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Protective clothing against heat and flame — Determination of heat transmission on exposure to flame

*Vêtements de protection contre la chaleur et les flammes —
Détermination de la transmission de chaleur à l'exposition d'une
flamme*

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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.

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. www.iso.org/directives

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For an explanation on 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 the following URL: <http://www.iso.org/iso/foreword.html>

The committee responsible for this document is ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 13, *Protective clothing* and by Technical Committee CEN/TC 162, *Protective clothing including hand and arm protection and lifejackets* in collaboration.

This second edition cancels and replaces the first edition (ISO 9151:1995), of which Clauses/[subclauses 2, 3.3, 5.1, 5.2, 5.3, 5.6, 6, 8.1, 8.2, 9.1.2, 9.3.1, 9.3.2, 10](#), all figures, and [Annexes A and B](#) have been technically revised. Tolerances have been added to specified dimensions where appropriate. Results of a recent inter-laboratory trial have been added to [Annex A](#).

To improve reproducibility, the following major modifications have been made from the previous version of this test method:

- a) The percentage minimum purity of the propane used has been provided (see [5.2](#));
- b) Two alternative methods for constructing the calorimeter are described with additional information on the figures; additional instructions are given for inserting the calorimeter into the mounting block; and the total mass of the calorimeter and mounting block is specified (see [5.3](#));
- c) Tolerances for the dimensions of machined parts have been added to text and drawings where required;
- d) Control of air movement during testing is specified (see [Clause 6](#));
- e) The specified relative humidity and temperature ranges for the conditioning and testing atmospheres have been changed (see [8.1](#) and [8.2](#));
- f) Additional procedures for calibration and stabilization of thermocouple temperature, including a procedure to check on the linearity of the thermocouple output during regulation of the incident heat flux density, have been added (see [9.1.1](#) and [9.1.2](#)); and
- g) Test report requirements have been revised (see [Clause 10](#)).

This corrected version of ISO 9151:2016 includes the following changes:

- in 5.3, second paragraph, the tolerance's value has been corrected from “ ± 002 ” to “ $\pm 0,002$ ”;
- in 9.3.3, second paragraph, the reference to [Annex A](#) has been corrected to [Annex B](#).

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Introduction

Heat transmission through clothing is largely determined by its thickness including any air gaps trapped between adjacent layers. The air gaps can vary considerably in different areas of the same clothing assembly. The present method provides a grading of materials when tested under standard test conditions without an air gap.

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Protective clothing against heat and flame — Determination of heat transmission on exposure to flame

1 Scope

This document specifies a method for determining the heat transmission through materials or material assemblies used in protective clothing. Materials may then be ranked by comparing heat transfer indices, which provide an indication of the relative heat transmission under the specified test conditions. The heat transfer index should not be taken as a measure of the protection time given by the tested materials under actual use conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 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*

IEC 60584-1, *Thermocouples — Part 1: Reference tables*

IEC 60584-3, *Thermocouples — Part 3: Extension and compensating cables — Tolerances and identification systems*

3 Terms and definitions

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

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

test specimen

all the layers of fabric or other materials arranged in the order and orientation as used in practice, including, where applicable, undergarment fabrics

3.2

incident heat flux

Q

amount of energy applied to the exposed face of the specimen, per unit time

Note 1 to entry: The unit is kW/m².

3.3 heat transfer index HTI

<flame> mean time, t_m , in whole seconds to achieve a temperature rise of $(24 \pm 0,2) ^\circ\text{C}$ when tested by the method described in this document using a copper disc of mass $(18 \pm 0,05) \text{ g}$ and incident heat flux of $(80 \pm 2) \text{ kW/m}^2$

Note 1 to entry: Within the context of this document, the heat transfer index refers to the heat transfer between a flame and the test specimen. See [Annex A](#).

4 Principle

A horizontally oriented test specimen is restrained from moving and subjected to an incident heat flux of $(80 \pm 2) \text{ kW/m}^2$ from the flame of a gas burner placed beneath it. The heat passing through the specimen is measured by means of a small copper calorimeter on top of and in contact with the specimen. The time, in seconds, for the temperature in the calorimeter to rise $(24 \pm 0,2) ^\circ\text{C}$ is recorded. The mean result for three test specimens is calculated as the "heat transfer index (flame)".

5 Apparatus

5.1 General

The apparatus consists of:

- a Meker gas burner;
- a copper disc calorimeter;
- a specimen support frame;
- a calorimeter location plate;
- a support stand;
- suitable measuring and recording equipment;
- a template.

5.2 Gas burner

A flat topped Meker burner with a perforated top area of $(38 \pm 2) \text{ mm}$ diameter and a jet suitable for propane gas shall be used. (See [Annex B](#) for possible sources.)

