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Protective clothing against heat and flame —

Part 1: Test method for complete garments — Measurement of transferred energy using an instrumented manikin

Vêtements de protection contre la chaleur et les flammes —

Partie 1: Méthode d'essai pour vêtements complets — Mesurage de l'énergie transférée à l'aide d'un mannequin instrumenté

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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).

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 on 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 the following URL: www.iso.org/iso/foreword.html

This document was prepared by Technical Committee ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 13, *Protective clothing*.

This first edition of ISO 13506-1, together with ISO 13506-2, cancels and replaces the first edition of ISO 13506:2008, which has been technically revised. The assessment of skin burn injury has been transferred to ISO 13506-2.

A list of all parts in the ISO 13506 series can be found on the ISO website.

Introduction

The purpose of heat and flame-resistant protective clothing is to shield the wearer from hazards that can cause skin burn injury. The clothing can be made from one or more materials. The evaluation of materials for potential use in this type of clothing generally involves two steps. First, the materials are tested to gauge their ability to limit flame spread. They are then tested to determine the rate of transferred energy through them when exposed to a particular hazard. A variety of test methods are used in these two steps. The test method selected depends on the nature of the potential hazards and the intended end use of the materials. Once suitable materials have been identified, they can be made into complete garments or ensembles for testing on a manikin-fire exposure system.

Laboratory bench scale transferred energy tests are used to select suitable materials for a protective clothing ensemble. While these tests can allow ranking of garment or ensemble materials and components, the tests do not allow a complete assessment of a garment or ensemble made of the materials.

Bench scale transferred energy test methods use small amounts of material, up to 150 mm × 150 mm in area, and hold the material initially flat, either in a vertical or horizontal plane. Multiple layers are used where appropriate (e.g. fire-fighting ensembles). In this case, the layer normally worn on the exterior is exposed directly to the energy source, while the layer normally worn on the inside is away from the energy source. With the planar orientation and alignment of materials, shrinkage has little effect on the outcome of the test, unless the shrinkage is so severe as to cause holes to form in the material during the exposure to the energy source. Sagging, however, does directly affect the results, as an air gap can form or grow in size, adding an insulating effect. With the aforementioned test methods, it is possible to test seams, zippers, pockets, buttons or other closures, metal and plastic clips or other features that can be included in a complete garment such as heraldry, company logos, etc. However, it is often considered easier to evaluate these aspects together with the overall design features of a garment or ensemble that can affect the performance by testing complete garments or ensembles on a manikin. It is for this purpose that this document was established.

In the test method in this document, a stationary, upright adult-sized manikin is dressed in a complete garment and exposed to a laboratory simulation of a fire with controlled heat flux, duration and flame distribution. The average incident heat flux to the exterior of the garment is 84 kW/m^2, a value similar to those used in ISO 9151, ISO 6942 and ISO 17492. Heat flux sensors fitted to the surface of the manikin are used to measure the heat flux variation with time and location on the manikin and to determine the total energy absorbed over the data-gathering period. The data gathering period is selected to ensure that the total energy transferred has been completed. The information obtained can be used to assist in evaluating the performance of the garment or protective clothing ensembles under the test conditions. It can also be used to estimate the extent and nature of skin damage that a person would suffer if wearing the test garment under similar exposure conditions (see ISO 13506-2).

The manikin is used in a standing position in initially quiescent air. Controlled air motion for simulating wind effects or body movement is not presently possible. It is possible to move the manikin through a stationary flame but motion of this nature is not within the scope of this document. Variations in the fit of the test garment that can occur when sitting or bending are not evaluated.

The fire simulations are dynamic. As such, the exposure is more representative of an actual industrial accident fire than the exposures used in bench scale tests (see Annex B). The heat flux resulting from the exposure is neither constant nor uniform over the surface of the manikin/garment. Under these conditions, the results are expected to have more variability than carefully controlled bench scale tests. In addition, the garment is not constrained to be a flat surface but is allowed to have a natural drape on the manikin. The effect these variables have on a garment can be seen in several ways: ignition and burning of the garment and heraldry, sagging or shrinkage in all directions after flaming, hole generation, smoke generation and structural failure of seams. Many of these failures rarely appear in the bench scale testing of the materials because they are a result of garment design variables, interaction between material properties and design variables, construction techniques and localized exposure conditions that are more severe.

Fit of the garment on the manikin is important. Thus variations in garment design and how the manikin is dressed by the operator can influence the test results. A test garment or specimen size is selected by the laboratory from the size range provided by the manufacturer to fit the laboratory's manikin. Experience suggests that testing a garment one size larger than the standard will reduce the total energy transferred and percentage body burn by about 5 %.

