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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17492 was prepared by Technical Committee ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 13, *Protective clothing*. It is based on Section 6-10 of NFPA 1971:2000 [2].

Introduction

The transfer of heat from the exterior of a material to the interior can be a significant factor in 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 impact 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 burn injury to the wearer. The performance of a product is determined by comparing the heat-transferred through the protective material to a known point where the thermal exposure would produce a burn injury. The total energy transferred that would cause a second-degree burn in human tissue is determined as the thermal protection index (TPI). In the TPI analysis of the data, the specimen is stressed by exposure to heat until the energy transferred through the specimen is equivalent to the energy that could cause a second-degree burn.

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

Unlike what is described in ISO 6942 or ISO 9151, the heat source in this test method is produced by 50 % radiant energy and 50 % convective energy. This equalized output is set to a thermal energy exposure having a heat flux of 80 kW/m^2. The intensity 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 may exist in actual fire situations. The intensity level of this heat flux represents a moderately high industrial or emergency fire-fighting exposure that requires the use of a protective material, and thus, measures the performance of the specimen under realistic conditions relatively close to a realistic exposure intensity.

NOTE 1 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 thermal protection index and the heat-transfer index measure the accumulated heat energy received which is an indication of the ability of the material to inhibit the transfer of heat.

NOTE 2 A human tissue burn will result when the total thermal energy transmitted by the material reaches the second-degree burn threshold.

NOTE 3 The thermal protection index or the heat-transfer index for flame-resistant materials can be used to establish anticipated performance levels of thermal resistance for single layer or multilayer constructions or assemblies.

NOTE 4 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 property of the sample and represents the way in which the material is used in the end-use application.

NOTE 5 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 actual exposure during a flash fire. This mounting condition measures the thermal resistance of the specimen plus the air gap and barrier performance of the specimen.

NOTE 6 The contact configuration, with the sensor in contact with the specimen, measures the insulation property 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 International Standard specifies a test method for measuring the heat-transfer of horizontally mounted flame-resistant textile materials when exposed to a combination of convective and radiant energy.

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

This test method can be used for 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 is not intended to be used on materials that are not flame resistant.

This test method is not intended for evaluating materials exposed to any other type of thermal-energy sources, such as radiant heat only or flame contact only. Use ISO 6942 when evaluating heat-transfer through materials due to radiant heat only and use ISO 9151 when evaluating heat-transfer through materials due to flame contact only.

This test method may not identify textile materials that can ignite and continue to burn after exposure to convective and radiant energy.

This International Standard should be used to measure and describe the properties of materials, products or assemblies in response to both convective and radiant energy under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products or assemblies under actual fire conditions. However, the results of this test method may be used as elements of a fire-risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end-use.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 6942, *Protective clothing — Protection against heat and fire — Method of test: Evaluation of materials and material assemblies when exposed to a source of radiant heat*

ISO 9151, *Protective clothing against heat and flame — Determination of heat transmission on exposure to flame*

3 Terms and definitions

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

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

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

NOTE 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 International Standard is related to second-degree burn injury, and is determined by the amount of thermal energy transferred through the specimen which is sufficient to cause a second-degree burn. A second-degree burn injury involves the epidermis/dermis interface.

3.3
charring
formation of carbonaceous residue as the result of pyrolysis or incomplete combustion

3.4
dripping
material response shown by 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
incident energy
maintained thermal energy that is incident to the test specimen

3.7
exposure time
total time over which the exposure energy is applied to the test material

3.8
heat flux
thermal intensity indicated by the amount of energy transmitted per unit area and per unit time

NOTE Heat flux is expressed in kilowatts per square metre (kW/m^2).

3.9
heat-transfer index-thermal
HTI-T
time, in seconds, to cause a temperature rise of the copper sensor by 12 °C and 24 °C from a combined convective and radiant heat (thermal) exposure

NOTE The time to cause a 12 °C temperature rise is indicated with a subscript of 12, and that for a 24 °C rise with a subscript of 24, e.g. $HTI\text{-}T_{12}$ and $HTI\text{-}T_{24}$. The relative value between these two indices indicates the characteristic of the heat-transfer. If $HTI\text{-}T_{24}$ is twice that of $HTI\text{-}T_{12}$, the rate of heat-transfer is constant. If $HTI\text{-}T_{24}$ is greater than twice that of $HTI\text{-}T_{12}$, the rate of heat-transfer is increasing, showing a loss in insulation performance. If $HTI\text{-}T_{24}$ is less than twice that of $HTI\text{-}T_{12}$, the rate of heat-transfer is decreasing, showing increasing insulation performance.

3.10
heat-transfer burn intersection
point at which the thermal energy transferred through the material intersects the point on a Stoll Curve where a second-degree burn injury is predicted to take place

3.11
heat-transfer burn time
time from the start of the thermal exposure to heat-transfer burn intersection

NOTE Heat-transfer is measured using a copper calorimeter as the sensor. The sensor diameter is large enough to average the heat received through the exposed specimen. The sensor thickness causes the temperature rise of the sensor to be similar to that of human tissue when exposed to heat. The sensor is painted a dull black to cause it to receive radiant energy with a coefficient of absorption similar to human tissue.

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

NOTE The tolerance of human tissue to heat exposure was developed by Stoll et al. (see Table 1) and is referred to as the Stoll Curve. It is used in this method as the heat-transfer criteria in determining the thermal-threshold index (TTI) value of the test material.

