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Second edition
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Clothing for protection against heat and flame — Determination of heat transmission on exposure to both flame and radiant heat

Vêtements de protection contre la chaleur et la flamme — Détermination de la transmission de chaleur lors de l'exposition simultanée à une flamme et à une source de chaleur radiante

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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 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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*.

This second edition cancels and replaces the first edition (ISO 17492:2003), which has been technically revised. It also incorporates the Technical Corrigendum ISO 17492:2003/Cor.1:2004. The main changes compared with the previous edition are as follows:

- technical modifications and rewording have been made to all clauses, including to Annexes A and B;
- Clauses 5 to 12 have been renumbered;
- modifications have been made to Figures 1, 2 and 3.

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

The measurement of the thermal energy transferred from the exterior of a material to the interior when exposed to a thermal hazard can be a significant factor in determining the level of protection or insulation provided by an assembly. While full-scale test methods are a better means of determining how an assembly performs, small scale tests such as those described in ISO 6942 and ISO 9151 can be used in establishing benchmarks of performance for the materials from which these assemblies are made. These tests enable the user of a material to anticipate how the properties of a particular material could affect the performance of the assembly when exposed to a high heat flux.

The purpose of an assembly for thermal protection is to prevent or reduce the potential for skin burn injury to the wearer. The performance of a product can be determined by comparing the total exposure energy to that which is transferred through the protective material to a known point where the thermal exposure would produce a burn injury in human tissue. The total exposure energy required to cause the onset of a second-degree burn in human tissue is identified as the thermal protection index (TPI). In the TPI analysis of the data, the specimen is exposed to steady heat until the energy transferred through the specimen is equivalent to the energy that would cause the onset of a second-degree burn injury (e.g. a blister).

Other uses include comparison of the insulation from a high-temperature exposure in terms other than the response of human tissue to heat exposure. For these uses, an alternate method of evaluating the heat transfer is provided. The total energy transferred that causes a temperature rise of the copper sensor by 12 °C and 24 °C is determined as the heat transfer index (HTI). In the HTI analysis of the data, the specimen is exposed to heat until a specified amount of energy is transferred. This is a measure of the insulation performance and thermal capacity of the specimen.

Unlike what is described in ISO 6942 or ISO 9151, the heat source in this test method is approximately 50 % radiant heat and 50 % convective heat. This equalized radiant/convective output is set to a thermal energy exposure having a heat flux of 84 kW/m^2. The magnitude of this heat flux is intended to determine the performance of the specimen when exposed to both the high temperature radiation and hot gases that exist in actual fire situations. The level of this heat flux represents a moderately high industrial or emergency fire-fighting exposure that requires the use of a protective material.

This document can be used to measure and describe the properties of materials, products or assemblies in response to both convective and radiant heat under controlled laboratory conditions. It is not recommended to use this document to describe or appraise a fire hazard or fire risk of materials, products or assemblies under actual fire conditions. However, the results of this test method can be used as elements of a fire-risk assessment that takes into account all of the factors pertinent to an assessment of the fire hazard of a particular end use.

NOTE 1 This test method does not necessarily correlate to the heat-insulation performance of vertically oriented flame-resistant textile materials when exposed to convective and radiant heat or used in actual clothing configurations.

NOTE 2 The performance of materials made of flame-resistant fibres can be determined by the amount of heat energy transferred through the specimen and by observing any changes affected by the exposure on the specimen. The TPI and the HTI measure the accumulated thermal energy received by a sensor, which is an indication of the ability of the material to inhibit the transfer of heat.

NOTE 3 A human tissue burn (blister) is predicted to result when the total thermal energy transmitted by the material reaches the second-degree burn threshold identified by the Stoll curve.

NOTE 4 The TPI or the HTI for flame-resistant materials can be used to establish anticipated thermal performance levels for single layer or multilayer constructions or assemblies.

NOTE 5 Different specimen-mounting conditions, which are determined by the number of layers of material in the test specimen, are provided in this method. Each condition emphasizes a different thermal characteristic of the sample and represents the way in which the material is used in the end-use application.

NOTE 6 The spaced configuration, with a spacer placed between the back surface of the specimen and the sensor, reflects applications in which there is an air space or gap between the specimen and the protected surface. This spaced configuration also eliminates the cooling effect, which occurs due to specimen contact with the sensor and allows the specimen to heat to a temperature during the test the same as that which might occur in an actual fire exposure. This mounting condition gives a measure of the insulation performance and thermal capacity of the specimen and air gap as a combination.

NOTE 7 The contact configuration, with the sensor in contact with the specimen, gives a measure of the insulation performance and thermal capacity of the specimen and reflects applications in which the textile is in contact with the protected surface.

Clothing for protection against heat and flame — Determination of heat transmission on exposure to both flame and radiant heat

1 Scope

This document specifies a test method for measuring the heat transferred through horizontally mounted flame-resistant textile materials when exposed to a combination of convective and radiant heat. The exposure conditions are adjusted to be approximately a 50/50 mixture of pure convective heat and pure radiant heat. The total exposure heat flux is 84 kW/m^2.

This test method is applicable to any type of sheet material used either as a single layer or in a multilayer construction when all structures or sub-assemblies are made of flame-resistant materials. It does not apply to materials that are not flame resistant.

This test method does not apply to the evaluation of materials exposed to any other type of thermal energy sources, such as radiant heat only or flame contact only. ISO 6942 is applicable when evaluating materials for exposure to radiant heat only. ISO 9151 is applicable when evaluating materials due to flame contact only.

NOTE Some, but not all, textiles materials can ignite and continue to burn after exposure to the convective and radiant heat produced by this test method.