Commercial grade propane of 95 % minimum purity shall be used with the flow being controlled by a fine control valve and flow meter. Alternatively, other gases may be used but such use shall be reported as part of the test report.

5.3 Copper disc calorimeter and mounting block

Copper disc calorimeter, consisting of a disc of copper of minimum 99 % purity, having a diameter of $(40 \pm 0,05) \text{ mm}$ and thickness 1,6 mm, and a mass of $(18 \pm 0,05) \text{ g}$. The disc shall be weighed before drilling and assembly.

The calorimeter shall be constructed as indicated in [Figure 1](#) (method A) or [Figure 2](#) (method B). Insulated copper-constantan thermocouple wire in accordance with IEC 60584-1 and IEC 60584-3, diameter $0,254 \text{ mm} \pm 0,002 \text{ mm}$ shall be used. The constantan wire shall be either inserted into predrilled hole in the centre of the calorimeter and soldered in place with a minimum of solder (method A) or shall be soldered to the back face of the calorimeter as shown in [Figure 2](#) (method B).

The copper wire shall be attached in the same manner, 15 mm to 18 mm from the centre, so as not to interfere with the seating of disc in the mounting block.

NOTE The specified thermocouple wire is equivalent to Type T – 36 gauge.

The calorimeter is located in a mounting block which shall consist of a 89 mm diameter circular piece of asbestos-free non-combustible heat insulating board (See [Annex B](#)) of nominal thickness 13 mm (see [Figure 3](#)). The thermal characteristics shall comply with the following specification:

Density $(750 \pm 100) \text{ kg/m}^3$

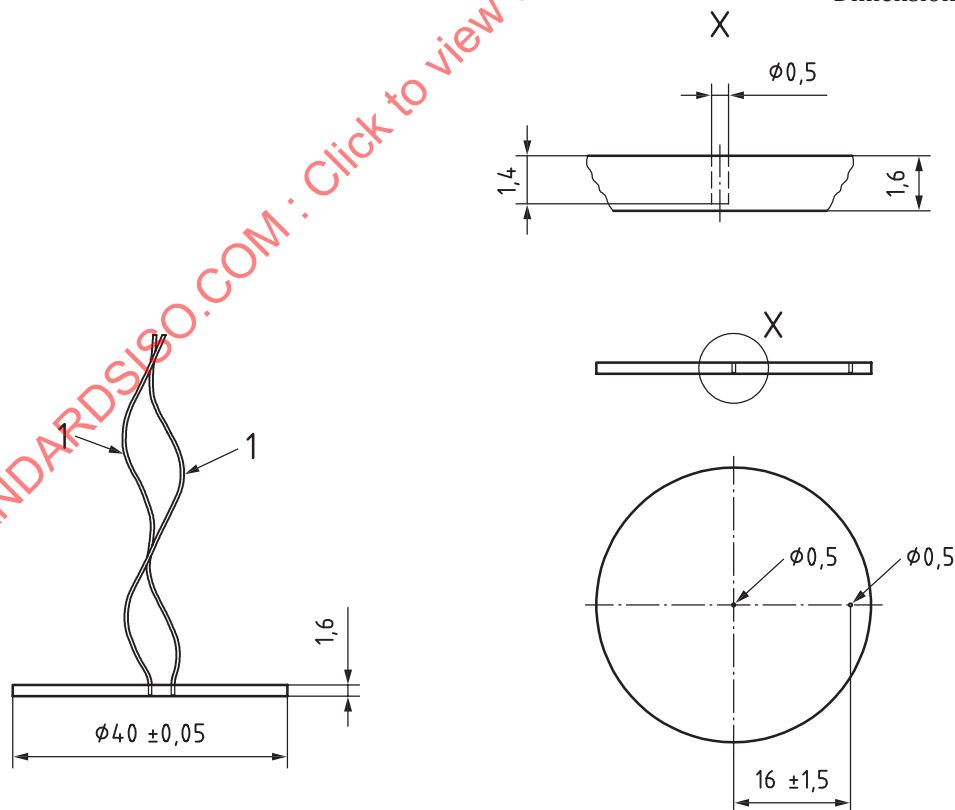
Thermal conductivity $(0,180 \pm 0,018) \text{ W/(m}\cdot\text{K)}$

A circular cavity is machined in the centre of the block to accommodate the disc and an air gap as shown in [Figure 3](#). The disc is held in position using small stainless steel pins (0,45 mm diameter or less) which protrude through the back of the insulating block with sufficient length that they can be used to secure the disc (method A – [Figure 4](#)). The mounting pins shall be stainless steel, soft soldered to the calorimeter using the minimum quantity of solder necessary. If method B of mounting the calorimeter is chosen the calorimeter shall be attached to the mounting block with a suitable high temperature adhesive.