This document is not designed to measure material properties directly, but to evaluate the interaction of material behaviour and garment design. One can compare relative material behaviour by making a series of test garments out of different materials using a common pattern. The performance of the complete garments will not necessarily be ranked in the same order as might be obtained when the materials are tested using ISO 9151. Correlations between small scale tests and results from single-layer garments have been examined[15].

Most manikins do not have sensors on the hands and feet, but it is possible to assess some aspects of hand protection depending upon the specific design of the hands. The head, however, does contain heat flux sensors. The reason for this is that many outer garments include an integral hood, but not gloves or footwear. Tests for gloves and footwear are covered by other ISO documents for specific end uses.

The protection offered by the test specimens is evaluated through quantitative measurements and observations. Heat flux sensors fitted to the manikin are used to measure the energy transferred to the manikin surface during the data-gathering period. This information can be reported directly (this document) or used to calculate the nature, location and extent of the damage that would occur to human skin from the exposure (see ISO 13506-2).

References [16] and [17] give details of manikin and sensor construction, data acquisition, computer software requirements, flame exposure chamber and fuel and delivery system. They also suggest numerical techniques that can be used to carry out the calculations required.

The ISO/TC 94, SC 13 and SC 14 committees and European Committee for Standardization (CEN TC 162) specify the method described in this document as an optional part in the fire fighter standards ISO 11999-3 and EN 469[11], and as an optional part in the industrial heat and flame protective clothing standard ISO 11612. The National Fire Protection Association (NFPA) specifies a test method similar to the one described in this document as part of a certification process for garments (see NFPA 2112[13]).

Protective clothing against heat and flame —

Part 1: Test method for complete garments — Measurement of transferred energy using an instrumented manikin

1 Scope

This document specifies the overall requirements, equipment and calculation methods to provide results that can be used for evaluating the performance of complete garments or protective clothing ensembles exposed to short duration flame engulfment.

This test method establishes a rating system to characterize the thermal protection provided by single-layer and multi-layer garments made of flame resistant materials. Any material construction such as coated, quilted or sandwich can be used. The rating is based on the measurement of heat transfer to a full-size manikin exposed to convective and radiant energy in a laboratory simulation of a fire with controlled heat flux, duration and flame distribution. The heat transfer data are summed over a prescribed time to give the total transferred energy.

For the purposes of this test method, the incident heat flux is limited to a nominal level of 84 kW/m^2 and limited to exposure durations of 3 s to 12 s dependant on the risk assessment and expectations from the thermal insulating capability of the garment. The results obtained apply only to the particular garments or ensembles, as tested, and for the specified conditions of each test, particularly with respect to the heat flux, duration and flame distribution.

This test method requires a visual evaluation, observation and inspection on the overall behaviour of the test specimen during and after the exposure as the garment or complete ensemble on the manikin is recorded before, during and after the flame exposure. Visuals of the garment or complete ensemble on the manikin are recorded (i.e. video and still images) before, during and after the flame exposure. This also applies to the evaluation of protection for the hands or the feet when they do not contain sensors. For the interfaces of ensembles tested, the test method is limited to visual inspection. The effects of body position and movement are not addressed in this test method.

The heat flux measurements can also be used to calculate the predicted skin burn injury resulting from the exposure (see ISO 13506-2).

This test method does not simulate high radiant exposures such as those found in arc flash exposures, some types of fire exposures where liquid or solid fuels are involved, nor exposure to nuclear explosions.

NOTE 1 This test method provides information on material behaviour and a measurement of garment performance on a stationary upright manikin. The relative size of the garment and the manikin and the fit of the garment on the shape of the manikin have an important influence on the performance.

NOTE 2 This test method is complex and requires a high degree of technical expertise in both the test setup and operation.

NOTE 3 Even minor deviations from the instructions in this test method can lead to significantly different test results.

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 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 9162, *Petroleum products — Fuels (class F) — Liquefied petroleum gases — Specifications*

ISO/TR 11610, *Protective clothing — Vocabulary*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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 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
absorbed energy
energy (3.5) absorbed by each *manikin sensors* (3.14) mounted in the surface of the manikin when exposed to the *incident energy* (3.12)

Note 1 to entry: This does not account for radiant or convective losses unique for each style of sensor.

3.2
associated area
area of body region divided by the number of sensors in that body region

Note 1 to entry: See Table 2.

3.3
complete garments
single garment or combination of garments designed to protect the torso, arms and legs of the wearer

Note 1 to entry: Both a single garment and a combination of garments can include protection for the head of the wearer by means of a hood (integral or separate) or balaclava. A combination of garments can include undergarments and outer garments.