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 139, *Textiles — Standard atmospheres for conditioning and testing*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
break-open
formation of a hole in the material during thermal exposure

3.2
burn injury
burn damage that occurs at various levels of depth within human tissue

Note 1 to entry: Burn injury in human tissue occurs when the tissue is heated and kept at an elevated temperature for a critical period of time. The amount of burn injury (first, second or third degree) depends upon both the level of the elevated temperature and the duration. The material performance in this document is related to a second-degree burn injury and is determined by the amount of thermal energy transferred through the specimen that is sufficient to cause the onset of a second-degree burn. The onset of a second-degree burn injury involves damage to the epidermis and part of the dermis.

3.3
charring

formation of carbonaceous residue as the result of pyrolysis or incomplete combustion

3.4
dripping

material response shown by the flow of the material and formation of falling droplets

3.5
embrittlement

formation of a brittle residue as the result of pyrolysis or incomplete combustion

3.6
exposure energy

thermal energy that is incident to the test specimen

3.7
exposure time

total time over which the *exposure energy* (3.6) is applied to the test material

3.8
heat flux

thermal intensity indicated by the amount of energy transmitted divided by time and by area to the surface

Note 1 to entry: Heat flux is expressed in kilowatts per square metre (kW/m^2).

3.9
heat transfer index (dual exposure)

HTI(DE)

time, in whole seconds, to cause a temperature rise of the copper calorimeter by 12 °C and 24 °C from a combined convective and radiant heat exposure

Note 1 to entry: The time to cause a 12 °C temperature rise is indicated with a suffix of T12, and that for a 24 °C rise with a suffix of T24, e.g. HTI(DE)-T12 and HTI(DE)-T24. The relative value between these two indices indicates the characteristic of the energy transfer. If HTI(DE)-T24 is twice that of HTI(DE)-T12, the rate of energy transfer is constant. If HTI(DE)-T24 is less than twice that of HTI(DE)-T12, the rate of energy transfer is increasing, showing a loss in insulation performance. If HTI(DE)-T24 is greater than twice that of HTI(DE)-T12, the rate of energy transfer is decreasing, showing increasing insulation performance.

3.10
heat transfer burn intersection

time, in seconds, at which the thermal energy transferred through the material and absorbed by the copper calorimeter intersects the *Stoll curve* (3.18) where a second-degree burn injury is predicted to begin

3.11
heat transfer burn time

time from the start of the thermal exposure to *heat transfer burn intersection* (3.10)

Note 1 to entry: Heat transfer is determined from the measured temperature rise of a sensor. In this test method, a copper calorimeter is used as the sensor. The calorimeter diameter is large enough to average the heat received through the exposed specimen. The calorimeter thickness is selected so as to cause the temperature rise of the sensor to be similar to that of human tissue when exposed to heat. The sensor face is painted a dull black to cause it to absorb radiant heat similarly to human tissue.

3.12
human tissue heat tolerance
amount of thermal energy transferred to human tissue that predicts a reaction in human tissue, such as a pain sensation or the onset of a second-degree burn

Note 1 to entry: The tolerance of human tissue to heat exposure was developed by Stoll et al.[4] (see Table 1) and is referred to as the *Stoll curve* (3.18). It is used in this method as the heat transfer criteria in determining the *thermal protection index (TPI)* (3.19) value of the test material.

3.13
ignition
initiation of combustion

3.14
melting
liquefaction of a material when exposed to heat

3.15
response to heat exposure
observable response of the textile to the *exposure energy* (3.6) as indicated by *break-open* (3.1), *melting* (3.14), *dripping* (3.4), *charring* (3.3), *embrittlement* (3.5), *shrinkage* (3.16), *sticking* (3.17) or *ignition* (3.13)

3.16
shrinkage
decrease in one or more dimensions of an object or material

3.17
sticking
response evidenced by softening of a material and adherence of one material to the surface of itself or another material

3.18
Stoll curve
relationship between the amount of thermal energy absorbed by human tissue and the time of exposure which predicts the onset of a second-degree burn in human tissue

Note 1 to entry: See Table 1.

3.19
thermal protection index
TPI
total *exposure energy* (3.6) experienced by the specimen to cause a second-degree *burn injury* (3.2) to begin which is defined by the time the measured temperature of the copper calorimeter intercepts the *Stoll curve* (3.18)

Note 1 to entry: The exposure energy is expressed as energy per unit area in kJ/m^2.

4 Principle

A flame-resistant specimen, mounted in a static horizontal position, is placed a specific distance from a combined convective/radiant heat source and exposed to a heat flux of (84 ± 2) kW/m^2 until sufficient thermal energy passes through the specimen to cause the equivalent of the onset of a second-degree burn injury in human tissue, or to indicate a temperature rise of 24 °C in the copper calorimeter.

The specimen is mounted either in direct contact with the copper calorimeter, designated as the “contact configuration”, or with a (6,35 ± 0,05) mm air space between the specimen and the copper calorimeter, designated as the “spaced configuration”.

The test exposure is composed of convective energy supplied by two gas burners and radiant heat from nine radiant tubes. The combined total energy of the exposure is achieved by first setting the radiant exposure and then adding the convective source. The total energy exposure is then confirmed with the copper calorimeter. Note that the gas burner flames contribute both convective and radiant heat to the surface of the specimen.

