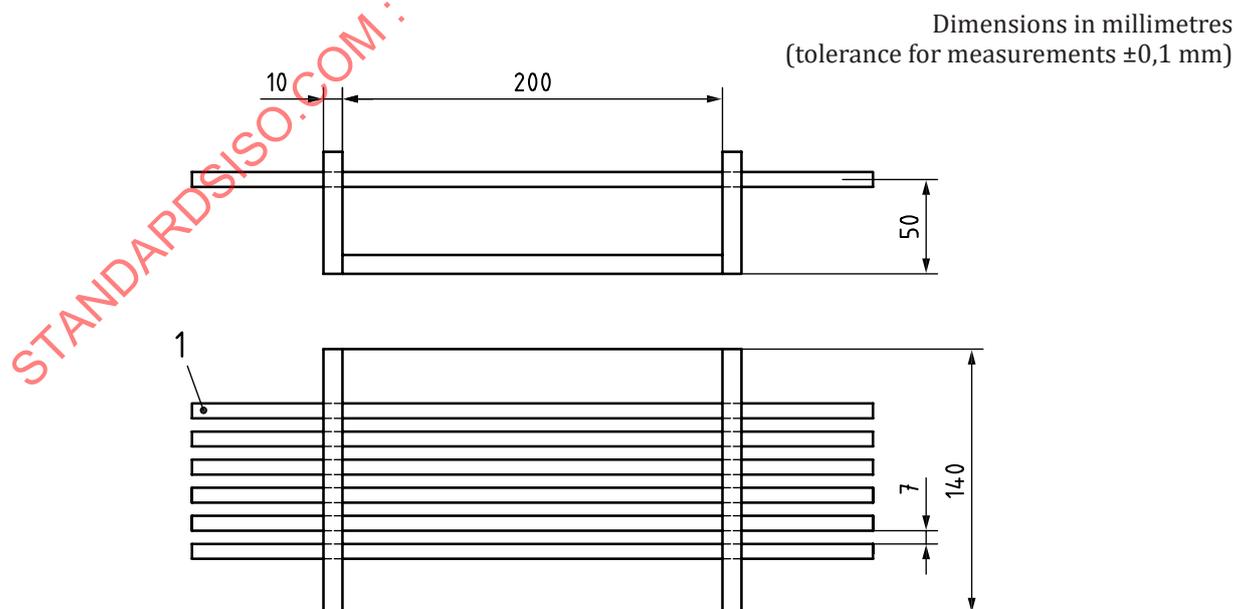
Figure 1 — Source of radiation

A diagram of a possible power supply for the radiation source is shown in <u>Figure 2</u>. 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 Ω. For other supply voltages, the circuit has to be changed accordingly. If the supply voltage fluctuates by more than ±1 % during a measurement, stabilisation has to be provided.

Key
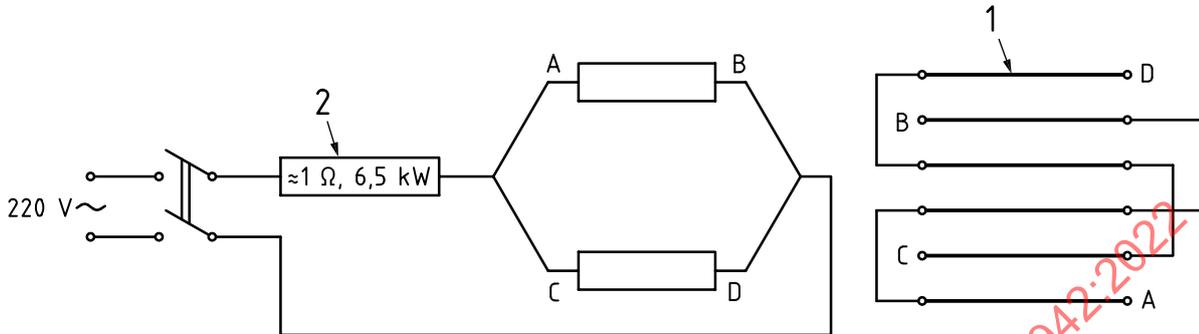
1   silicon carbide rod
2   pre-resistance

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 shall 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 5 min, the rods should have reached a temperature of about 1 100 °C.

5.3   Specimen holder

Different specimen holders are used for methods A and B. They are constructed from 2 mm thick steel sheets fixed to a 10 mm thick aluminium plate. The specimen holder for method A has wider side plates than the specimen holder for method B. The specimen holder for method 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 method 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 method 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 ~50 mm. The copper plate should be accurately weighed before assembly and should have a mass of 35,9 g 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:

— density: (750 ± 50) kg/m^3;

— thermal conductivity: 0,18 W/(m·K) ± 0,018 W/(m·K).

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, α, greater than 0,9.

NOTE   "NEXTEL Velvet Coating 811-21 9218 black" has been found to be suitable as an optically black paint.