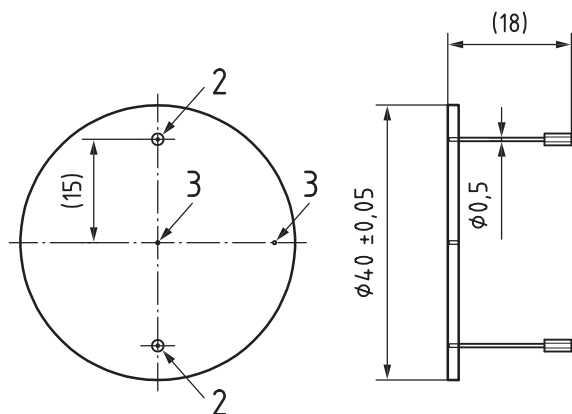
The face of the copper disc shall be flush with the surface of the mounting block. It shall also be coated with a thin layer of an optically black paint having a coefficient of absorption, α , greater than 0,9 (see [Annex B](#)).

The total mass of the calorimeter/mounting block assembly shall be $(80 \pm 10) \text{ g}$.

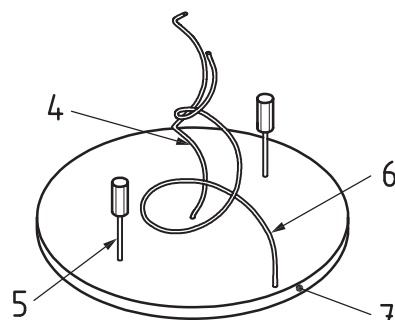
Dimensions in millimetres



a) Calorimeter assembly with mounting pins omitted for clarity



b) Copper calorimeter showing location of mounting pins (additional thermocouple wires omitted for clarity)



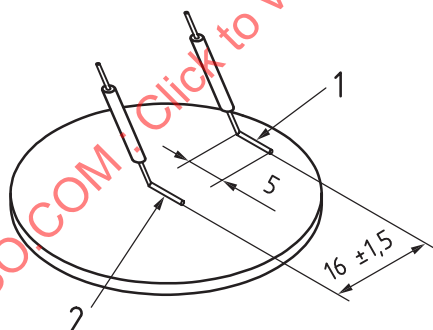
c) Copper calorimeter assembly

Key

- | | | | |
|---|-----------------------------|---|------------------|
| 1 | thermocouple wire | 5 | mounting pin |
| 2 | blind hole for mounting pin | 6 | copper wire |
| 3 | blind hole for thermocouple | 7 | copper disk |
| 4 | constantan wire | X | detail scale 5:1 |

Figure 1 — Copper calorimeter (method A)

Dimensions in millimetres

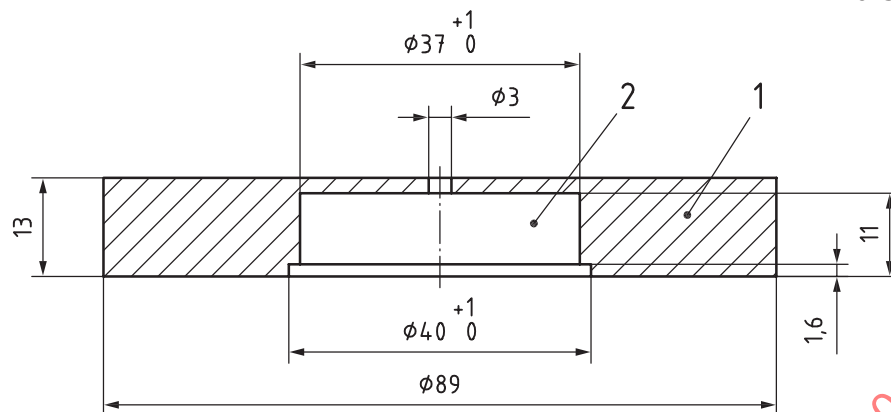


Key

- | | |
|---|--|
| 1 | copper thermocouple wire, as close as practical to edge of calorimeter |
| 2 | constantan thermocouple wire, approximately centre of calorimeter |

Figure 2 — Alternative calorimeter construction (method B) (additional thermocouple wires omitted for clarity)

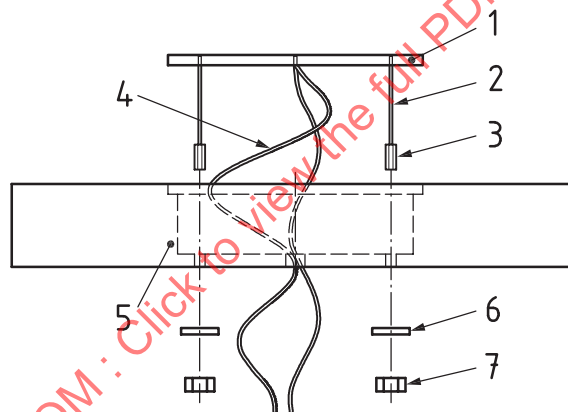
Dimensions in millimetres



Key

- 1 heat insulation board
- 2 cavity

Figure 3 — Calorimeter mounting block (informative)