3.4
conditioning
keeping samples under standard conditions of temperature and relative humidity for a minimum period of time

3.5
energy
heat flux (3.10) multiplied by the time period of measurement and by *associated area* (3.2)

3.6
energy transmission factor
ratio of the *transferred energy* (3.18) to the *incident energy* (3.12), for the energy calculation period

3.7
fire
rapid oxidation process which is a chemical reaction of fuel and oxygen resulting in the evolution of light, heat and combustion products in varying intensities

Note 1 to entry: The fuel can be a solid, dust, a gas or vapours of an ignitable liquid. The fire will last as long as there is a combustible fuel-air mixture.

3.8
flame distribution
spatial distribution of incident flames from the test facility burners which provides a controlled *heat flux* (3.10) over the manikin surface

3.9
garment ease
difference between body (manikin) dimensions and garment dimensions

3.10
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 kW/m^2.

3.10.1
absorbed heat flux
heat flux (3.10) absorbed by the *manikin sensors* (3.14) mounted in the surface of the manikin when exposed to the *incident heat flux* (3.10.2)

3.10.2
incident heat flux
heat flux (3.10) to which a test item or nude manikin is exposed

Note 1 to entry: The incident heat flux is determined from the characteristics of the *manikin sensors* (3.14) and their measured output during a nude manikin exposure.

3.11
heat flux sensor
device capable of directly measuring the *heat flux* (3.10) to the manikin's surface under test conditions, or of providing data that can be used to calculate the heat flux

Note 1 to entry: In either case, the created data needs to be in a form that can be processed by a computer program to assess the total energy transferred over the recording period and/or the predicted skin burn injury.

3.12
incident energy
energy (3.5) to which a test item or nude manikin is exposed

3.12.1
total incident energy
sum of the *incident energy* (3.12) of all the *manikin sensors* (3.14) during the nude exposure

3.13
instrumented manikin
model representing an adult-sized human which is fitted with *manikin sensors* (3.14) in the surface

3.14
manikin sensor
heat flux sensor (3.11) fulfilling the requirements of this document

Note 1 to entry: See 3.11 and 5.3.

3.15
maximum heat flux
highest value of *absorbed heat flux* (3.10.1) calculated from the recorded output of a *manikin sensor* (3.14) during a test

3.16
protective clothing ensemble
combination of complete protective garments

Note 1 to entry: This document does not include energy transferred to the hands and feet. Gloves and footwear can be included in the ensemble for visual inspection. This will allow a more realistic representation of interfaces and make possible a visual inspection of gloves and footwear during and after the test.

3.17
thermal protection
overall protective performance of a garment or *protective clothing ensemble* (3.16) relative to how it limits the transfer of energy to the manikin surface over the defined calculation period

Note 1 to entry: In fire testing of clothing, thermal protection of a garment or ensemble can be quantified by the measured *manikin sensor* (3.14) response which indicates how well the garment or protective clothing ensemble limits heat transfer to the manikin surface. In addition to the measured sensor response, the physical response and degradation of the garment or ensemble are observable phenomena which are associated with the manikin sensor calculation and are useful in understanding garment or protective clothing ensemble thermal protection.

3.18
transferred energy
energy (3.5) transferred through the test item and absorbed by a *manikin sensor* (3.14) over the defined calculation period

3.18.1
total transferred energy
sum of the *transferred energy* (3.18) of all *manikin sensors* (3.14) over the *transferred energy calculation period* (3.18.2)

Note 1 to entry: Each manikin sensor has an *associated area* (3.2). It is assumed that the measured energy transferred for each manikin sensor is uniform over this associated area. Some manikins have a sensor layout that has the same area associated with each manikin sensor, others do not.

3.18.2
transferred energy calculation period
measurement time when *transferred energy* (3.18) is gathered

Note 1 to entry: See 8.2.6.

4 General

The method evaluates the thermal protective performance of the test specimen, which is either a garment or an ensemble. The protective performance is a function of both the materials of construction and design. The average incident heat flux is 84 kW/m^2 with an exposure duration of 3 s to 12 s.

The product standard shall indicate the minimum exposure time and the minimum number of samples to be tested.

The conditioned test specimen is placed on a stationary upright adult-size manikin and exposed to a laboratory simulation of a fire with controlled heat flux, duration and flame distribution. The test procedure, data acquisition, result calculations and preparation of the test report are performed with computer hardware and software programs.

Energy transferred through the test specimen during and after the exposure is measured by manikin sensors. These measurements shall be used to calculate the total energy transferred to the surface of the manikin and the energy transmission factor.