Dimensions in millimetres
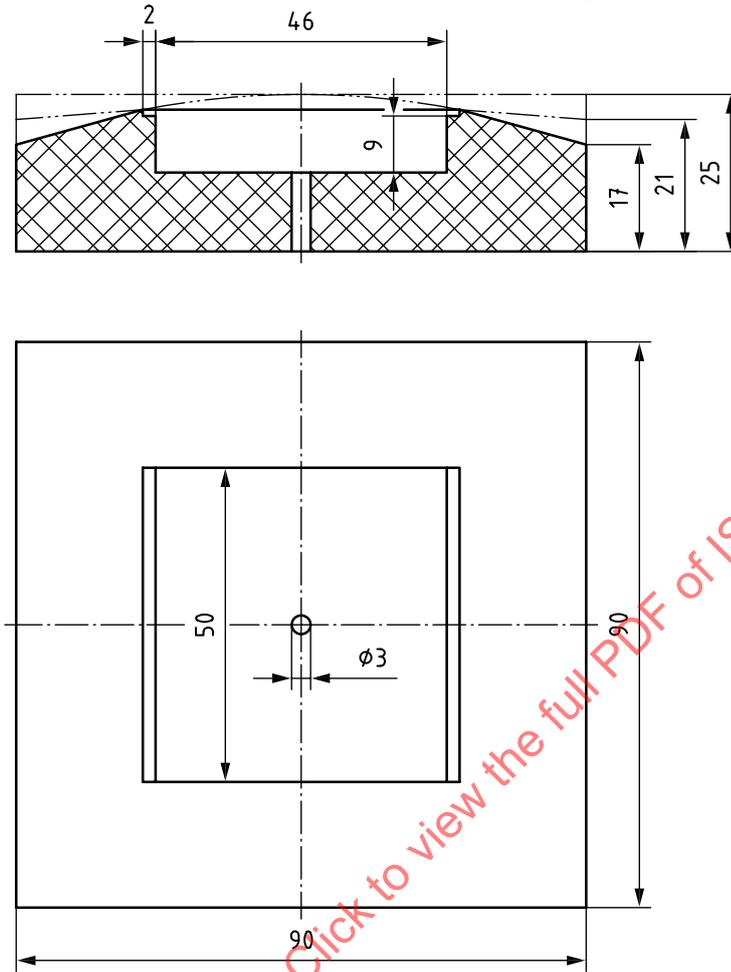(tolerance for measurements ±0,1 mm)

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 µV 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 × 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 multi-layer clothing assembly as 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 ± 2) °C and a relative humidity of (65 ± 4) %. As the test results depend very strongly on the humidity of the specimens, the conditioning atmosphere should be very carefully controlled. The test shall begin no more than 3 min. after the specimen has been taken from the conditioning atmosphere.

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 ±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 kW/m^2 and 10 kW/m^2;

medium levels: 20 kW/m^2 and 40 kW/m^2;

high level: 80 kW/m^2;

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, consideration should be given to carrying out method A 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 (>0,90) absorption factor α. This blackening shall be renewed before each calibration and after at least every 20 tests, or as soon as the copper calorimeter plate becomes visible. The blackening shall be done after removing the previous layer of paint with a suitable solvent. Deposits shall be removed from the calorimeter after each set of tests.

Before the start of the calibration and of every measurement the temperature of the copper calorimeter shall be in a relatively steady state and within ±2 °C of ambient temperature. 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, and

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   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/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^2, is then determined from Formula (1):

$$Q_0 = \frac{M \cdot C_p \cdot R}{A \cdot \alpha}$$ (1)

where

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^2;

α is the absorption coefficient of the painted surface of the calorimeter.

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

8.3   Procedure for method A

One of the narrow sides of the test specimen (see Clause 6) is fastened, folded to one side plate of the specimen holder A (see 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 gives the required incident heat flux density, Q_0. 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 Procedure for method 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 gives the required incident heat flux density, Q_0. 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^2, is calculated from Formula (2):

$$Q_c = \frac{M \cdot C_p 12}{A \cdot (t_{24} - t_{12})} \tag{2}$$

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^2.

The heat transmission factor, TF (Q_0), for the incident heat flux density level, Q_0, is given by Formula (3):

$$TF(Q_0) = \frac{Q_c}{Q_0} \tag{3}$$

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

The radiant heat transfer index, RHTI$_{12}$ (Q_0), for the incident heat flux density level Q_0 is determined as the mean of t_{12}, the time in 0,1 s, for a temperature rise in the calorimeter of $(12 \pm 0,1)$ °C.

The radiant heat transfer index, RHTI$_{24}$ – RHTI$_{12}$ (Q_0), for the incident heat flux density level Q_0 is determined as RHTI$_{24}$ minus RHTI$_{12}$.

9 Test report

The test report shall contain the following particulars:

a) reference to this document, i.e. ISO 6942:2022;

b) a description of the material tested (including the colour 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_o), 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}, and the difference between t_{24} and t_{12} per level of incident heat flux density;

j) $RHTI_{24}$, $RHTI_{12}$ and $RHTI_{24} - RHTI_{12}$ per level of incident heat flux density;

k) the date of testing;

l) any deviations from this document.