Key

- 1 copper calorimeter
- 2 0,45 mm stainless pin
- 3 2-56 set screw
- 4 thermocouple wires
- 5 sensor mounting block
- 6 flat washer
- 7 2-56 hex nut

Figure 4 — Calorimeter and mounting block assembly (method A shown)

5.4 Specimen support frame

Specimen support frame consisting of a piece of mild steel (carbon content < 0,5 %) ($150^{+0,5}_{-0}$) mm square and ($1,6 \pm 0,1$) mm thick with a ($50 \pm 0,5$) mm square hole in its centre (see [Figure 5](#)). Materials other than mild steel (e.g. copper) may also be used. Tolerances for machined parts shall be $^{+0,5}_{-0}$ mm to fit the calorimeter location plate.

5.5 Calorimeter location plate

Calorimeter location plate made from a piece of aluminium ($149^{+0}_{-0,5}$) mm square and ($6 \pm 0,1$) mm thick and having a circular hole 90 mm in diameter located centrally (see Figure 6). The plate shall have a mass of (264 ± 13) g. Tolerances for machined parts shall be $^{+0}_{-0,5}$ mm to fit the specimen support frame.

5.6 Support stand

Support stand, used to locate the specimen and calorimeter relative to the burner. The top face of the specimen support stand shall be (50 ± 2) mm above and parallel with the top face of the burner, with the axis of the burner aligned with the centre of the opening in the support frame (see Figure 7).

It is convenient to have a shutter between the burner and the specimen support frame. If used, the shutter shall open completely in less than 0,5 s and shall be operated immediately after placing the burner in position. It is useful if the positioning of the burner, or the opening of the shutter, if fitted, can be used to record the start of the exposure.