The amount of energy transferred through and by the specimen is measured with a copper calorimeter and analysed by one of the following two methods.

a) The thermal performance can be evaluated from the times for a 12 °C and 24 °C temperature rise in the copper calorimeter: the HTI(DE)-T12 and HTI(DE)-T24 values. The rate at which the temperature of the copper calorimeter rises is a direct measurement of the thermal energy transferred.

b) The thermal performance can also be compared with the times for the energy transferred through and by the specimen to cause the onset of a second-degree burn: the TPI. This index is based on the human tissue heat tolerance data of Stoll et al[4].

The effect of the exposure on the physical appearance of the specimen shall be noted as specified in 10.4.

5 Apparatus

5.1 Heat source, consisting of a convective heat source and a radiant heat source. The convective heat source shall consist of two Meker or Fisher burners affixed beneath the specimen holder assembly opening and subtended at an angle between 30° to 45° from the horizontal so that the flames converge at a point immediately beneath the specimen. The radiant heat source shall consist of nine 500W quartz T3 translucent (frosted) infrared lamps affixed beneath and centred between the burners as shown in Figure 1. The burners shall be Meker or Fisher burners with a 40 mm diameter top and with an orifice size appropriate for propane gas.

NOTE Two different energy sources are used in this test method. The energy from the Meker burners is primarily convective due to the flowing high temperature gases. These gases do emit thermal radiation. About 1/3 of the energy from the burners is in this form[5]. The lamps are primarily radiant heaters but, because of their location below the test specimen, convection currents will rise and strike the test specimen. The fraction of the energy from the lamps that is convection is small.

5.2 Specimen holder assembly, consisting of a steel frame (7 850 ± 200) kg/m^3 that rigidly holds and positions, in a reproducible manner, the specimen support holder plate and specimen relative to the heat source.

5.3 Protective shutter, placed between the heat source and the specimen. The protective shutter shall be capable of completely dissipating the thermal load from the heat source (usually by means of water cooling) for the time period before and after each specimen exposure. A microswitch shall be connected to the shutter or manually operated to indicate the start of the exposure to the data acquisition system. The start of exposure (i.e. time zero) shall be when the following edge clears the heat source.

5.4 Specimen mounting plate, consisting of a piece of steel (7 850 ± 200) kg/m^3, 200 mm square and 3,2 mm thick, with a 100 mm square hole in its centre. A piece of 90° angle section steel (6,35 mm by 25 mm long) shall be welded to the outside edge of each corner perpendicular to the plane of the plate. The overall dimension, including the angle sections, will be about (212,7 ± 1) mm (see Figure 2).

5.5 Specimen holding plate, 200 mm × 200 mm × 3,2 mm thick steel (7 850 ± 200) kg/m^3 with a 130 mm × 130 mm centred square hole. The spacer and sensor assembly shall fit without binding into the hole of the specimen holding plate (see Figures 1 and 2).

5.6 Spacer, 130 mm × 130 mm × (6,35 ± 0,05) mm thick steel (7 850 ± 200) kg/m^3 with a 100 mm × 100 mm centred square hole (see Figures 1 and 2).

5.7 Sensor assembly, a copper calorimeter assembled in a mounting block with an additional weight on top.

The assembly consists of the following components.

- Copper calorimeter, consisting of a disc of copper of at least 99 % purity, weighing (18,0 ± 0,05) g and having a diameter of 40 mm and thickness of 1,6 mm with one thermocouple connected as specified in Figure 3. The thermocouple shall be bonded to the copper disk by pinning or using a high melting point solder. The thermocouple wire size shall be AWG 30 or equivalent.
- Copper calorimeter mounting block consisting of a 128 mm × 128 mm square piece of asbestos-free non-combustible heat-insulating board of nominal thickness 13 mm machined as specified in Figure 3. The thermal conductivity of the mounting block shall be ≤ 0,15 W/m·K.
- The copper calorimeter shall be pinned to its mounting block at three locations around its circumference with flat head pins. An alternate means of mounting that has been found effective is to use a high-temperature epoxy for securing the copper calorimeter to its mounting block.
- The face of the copper calorimeter shall be flush with the surface of the mounting block. The face of the copper calorimeter shall also be spray-coated with a thin layer of flat black paint with an absorptivity of 0,95 or greater. See Annex A for possible suppliers of the paint.
- The weight shall be selected so that the complete sensor assembly (copper calorimeter in its mounting board plus the weight) shall weigh (1 000 ± 10) g in total. This weight shall produce a uniformly distributed load on the test specimen.

5.8 Data acquisition/analysis/equipment control system, which is required to control the timing of movement of parts of the test apparatus, to record the data, and to calculate the time intervals. The timing functions are to open and close the shutter and to start and stop the temperature recording. The copper calorimeter temperature shall be recorded at least four times per second up to a temperature of 200 °C with a minimum resolution of 0,1 °C and an accuracy of ±0,75 °C. Timing accuracy shall be ±2 %. It shall have a built-in cold junction correction and be capable of converting the millivolt signals from the type J thermocouple to temperature.

NOTE Other thermocouple types that meet the requirements of IEC 60584-1:1977 have been used, e.g. type K. This requires modification of the reference tables and Table 1 to reflect the thermocouple output as a function of temperature.

5.9 Gas supply, propane (minimum 95 % by volume C_3H_8), with an appropriate reducer and valve arrangements to control the gas-supply pressure at (55 ± 1) kPa and capable of providing a flow equivalent to 2 l/min air at standard conditions (conditions are set for air and then an appropriate gas is used at those settings).

5.10 Gas flow control, any gas rotameter or mass flow controller with a range that gives a flow equivalent to 2 l/min air at standard conditions.