3.13
ignition
initiation of combustion

3.14
inherent flame resistance
flame resistance that derives from the essential characteristics of the fibre from which the textile is made

3.15
melting
liquefaction of a material when exposed to heat resulting in a non-reversible change

3.16
response to heat exposure
observable response of the textile to the energy exposure as indicated by break-open, melting, dripping, charring, embrittlement, shrinkage, sticking or ignition

3.17
shrinkage
decrease in one or more dimensions of an object or material

3.18
sticking
response evidenced by softening of a material and adherence of one material to the surface of itself or another material

3.19
Stoll curve
relationship between the amount of thermal energy transferred to human tissue and the time of exposure which predicts a second-degree burn in human tissue

See Table 1.

3.20
thermal-threshold index
TTI
time, in seconds, for the heat transmitted through a material to just cause a second-degree burn in human tissue

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 until sufficient heat energy passes through the specimen to cause the equivalent of a second-degree burn injury in human tissue, or indicate a temperature rise of 24 °C in the sensor.

The specimen is mounted either in contact with the sensor, designated as contact configuration, or with a 6,5 mm space between the specimen and the sensor, designated as spaced configuration.

The test exposure is composed of convective energy supplied by two gas burners, and radiant energy from nine quartz radiant tubes.The combined total energy of the exposure is calibrated using a total calorimeter and radiometer combination.The total energy exposure is then confirmed with the copper sensor.

The amount of heat transferred by the specimen is measured with a heat sensor and analysed by one of the following two methods.

— The heat transferred may be compared with times for 12 °C and 24 °C temperature rises in the sensor to determine the heat transfer index (HTI) of the specimen to indicate the thermal insulation performance. The rate at which the temperature of the heat sensor rises is a direct measurement of the heat energy transferred.

— The heat transfer may also be compared with the times for the heat energy transferred through the specimen to cause a second-degree burn, the thermal threshold index (TTI), as based on human-tissue tolerance data.

The effect of the exposure on the physical appearance of the specimen can also be noted.

5 Apparatus

5.1 General, the test apparatus shall consist of

— a thermal-flux source,

— a specimen holder support,

— a protective shutter,

— a specimen holder assembly, and

— a sensor assembly.

The apparatus shall also have a gas supply, gas rotameter and recorder. A diagram of the test apparatus is provided in Figure 1.

See Annex A for possible suppliers.

5.2 Thermal-flux source, consisting of a convective thermal-flux source and a radiant thermal-flux source. The convective thermal-flux source shall consist of two Meker or Fisher burners affixed beneath the opening of the specimen holder assembly opening, and subtended at a nominal 45° angle from the vertical so that the flames converge at a point immediately beneath the specimen. The radiant thermal-flux source shall consist of nine quartz T-500 infrared tubes 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 to the gas used.

5.3 Specimen holder support, consisting of a steel frame that rigidly holds and positions, in a reproducible manner, the specimen support frame and specimen relative to the thermal-flux.

5.4 Protective shutter, placed between the thermal-flux source and the specimen. The protective shutter shall be capable of completely dissipating the thermal load from the thermal-flux 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 chart recorder or computer.

5.5 Specimen mounting plate, consisting of a piece of steel 150 mm square and 1,6 mm thick, with a 100 mm square hole in its centre. Angles of 6,5 mm shall be welded to each corner perpendicular to the plane of the plate (see Figure 2).

5.6 Specimen holding plate, 149 mm × 149 mm × 15 mm thick metal 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.

5.7 Spacer, 128 mm × 128 mm × 6,4 mm (0,25 in) thick metal with a 110 mm × 110 mm centred square hole.

5.8 Sensor assembly, a copper calorimeter assembled in a mounting block.

The assembly consists of the following components.

— Copper-disc calorimeter, consisting of a disc of copper of at least 99 % purity, having a diameter of 40 mm and thickness of 1,6 mm with three thermocouples connected as specified in Figure 3.

— Calorimeter mounting block consisting of a 128 mm × 128 mm square piece of asbestos-free noncombustible heat-insulating board of nominal thickness 13 mm machined as specified in Figure 4.

— The calorimeter disk shall be bonded in position around its circumference with an adhesive capable of withstanding temperatures of about 200 °C. The face of the copper disk shall be flush with the surface of the mounting block. The face of the copper disc shall also be coated with a thin layer of flat black paint by spraying.

— The complete sensor assembly, including the copper calorimeter shall be uniformly weighted such that it weighs (1 000 ± 10) g in total.

5.9 Recorder, any strip-chart recorder with a full-scale deflection of at least 150 °C or 10 mV and sufficient sensitivity and scale divisions to read the sensor response to 1 °C or 0,05 mV and exposure time to ± 0,1 s (a chart speed of 12 mm/s is satisfactory). Alternatively, an equivalent automated data-acquisition system meeting or exceeding the sensitivity and accuracy requirements of the strip-chart recorder shall be permitted to be used instead of a strip-chart recorder.

5.10 Gas supply, propane, methane or natural gas with appropriate reducer and valving 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).

5.11 Gas rotameter, any gas rotameter with a range which gives flow equivalent to 2 l/min air at standard conditions.

5.12 Radiometer, a Gardon-type radiation transducer with a diameter of 25 mm, a minimum 150° view angle, and a heat flux operating range from 0 kW/m^2 to 80 kW/m^2. If the radiometer is water cooled, the cooling-water temperature shall be above the ambient dew-point temperature (for the laboratory environment).

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

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

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 in handling materials around the quartz tubes or the burner with the open flame.