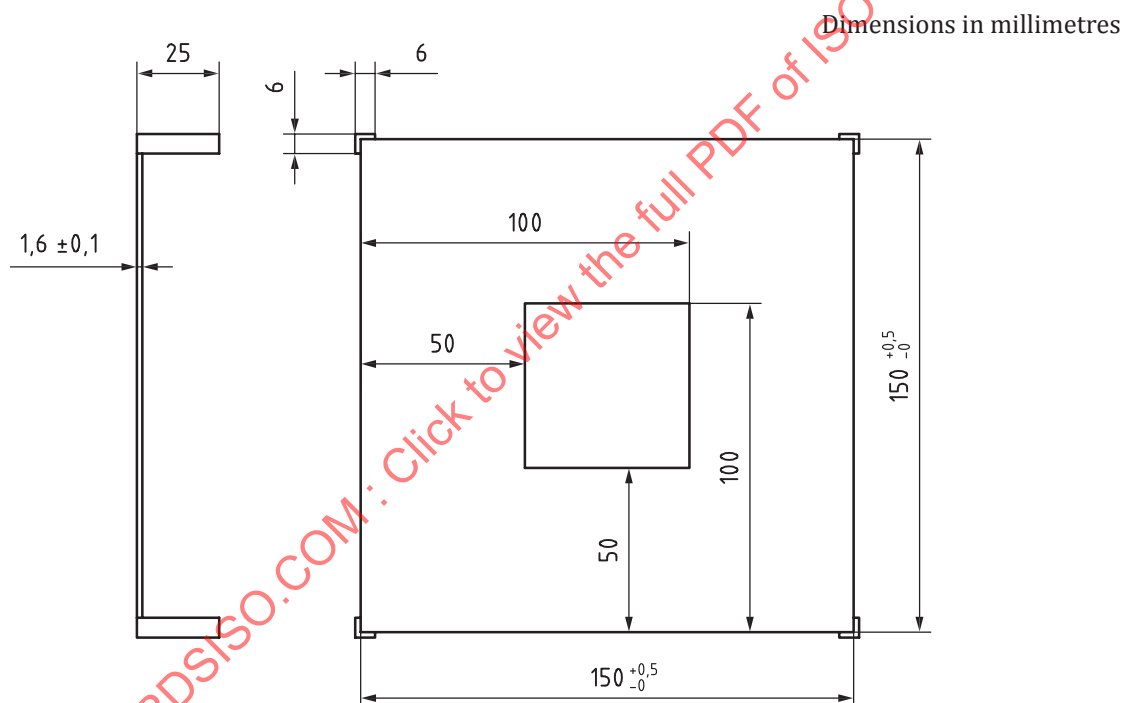


Figure 5 — Specimen support frame

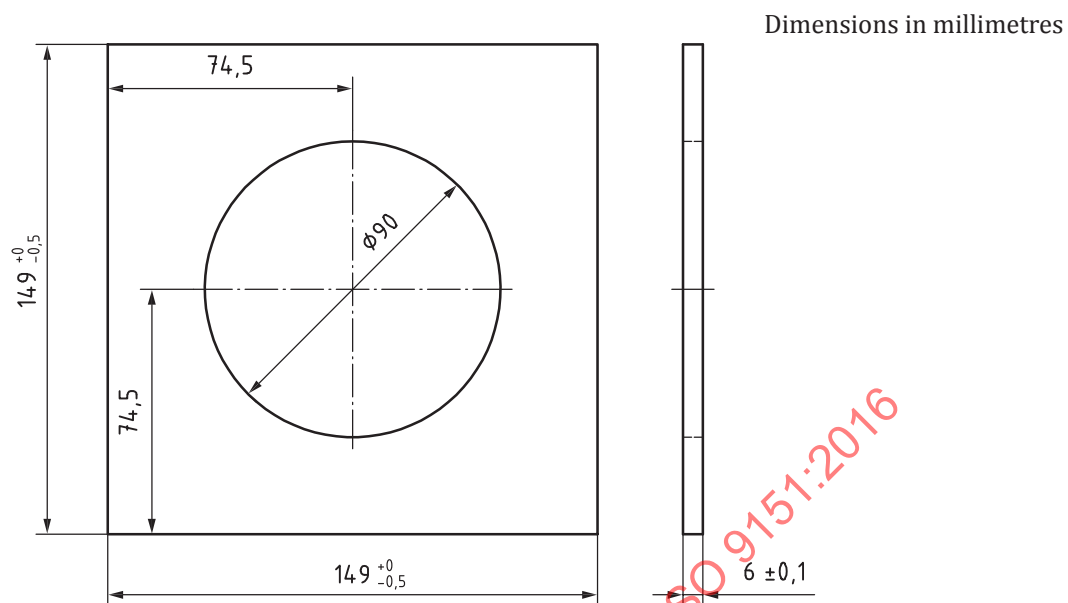
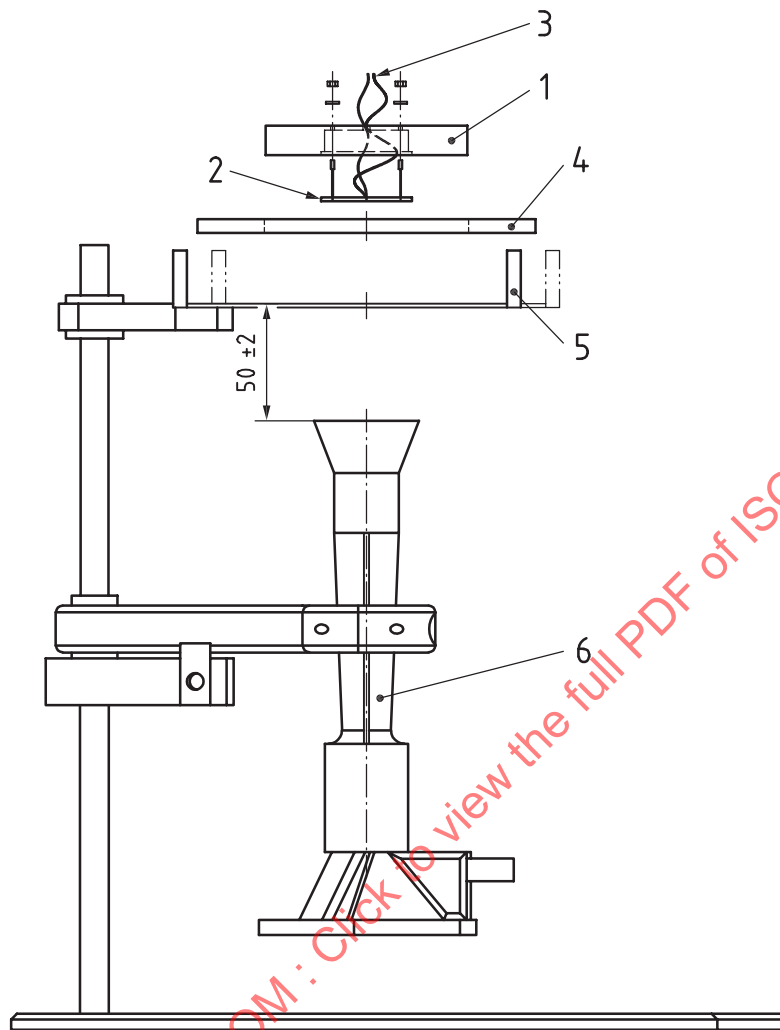


Figure 6 — Calorimeter location plate

Dimensions in millimetres



Key

- 1 sensor mounting block
- 2 copper calorimeter
- 3 thermocouple wires
- 4 sensor locating plate
- 5 support stand
- 6 Meker burner

Figure 7 — Equipment setup

5.7 Recorder

The output of the thermocouple shall be read using a recorder or data logger with a temperature resolution of at least 0,25 °C and a time resolution of a minimum of 0,2 s.