5.11 Heat flux transducer, a Schmidt-Boelter or Gardon-type radiation heat flux transducer with a diameter of 25 mm and a minimum heat flux operating range from 0 kW/m^2 to 20 kW/m^2 (see 9.1.3). The heat flux transducer shall have a minimum view angle of 150° and a minimum spectral response flat within 3 % over a range of at least 1,0 µm to 3,0 µm. The unit used shall be traceable to a recognized national standards body such as NIST. The heat flux transducer shall have an accuracy of ±3 %. If the heat flux transducer is water cooled, the cooling-water temperature shall be above the ambient dew-point temperature (for the laboratory environment).

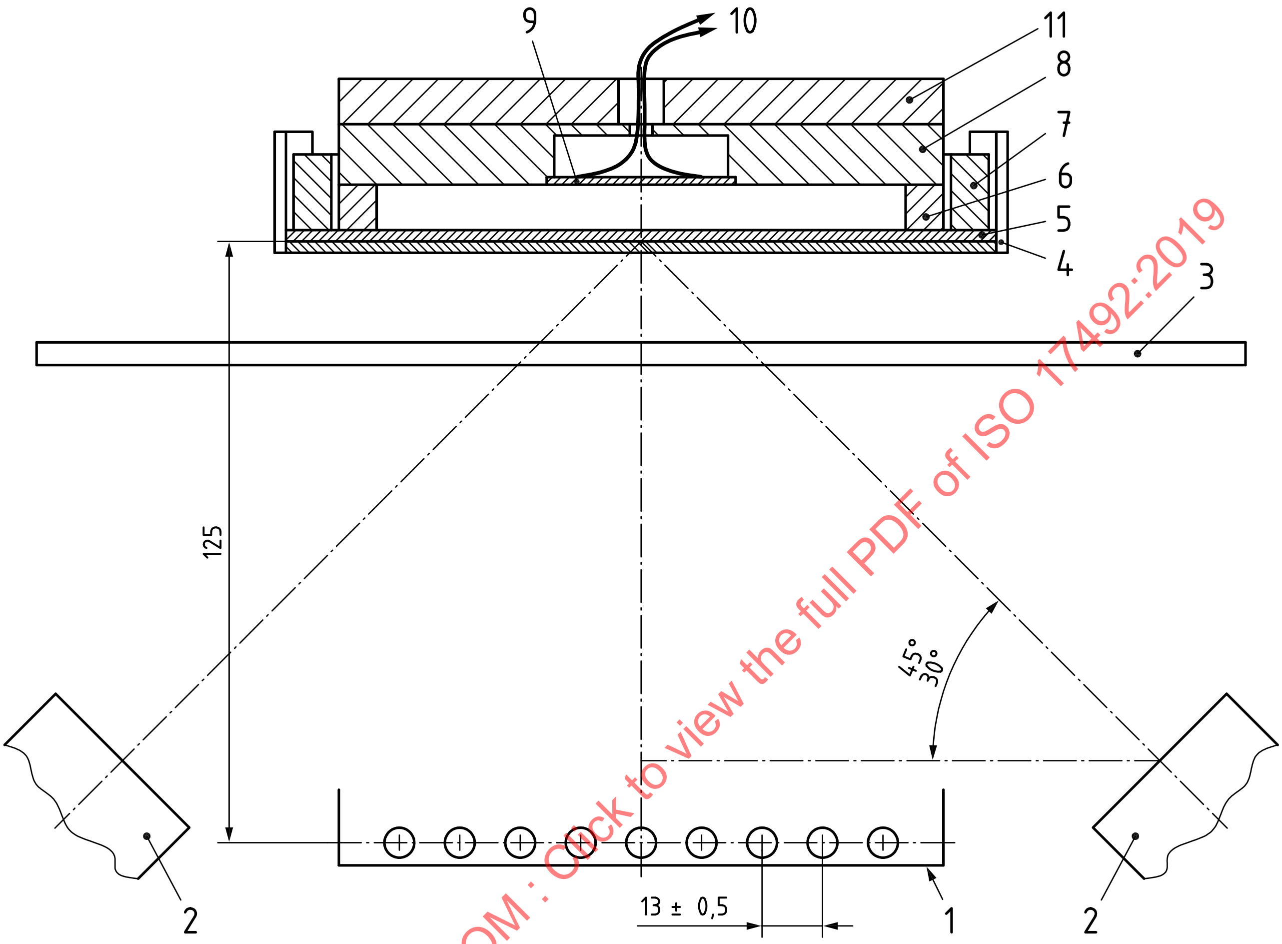
5.12 Solvent, acetone or petroleum, to clean the sensor.

WARNING — Exercise care in using these solvents around heat sources.

The apparatus shall also have a gas supply, gas rotameter and data acquisition system. Figure 1 shows the general layout of the apparatus and the arrangement for the specimen holder assembly.

See Annex A for possible suppliers.

Dimensions in millimetres



Key

1	radiant heat source
2	Meker or Fisher burner
3	water-cooled protective shutter
4	specimen mounting plate
5	test fabric or test specimen
6	spacer (if used)
7	specimen holding plate
8	sensor assembly
9	copper calorimeter
10	thermocouple wires to recorder or computer
11	weight

NOTE The specimen holder support is not shown.