NOTE 1 The purpose of this test method is to measure the heat flux and calculate transferred energy. The results can also be used to calculate the degree of predicted skin burn injury and total predicted skin burn injury areas resulting from the exposure as described in ISO 13506-2.

Identification of the test garment, test conditions, comments and response of the test specimen to the exposure are recorded and are included as part of the test report. The performance of the test specimen is indicated by the calculated total transferred energy through the test specimen over the data acquisition period, the total energy transmission factor and the way the test specimen responds to the test exposure.

NOTE 2 This test method can be used for other purposes such as for research on fabrics and garment designs, comparison of garment ensembles, or evaluation of any garment or ensemble to particular applications or end use standards or specifications.

5 Apparatus

5.1 Instrumented manikin

An upright manikin, which is the shape and size of an adult human, shall be used [see Figure 2 a) and b)]. The manikin shall be constructed to simulate the body of a human and shall consist of a head, a chest/back, an abdomen/buttocks, arms, hands, legs and feet. The arms should be able to rotate through a sufficient arc at the shoulder to ease the garment donning and doffing on the manikin.

NOTE 1 Figure 2 illustrates a male shape and the dimensions of Table 1 are for a male manikin. A standard female form has not yet been determined.

The manikin shall be constructed of flame-resistant, thermally stable, non-metallic materials such as ceramics or glass-reinforced vinyl ester resin that will not contribute to the combustion process. The shell thickness shall be in the range of 3 mm to 6 mm other than in localized areas (e.g. joints).

NOTE 2 The manikin thickness is dependent on structural requirements needed to maintain a stable physical form related to the thermal properties of the manikin material and it has been historically observed to affect the operability of the manikin rather than the reproducibility of results. For example, the variance of thickness of a manikin has been found to affect its durability due to differential thermal stresses that increase the risks of cracking. In addition, the greater the thickness of the manikin, the longer it takes to cool. The manikin utilizes a hollow structure to allow for the electrical wiring of the sensors.

The manikin shall not be made of a material, which may be affected by humidity or any cleaning liquid (e.g. water, acetone, etc.), which may be used for the cleaning of the manikin sensors.

5.2 Posture of the manikin

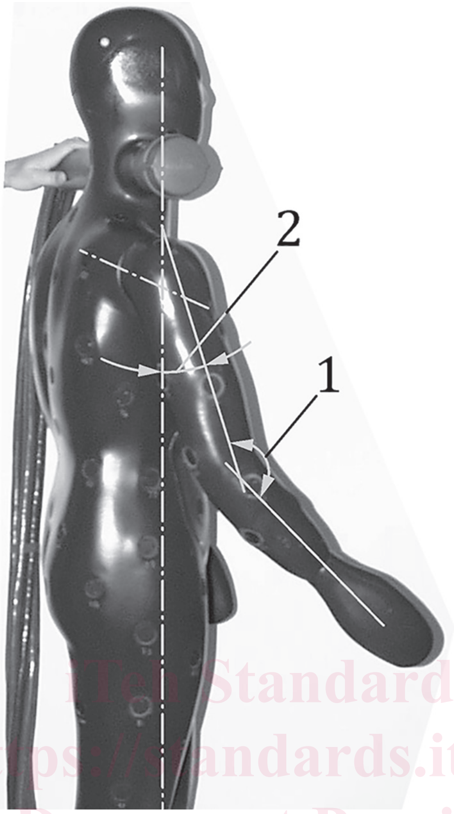
A reproducible positioning system is required for the manikin. It may consist of pin locators in the floor, a portable rigid positioning frame and/or light or laser beams for setting vertical orientation and arm position.

The elbow angle between the upper and lower arm (see Figure 1) shall be set in the range of 150° to 165°. The angle of the shoulder (see Figure 1) shall be set in the range of 25° to 35° from the centreline of the manikin. These angles apply to all manikin exposures (nude and with test items). Reference lines and angles are identified in Figure 1.

NOTE 1 Tape can be used to increase the friction of the joints of the arm to ensure that the position is maintained during the exposure[1)].

1) Gore® Joint Sealant is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product. Equivalent products may be used if they can be shown to lead to the same results.

NOTE 2 Most manikins have legs that cannot move. Some manikins have a slight twist of the torso as compared to the legs. The legs are less than 10° apart from the centre line and at the ankles, they are about 120 mm to 250 mm apart.



Key

1 angle between upper arm and lower arm

2 angle between line shoulder and hip to shoulder and elbow

Figure 1 — Definition of arm position