5.8 Flat rigid template

Flat rigid template, with dimensions 140 mm × 140 mm, used for cutting material specimens.

6 Precautions

Perform the test in a hood or ventilated area to carry away the fumes. The test location should be surrounded by a volume of air sufficient not to be affected by any reduction of oxygen concentration. It may be necessary to turn off the exhaust or to shield the apparatus during the test so as not to disturb the flame. Air movement at the point of test shall be less than 0,2 m/s at the commencement of the test of each specimen. The equipment becomes hot during testing and some test materials may melt or drip. Use protective gloves when handling hot objects.

Keep combustible materials away from the burner. Ensure that the solvent used for cleaning the calorimeter is kept away from hot surfaces and naked flames.

7 Sampling

7.1 Specimen dimensions

The specimens shall have the dimensions 140 mm × 140 mm and shall be taken from points more than 50 mm from the edge of the pieces of the material, in an area free from defects. Composite specimens shall reproduce the arrangement in which the layers are used in practice. Alternatively, specimens may be taken from clothing samples according to a given product standard.

The specimen shall be marked out using the template (see [5.8](#)).

7.2 Number of specimens

A minimum of three specimens shall be tested for each material or assembly of materials.

8 Conditioning and testing atmospheres

8.1 Conditioning atmosphere

Prior to testing, the specimens shall be conditioned for at least 24 h at a temperature of $(20 \pm 2) ^\circ\text{C}$ and a relative humidity of $(65 \pm 5) \%$. If testing is not carried out immediately after conditioning, place the conditioned test specimens in a sealed container. Begin testing of each specimen within 3 min of removing it from the conditioning atmosphere or sealed container.

8.2 Testing atmosphere

Perform the tests in an atmosphere having a temperature of $(23 \pm 5) ^\circ\text{C}$ and a relative humidity of 15 % to 80 % and which is free from draughts (see [Clause 6](#)).

9 Test procedure

9.1 Preparation and calibration

9.1.1 Preliminary procedures

Position the specimen support frame on the support stand so that the top surface of the support frame, on which the specimen is placed, is (50 ± 2) mm above the top face of the burner. It is suggested that a guide and stops be used to enable the burner to be positioned quickly with its axis in line with the centre of the specimen. Alternatively, a shutter system may be used (see [5.6](#)).

Place the burner to one side, activate and ignite the gas supply, and allow a minimum of three minutes for flame stabilization.

Connect the thermocouple to the recording device or data logger. Before every incident heat flux density regulation or specimen evaluation, the copper disc temperature shall be stable for 1 min and be within $\pm 2^\circ\text{C}$ of ambient temperature.

Note Cooling can be accelerated by the use of any dry, chilled heat sink, or by forced air draught. Alternatively, a number of calorimeter units can be rotated. Heating can be achieved by contact of the palm of the hand with the copper disc or by short exposure to the burner flame.

WARNING — On no account shall the calorimeter mounting block be allowed to come into contact with water. If this occurs accidentally it shall be dried out thoroughly before further use.

9.1.2 Regulation of the incident heat flux

The gas flow rate and burner setting will vary with the individual combination used, and regulation of the settings for one or both will be necessary during initial installation and at least at the beginning of each testing day. The correct flux should be achieved from a flame with clearly defined stable light blue cones firmly positioned on the burner grid with a large diffuse bluish flame above.

The flame setting is confirmed by measuring the heat flux with the calorimeter.

Place the calorimeter location plate on the specimen support frame, with the copper disc facing downwards.

Start the recording device and slide the burner quickly and smoothly under the calorimeter until it locates against its stops. Alternatively, if a shutter is used, open the shutter (see 5.6).

Allow the burner to remain in position for 8 s to 10 s. Exposure of more than 10 s may melt the solder and detach the thermocouples.

Withdraw the burner and/or close the shutter.