Figure 1 — Diagram test apparatus showing assembly details

Dimensions in millimetres

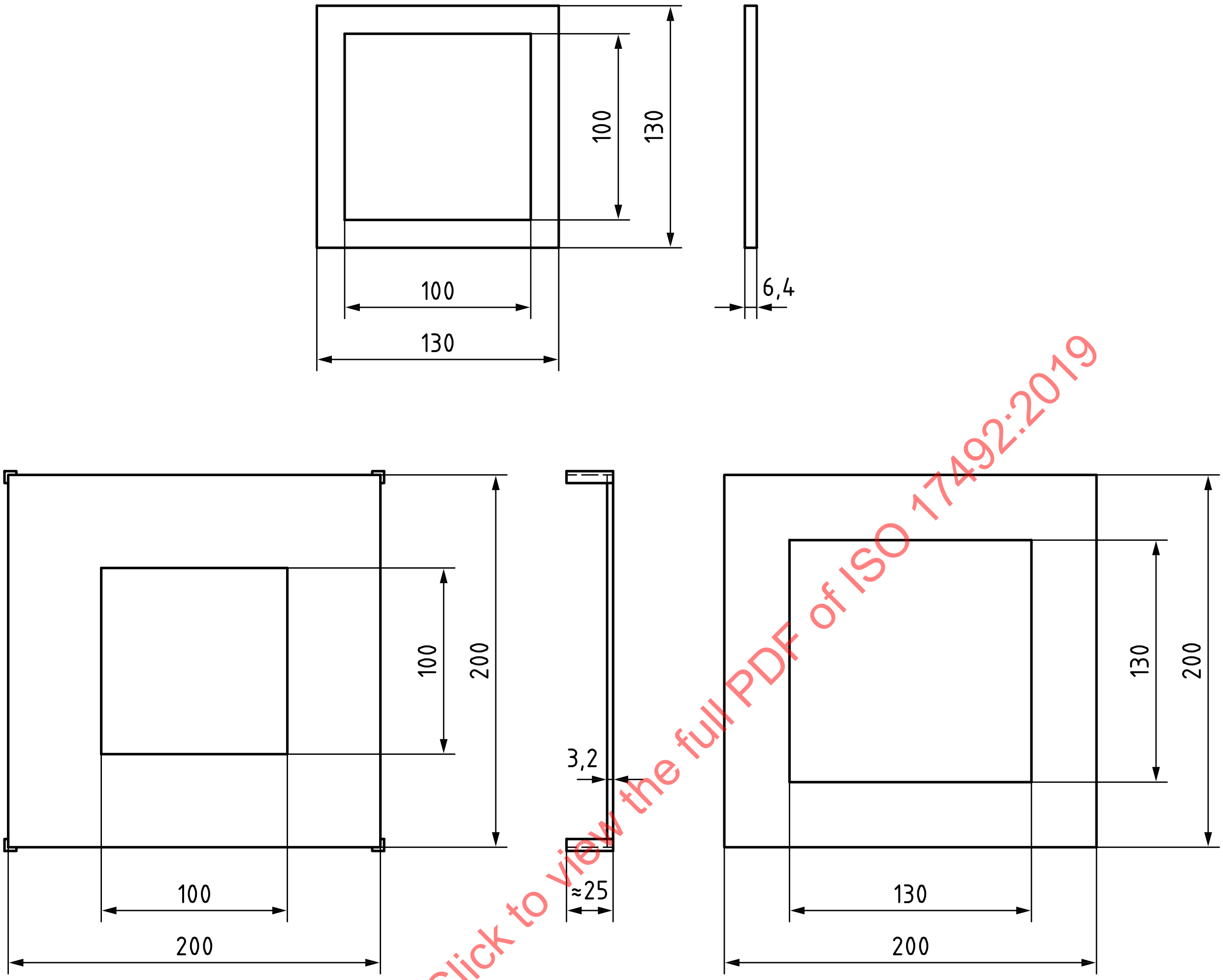
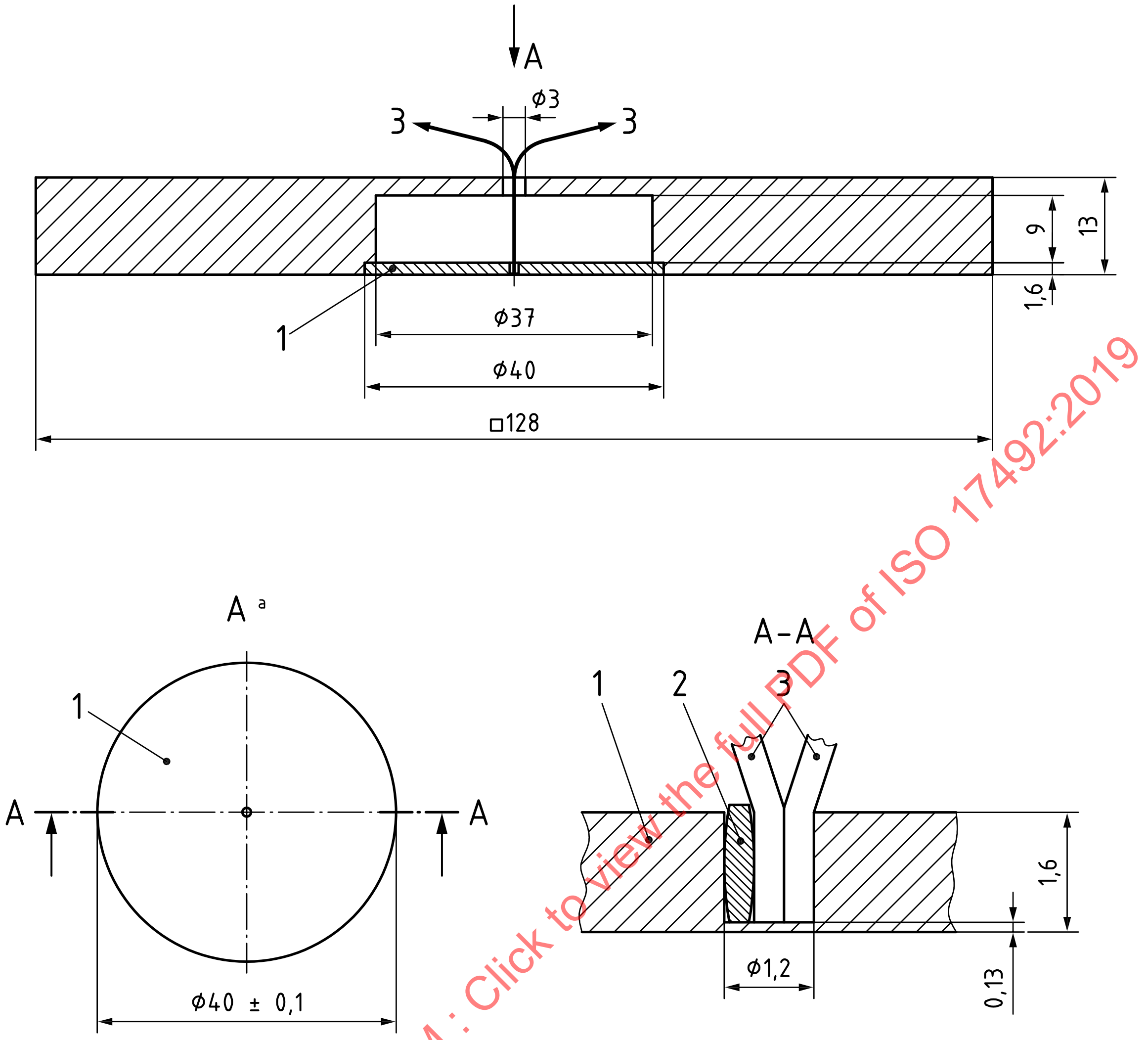