The recorded output should show a short nonlinear temperature-time region just after the start of the exposure, followed by a near-linear region which continues until the exposure is stopped (see Figure 8). See IEC 60584-1 for conversion of the thermocouple output to temperature in degrees Celsius. The heat flux, Q (in kW/m^2) is then determined from the near-linear region of the thermocouple output using the following equation:

$$Q = \frac{mc_p R}{A} \quad (1)$$

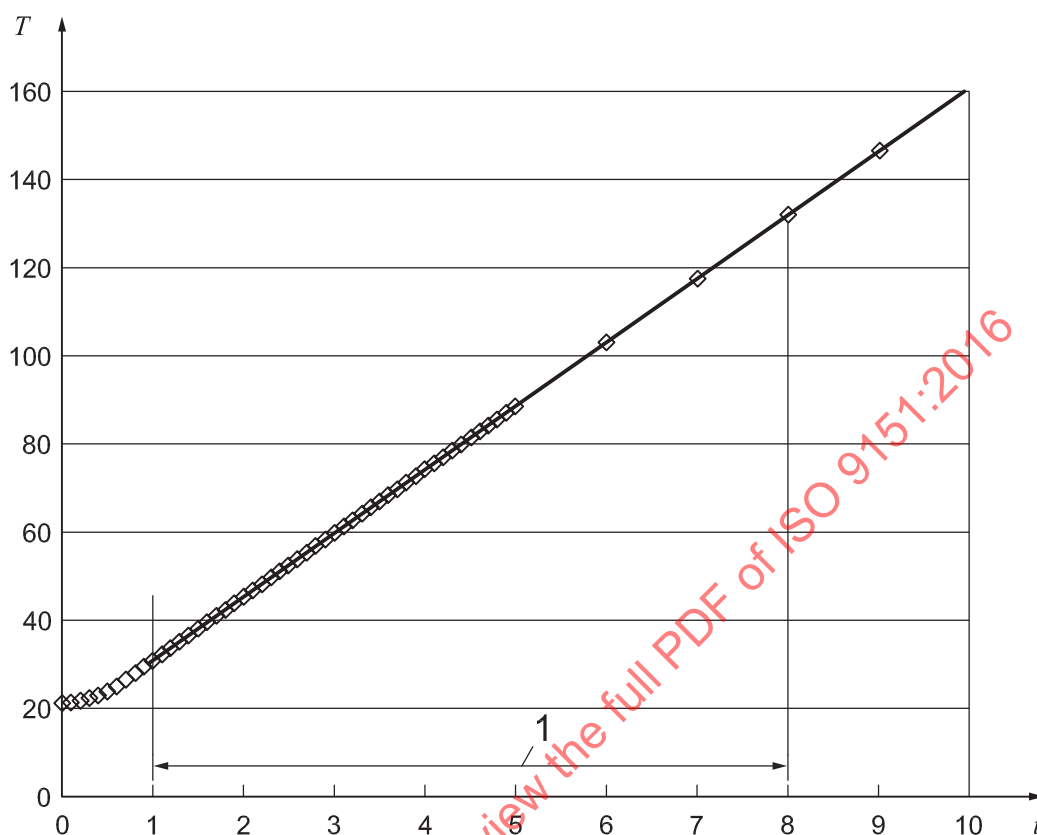
where

- m is the mass of the copper disc [kg];
- c_p is the specific heat capacity of the copper [0,385 kJ/(kg·°C) at 25 °C];
- R is the rate of rise in disc temperature in the near-linear region [°C/s];
- A is the disc area [m^2].

The heat flux determined by this procedure shall be within $\pm 2 \text{ kW/m}^2$ of the specified 80 kW/m^2 . Adjust the gas flow rate if required, and repeat until three consecutive values are obtained which fall within the required limits.

In addition, test the near-linear region of the thermocouple output for its deviation from pure linearity. Note the time of the start of the near-linear rate of temperature rise after more than 1 s to more than 8 s (see Key 1 in Figure 8). Calculate R from the temperature rise values in the linear region from 2 s to 5 s. Repeat this calculation of R for temperature rise values from the start of the near-linear region from 2 s to 8 s. If the two values of R differ by more than 3 %, repeat the heat flux setting until both the required heat flux and consistent R values are met.

CAUTION — Do not allow the calorimeter temperature to rise higher than the melting point of the solder used in construction.



Key

- T calorimeter temperature (°C)
- t time (s)
- 1 near-linear region of calorimeter response

Figure 8 — Example of copper calorimeter sensor response to calibration heat flux

9.2 Test specimen mounting

9.2.1 Place the outermost layer of the specimen face downwards on the specimen support frame (see 5.4). Place the location plate (see 5.5) on top of the specimen.

9.2.2 If the specimen consists of more than one layer and the layers are not attached to one another, mount each successive layer in the order and orientation as used in the assembly. Use the weight of the location plate, with no additional pressure, to press each layer into contact with the previous layer.

9.2.3 After the last (innermost) layer has been mounted, replace the location plate and place the calorimeter in the hole in the location plate so that the copper disc is in contact with the top of the innermost layer.

9.3 Test specimen exposure

9.3.1 Either slide the burner quickly and smoothly into position and immediately move the shutter, if fitted, from below the specimen OR quickly move the specimen over the flame. Start the recording device simultaneously with the exposure of the specimen to the burner flame or mark the start of the exposure with the recorder already running, depending on the equipment used.

9.3.2 Allow the test to continue until a temperature rise of at least 24 °C is observed. Terminate the exposure by withdrawing the burner or, if fitted, replacing the shutter. Observe and note any changes in specimen appearance during and immediately following the test, e.g. shrinkage, scorching, charring, hole formation, glowing, melting, dripping, or as required in specific product standard.

9.3.3 Remove the calorimeter and clean off any combustion products while it is still hot (see [Clause 6](#)). Cool to within ± 2 °C of ambient temperature (see [8.2](#)).

If the remaining deposit on the calorimeter is thick or uneven, if the black coating has deteriorated, or if the copper is exposed, the calorimeter disc shall be cleaned (see [Annex B](#)) and repainted (see [5.3](#)). At least one calibration run (see [9.1.2](#)) shall be carried out with the recoated calorimeter before testing further specimens.

9.3.4 Record the time in seconds for a temperature rise in the calorimeter of 24 °C (see [Annex C](#)).

It is also possible to measure the time in seconds for a temperature rise of 12 °C. This measurement can be used to determine to what extent heat transfer is delayed or reduced. However, it should be stressed that the times measured have only a limited accuracy and do not necessarily relate to protection times under actual use conditions.

9.3.5 Repeat the procedure with two more specimens. Calculate the heat transfer index as the mean of the times taken for a temperature rise of 24 °C, to the nearest whole number.

10 Test report (see [Annex C](#))

The test report shall contain the following particulars:

- a) the name of test laboratory;
- b) the date;
- c) a reference to this document, i.e. ISO 9151:2016;
- d) the identification reference of the materials tested;
- e) the description of the test materials and the arrangement in which they were tested, if possible details of generic names, mass per unit area;
- f) whether Method A or Method B calorimeter was used;
- g) the gas used, if other than the standard propane;
- h) the time, temperature and humidity of conditioning;
- i) the temperature and humidity in the testing laboratory;
- j) the time in seconds for a 24 °C temperature rise for each specimen tested and the heat transfer index calculated according to [9.3.5](#);
- k) if requested, the time in seconds for a 12 °C temperature rise for each specimen tested may also be reported;
- l) the description of any changes in the specimens as per [9.3.2](#);
- m) the graph and calculation of calibration shall be made available upon request.

Annex A (informative)

Significance of the heat transfer test

The heat transfer index (HTI) provides a means of ranking the ability of materials and material assemblies to delay the transfer of energy from a flame. It is derived from the time in seconds to achieve a 24°C temperature rise under the specified test conditions, which corresponds to a thermocouple output increase of $(1 \pm 0,01) \text{ mV}$ ($\pm 10 \text{ } \mu\text{V}$) and a total energy transfer of $(132,3 \pm 1,1) \text{ kJ/m}^2$.

The heat transfer through clothing is dependent on the thickness of the clothing assembly including any air gaps. The HTI is determined with the specimen compressed under a standard load so as to minimize any air gaps. Thicker clothing typically gives better protection and typically gives higher HTI values but with typically increased variability.

The heat transfer index should not be regarded as the time for which the clothing will provide protection against a flame. Under actual use conditions, the severity of the flame and the compression of the clothing are not constant and can vary considerably from the standard test conditions. The performance of wet clothing may differ from the performance of the dry test specimen.

An interlaboratory trial conducted in 2014 to 2015 involved six fabrics tested in eight different laboratories using both Method A and Method B calorimeters as described in this standard. The fabrics tested included the following:

- A para-aramid/pbi ripstop (approximately 258 g/m²);
- B aluminized para-aramid knit fleece laminate (approximately 430 g/m², layers tested together);
- C aramid twill (195 to 201) g/m²;
- D aramid doubleknit (approximately 306 g/m²)
- E FR cotton ripstop twill (approximately 296 g/m²)
- F “cotton-rich” cotton/nylon twill (approximately 259 g/m²).

HTI₂₄ data for three replications of the test in each laboratory were analysed following ISO 5725-2. Repeatability (within laboratory) and reproducibility (among laboratories) data derived from that trial are reported in [Tables A.1](#) and [A.2](#).

Table A.1 — HTI₂₄ data using Method A

HTI ₂₄ - Method A						
Fabric	A	B	C	D	E	F
Mean time, t_m	4,82	10,16	4,22	6,81	4,98	4,76
Repeatability standard deviation, s_r	0,15	0,14	0,17	0,13	0,10	0,13
Reproducibility standard deviation, s_R	0,59	0,61	0,60	0,50	0,54	0,55