Figure 2 — Details of specimen mounting plate (bottom left), specimen holder plate (bottom right) and spacer (top centre)

Dimensions in millimetres



Key

1 electrical grade copper disk (pinned in place)

2 copper plug

3 thermocouple (Type J or K)

A details of the square calorimeter mounting block

Aa centred thermocouple location

A–A thermocouple installation

Figure 3 — Calorimeter

6 Precautions

Perform the test in a hood or ventilated area to exhaust the combustion products, smoke and fumes. When currents disturb the flame, shield the apparatus or turn off the hood while running the test. Turn the hood on to clear fumes following a test.

Exercise care when handling materials around the quartz tubes or the burner with the open flame.

Maintain an adequate separation between heat sources and combustible materials (e.g. cleaning solvents).

The specimen holder and sensor assembly become heated during prolonged testing. Allow to cool or use protective gloves when handling these hot objects.

Some test specimens are hazardous when exposed to direct flames. Take care if the specimen ignites or releases combustible gases.

Shut off the gas supply at the cylinder and allow the flame to burn the gas from the lines when testing is completed.

7 Sampling

7.1 Specimen dimensions

Cut each specimen to (150 ± 2) mm × (150 ± 2) mm, with two of the sides parallel to the machine direction of the material, where known, for all layers. Include all the layers representative of the clothing item to be tested.

7.2 Number of specimens

A minimum of five 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 ± 2) °C and a relative humidity of (65 ± 4) % in accordance with ISO 139. If testing is not carried out immediately after conditioning, place the conditioned specimens in a sealed container. Begin the testing of each specimen within 3 min of removing it from the conditioning atmosphere or sealed container.

8.2 Testing atmosphere

Perform the test in an atmosphere having a temperature of (23 ± 5) °C and a relative humidity of 15 % to 80 % and that is free from draughts.

9 Test procedure

9.1 Initial set up and calibration procedures

9.1.1 Initial set up of the system and alignment of burner flames

Ensure that the apparatus is arranged according to Figures 1 and 2. Remove the sensor assembly and place the sensor holder directly over the heat source. Turn on the burner flames and adjust the angle of the burners so the resulting flames converge at a point directly under the centre of where the specimen would be located. Turn off the burner flames.

9.1.2 Initial setting of the 50/50 mix of convective and radiant heat

The setting of the combined heat flux from the flames and the quartz lamps is an iterative process that begins with the setting of a nominal heat flux with the lamps. After the setting with the lamps is established, the burners are turned on and adjusted to produce an overall heat flux of 84 kW/m^2. The thermal radiation from the burner flames contributes about 25 kW/m^2 to the radiant heat flux[5]. Thus, the lamps only need to contribute about 15 kW/m^2.

9.1.3 Setting the radiant heat from the lamps

Set the output of the radiative lamp assembly, after a minimum 15-min warm-up period, to (15 ± 4) kW/m^2 as measured by an independent traceable Schmidt-Boelter or Gardon type radiant heat flux transducer. The transducer is to be positioned in the same location as the copper calorimeter would be during a specimen test. This positioning is best accomplished by mounting the calibration sensor in an unused sensor supporting insulation board (see Figure 3). To be traceable, the sensor shall have been calibrated according to the principles outlined by national standards bodies such as NIST.

The output from the radiative lamps is adjusted using their variable power control. Once the desired value is achieved, close the water-cooled shutter and allow the heat flux sensor and its mounting board to cool.

9.1.4 Setting the total exposure heat flux

With the radiant exposure set according to 9.1.3, remove the calibration transducer and its mounting board and replace it with the copper calorimeter and its mounting board. Adjust the heat flux of the total combined exposure to (84 ± 2) kW/m^2 by setting the gas flow through the rotameter (or mass flow controller) and adjusting the flame with the needle valve in the base of the burners. Adjust the gas flow so that the flames converge with each other just below the centre of the specimen holder. The correct convective exposure results from a flame with clearly defined stable blue tips firmly positioned on the burner grids, with the larger diffuse blue flames converging in the centre. The total exposure energy level shall be confirmed using the same copper calorimeter used to measure the heat transferred through the specimen. This is to eliminate errors introduced by using two different sensors for the exposure energy and the heat transfer. Alternatively, use a matched pair of calorimeters that provide results within 2 % of each other. Annex B provides the basis of this procedure and information about determining adequate performance for the calibration calorimeter.

With the water-cooled shutter in position over the burners and radiant tubes, place the specimen holder, without the specimen, on its support and place the copper calorimeter in its mounting board on top of the holder with the blackened face of the copper calorimeter facing down. Then retract the shutter to expose the copper calorimeter directly to the total exposure energy from the combined convective and radiant sources.

Record the response of the copper calorimeter for at least 10 s and identify the initial portion of the curve with a linear (straight-line) response. Extend this straight-line portion of the curve for at least 10 s of response and take copper calorimeter readings for the 0 s and 10 s times. Subtract the 0 s reading from the 10 s reading to obtain the increase. The response should be (138 ± 3) °C; equivalent to a heat flux of (84 ± 2) kW/m^2. At the end of each exposure, close the shutter to dissipate all the energy.

Cool the copper calorimeter to 31 °C and ensure that it is stabilized ±1 °C for at least a 1 min duration before the next heat flux determination.

Annex B gives the heat flux calculation details.

9.2 Sensor care

9.2.1 Sensor care

The exposure conditions experienced by the copper calorimeter with and without a specimen under test are such that frequent inspections should be conducted and maintenance performed where necessary. As a minimum, after each specimen exposure, immediately wipe the surface of the copper calorimeter with a nonabrasive material.

9.2.2 Sensor inspection

Remove the copper calorimeter from its support board to check that the thermocouple-to-disk connection is secure. The exposure surface shall also be inspected for deposit build-up. If deposits are present, the surface shall be reconditioned.

9.2.3 Surface reconditioning

If a deposit collects and appears to be thicker than a thin layer of paint, or is irregular, the sensor surface requires reconditioning. Carefully clean the cooled copper calorimeter with acetone or petroleum solvent, making certain there is no ignition source nearby. If bare copper is showing on the surface, clean the entire surface to bare copper and repaint the surface with a thin layer of flat black high-temperature spray paint. Follow the paint manufacturer's instructions for curing the paint.

EXAMPLE Air dry for at least 30 min, followed by an oven or other heat cure for 30 min to 35 min at 125 °C (250 °F). Or, expose the newly painted calorimeter to the convective/radiant TPI/HTI(DE) heat source for at least 10 s prior to running a calibration procedure.

Perform at least one calibration run (see 9.1) before using a reconditioned sensor in a test run.

See Annex A for material details and sources.

9.3 Specimen holder care

Use dry specimen holders, at room temperature, for each test run. Alternate with several sets of holders to permit cooling between runs or force cool with air. When required, clean condensed tars and soot from holders with acetone or a petroleum solvent, as given in 9.2.3.

9.4 Computer processing of data

The information provided in Table 1 can be used as the criteria of performance in the software of a computer program. In this case, the copper calorimeter response is compared with the human tissue heat tolerance criteria to determine the heat transfer burn intersection. The product of the heat transfer burn time and the exposure energy heat flux is the TPI. The report shall include a plot of the heat sensor response for each specimen.

Table 1 — Stoll curve[a] — Human tissue heat tolerance to a second-degree burn

Exposure time	Heat flux[a]	Total energy	Calorimeter[b] equivalent	
s	kW/m^2	kJ /m^2	ΔT °C	Δmv
1	50	50	8,9	0,46
2	31	61	10,8	0,57
3	23	69	12,2	0,63
4	19	75	13,3	0,69
5	16	80	14,1	0,72
6	14	85	15,1	0,78
7	13	88	15,5	0,80
8	11,5	92	16,2	0,83
9	10,6	95	16,8	0,86
10	9,8	98	17,3	0,89
11	9,2	101	17,8	0,92
12	8,6	103	18,2	0,94
13	8,1	106	18,7	0,97
14	7,7	108	19,1	0,99
15	7,4	111	19,7	1,02
16	7,0	113	19,8	1,03
17	6,7	114	20,2	1,04
18	6,4	116	20,6	1,06
19	6,2	118	20,8	1,08
20	6,0	120	21,2	1,10
25	5,1	128	22,6	1,17
30	4,5	134	23,8	1,23

[a] See Reference [4]. [b] Iron/constantan thermocouple.

9.5 Test specimen mounting

9.5.1 Single layer specimens

Test materials, used primarily as a single layer in an application, may be tested in the contact configuration and the spaced configuration.

In the contact configuration, the copper calorimeter is positioned in contact with the specimen.

In the spaced configuration, a (6,35 ± 0,05) mm thick spacer is positioned between the copper calorimeter and the specimen.

Centre the specimen on the mounting plate with the surface that will be the inside surface (worn next to the skin) facing up.

Place the specimen holding plate on top of the specimen in order to restrain the specimen during the exposure.

If the test is one in the spaced configuration, place the spacer in the square hole in the specimen holding plate and then place the sensor assembly on top of the spacer so it fits into the square hole as shown in Figure 1. This condition measures the barrier characteristic of the surface material and the insulation characteristics of the total assembly.

Add the weight (5.9 and see Figure 1) to the assembly.

9.5.2 Multilayer assembly specimens

Test materials used in a multilayer assembly shall be tested with the copper calorimeter in contact with the inside surface of the assembly.

Place the surface of the material to be used as the outside of the assembly face down on the mounting plate. Place the subsequent layers on top in the order and position used in the assembly, with the inside surface facing up, to form the specimen-holder assembly.

Place the specimen holding plate on top of the multilayer specimen in order to restrain the specimen during the exposure.

Place the sensor assembly on top of the specimen by fitting it into the square hole in the specimen holder plate.

Add the weight (5.9 and see Figure 1) to the assembly.

9.6 Test specimen exposure when both TPI and HTI(DE) are measured

Place the shutter over the energy source to block the convective and radiant heat. Place the specimen-holder assembly (see 9.5.1 or 9.5.2) on the support and centre the sensor assembly on top with the black-painted surface facing downward. Place the weight on top of the copper calorimeter mounting block to secure the specimen. Retract the shutter to expose the specimen to the energy source and simultaneously start the data acquisition system to record the output from the copper calorimeter thermocouple.

Terminate the exposure by closing the shutter to block the energy source when the desired end point in the temperature of the copper calorimeter is reached. The end point temperature will be either the 24 °C rise or when the temperature rise of the copper calorimeter intersects the Stoll curve (see Table 1 and Formula 1), whichever occurs last.

Remove the sensor assembly and start cooling the copper calorimeter. Remove the specimen holder and allow it to cool. After each specimen exposure, immediately wipe the surface of the copper calorimeter with a nonabrasive material to remove any decomposition products that have condensed onto its surface. Cool the copper calorimeter to 31 °C and ensure that it is stabilized to ±1 °C for at least a 1 min duration before the next specimen is tested. If required, reheat the sensor to approximately body temperature by contact with the palm of the hand just prior to positioning over the test specimen.

Remove the specimen from the holder and examine it as directed in 10.4.

Test the remaining specimens.

9.7 Test specimen exposure when only HTI(DE) is measured

Place the shutter over the energy source to block the convective and radiant heat. Place the specimen-holder assembly (see 9.5.1 or 9.5.2) on the support and centre the sensor assembly on top with the black-painted surface facing downward. Place the weight on top of the copper calorimeter mounting block to secure the specimen. Retract the shutter to expose the specimen to the energy source and simultaneously start the data acquisition system to record the output from the copper calorimeter thermocouple.

Terminate the exposure by closing the shutter to block the energy source when the temperature of the copper calorimeter has risen at least 24 °C.

Remove the sensor assembly and start cooling the copper calorimeter. Remove the specimen holder and allow it to cool. After each specimen exposure, immediately wipe the surface of the copper calorimeter with a nonabrasive material to remove any decomposition products that have condensed onto its surface. Cool the copper calorimeter to 31 °C and ensure that it is stabilized to ±1 °C for at least a 1 min duration before the next specimen is tested.

Remove the specimen from the holder and examine it as directed in 10.4.

Test the remaining specimens.

10 Expression of results

10.1 Selection of analysis method

The thermal performance of the test specimen is evaluated with either the TPI or the HTI(DE), or both.

10.2 Thermal protection index analysis method

10.2.1 Time to onset of burn injury

The time of the onset of burn injury, $t_{i,}$ is determined when the energy absorbed, E_{ab}, by the copper calorimeter meets/exceeds the following empirical performance criteria, as shown by Formula (1):

$$E_{ab} = 50{,}204 \times t^{0{,}290\,1} \tag{1}$$

where t is the time value in seconds of the elapsed time since the initiation of the thermal exposure by retracting the water-cooled shutter.

Determine the time of intersection, $t_{i,}$ to the nearest 0,1 s.

10.2.2 Thermal protection index

Calculate the TPI, i_{TP}, in kilojoules per square metre, to the nearest 1 kJ/m², using Formula (2):

$$i_{TP} = F \times t_i \tag{2}$$

where

F is the exposure heat flux (from 9.1.4), in kilowatts per square metre;

t_i is the time of intersection of the copper calorimeter temperature rise and the curve generated by Formula 1, in seconds.

Calculate the average TPI of all specimens tested for the same material or material assembly.

10.3 HTI(DE) analysis method

Using the temperature data recorded, determine the time taken for the copper calorimeter to rise 12 °C and 24 °C for each specimen. This time should be determined to the nearest whole second.

10.4 Response to convective and radiant heat exposure

Test operators shall provide observations on the condition of the test specimen following exposure, including on individual layers of a multilayer specimen. Specimen conditions include, but are not limited to, break-open, charring, dripping, embrittlement, ignition, melting, shrinkage and sticking.

11 Interlaboratory test data

See Annex C.

12 Test report

The test report shall contain the following information:

a) name of the test laboratory;

b) date of report;

c) reference to this document, i.e. ISO 17492;

d) identification reference of the material or material assembly tested;

e) description of the test materials, including details of generic names, mass per unit area and thickness at a pressure of 3,4 kPa, and the arrangement in which they were tested (for multilayer specimens);

f) the conditions of testing, including the type of gas used, calibrated exposure energy, and the specimen/sensor configuration, contact or spaced;

g) the method(s) of heat transfer analysis used;

h) if the TPI analysis was used, a report of the TPI for each specimen and the average for all specimens;

i) if the HTI analysis was used, the time for the heat transfer to cause a temperature rise of 12 °C and 24 °C, the HTI(DE)-T12 and HTI(DE)-T24 for each specimen, and the average for all specimens;

j) the observations of the effect of exposure energy on each specimen;

k) a statement as follows: “These results have been obtained by a test method intended to solely rank the material or material assembly and are not necessarily applicable to actual fire or flashover conditions.”.