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Protective clothing for firefighters — Laboratory test methods and performance requirements

*Vêtements de protection pour sapeurs-pompiers — Méthodes d'essai et
exigences de performance*

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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 11613 was prepared by Technical Committee ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 13, *Protective clothing*.

Annexes A, B, C, D and E form a normative part of ISO 11613. Annexes F and G are for information only.

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Introduction

The purpose of this International Standard is to provide minimum performance requirements for protective clothing designed to protect against injury in firefighting operations. It provides guidance on the selection of firefighters' protective clothing (see clause 1) and considerations for conducting a risk assessment of firefighting risks (see annex F).

Two alternative approaches to the design and performance requirements for firefighting clothing are provided.

- Approach A Clause 4 specifies design and performance requirements based on EN 469 *Protective Clothing for Firefighters — Requirements and test methods for protective clothing for firefighting* and its clarification documents.
- Approach B Clause 5 specifies design and performance requirements based on NFPA 1971 *Standard on Protective Clothing for Structural Firefighting*.

A comparison of the requirements in clauses 4 and 5 is given in annex G. The two approaches are not directly comparable as they use different test procedures.

This International Standard has been prepared to fulfil the requirements of a number of countries and it combines both European and North American approaches. It is agreed that a revision of this International Standard will start immediately after its publication in order to specify levels of performance on single test methods and to take into account any changes in revision of both EN 469 and NFPA 1971.

Nothing in this International Standard is intended to restrict any jurisdiction, purchaser or manufacturer from exceeding these minimum requirements.

Protective clothing for firefighters — Laboratory test methods and performance requirements

1 Scope

This International Standard specifies test methods and minimum requirements for protective clothing to be worn during firefighting and associated activities where there is a risk of heat and/or flame.

This International Standard covers the general clothing design, the minimum performance levels of the materials used, and the methods of test for determining these performance levels. Clauses 4 and 5 define two separate sets of design and performance requirements.

This International Standard does not cover special clothing for use in other high risk situations such as specialized firefighting, or clothing for use in long term firefighting operations in high ambient temperature, for example brush, wildland, or forest firefighting. It does not cover protection for the head, hands and feet or protection against other hazards, for example chemical, biological, radiation and electrical hazards. These aspects may be dealt with in other standards.

Selection of the appropriate system of clothing is dependent on carrying out an effective risk assessment which identifies the hazards to be faced, evaluates the likelihood of those hazards, and provides the means to reduce or eliminate these hazards. Details on one example at a recommended risk assessment approach and some factors for consideration are included in annex F.

NOTE Additional personal protective equipment to protect the head, hands, and feet should be worn with clothing specified in this International Standard and in majority of situations breathing apparatus is also required to be worn. Firefighters should be trained in the use and care of protective clothing covered by this International Standard including an understanding of its limitations and of the other items of personal protective equipment that may be required depending on the risks encountered.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 811:1981, *Textile fabrics — Determination of resistance to water penetration — Hydrostatic pressure test.*

ISO 3146:1985, *Plastics — Determination of melting behaviour (melting temperature or melting range) of semi-crystalline polymers.*

ISO 3175-2:1998, *Textiles — Dry cleaning and finishing — Part 2: Procedures for tetrachloroethene.*

ISO 4674:1977, *Fabrics coated with rubber or plastics — Determination of tear resistance.*

ISO 4920:1981, *Textiles — Determination of resistance to surface wetting (spray test) of fabrics.*

ISO 5077:1984, *Textiles — Determination of dimensional change in washing and drying.*

ISO 5081:1977, *Textiles — Woven fabrics — Determination of breaking strength and elongation (Strip method)*.

ISO 5082:1982, *Textiles — Woven fabrics — Determination of breaking strength — Grab method*.

ISO 6330:1984, *Textiles — Domestic washing and drying procedures for textile testing*.

ISO 6530:1990, *Protective clothing — Protection against liquid chemicals — Determination of resistance of materials to penetration by liquids*.

ISO 6942:1993, *Clothing for protection against heat and fire — Evaluation of thermal behaviour of materials and material assemblies when exposed to a source of radiant heat*.

ISO 9073-4:1997, *Textiles — Test methods for nonwovens — Part 4: Determination of tear resistance*.

ISO 9151:1995, *Protective clothing against heat and flame — Determination of heat transmission on exposure to flame*.

ISO 9227:1990, *Corrosion tests in artificial atmospheres — Salt spray tests*.

ISO 13688:1998, *Protective clothing — General requirements*.

ISO 15025:—¹⁾, *Protective clothing — Protection against heat and flame — Method of test for limited flame spread*.

ISO 17492:—¹⁾, *Clothing for protection against heat and flame — Determination of heat transmission on exposure to both flame and radiant heat*.

ISO 17493:—¹⁾, *Clothing for protection against heat and flame — Determination of convective heat resistance using a hot air circulating oven*.

EN 532:1994, *Protective clothing — Protection against heat and flame — Test method for limited flame spread*.

ASTM E 809:1981, *Standard Practice for Measuring Photometric Characteristics of Retroreflectors*.

3 Terms, definitions and symbols

For the purposes of this International Standard, the following terms, definitions and symbols apply.

3.1 Terms and definitions

3.1.1

cargo pockets

pockets located on the protective garment exterior

NOTE As used in clause 5.

3.1.2

char

formation of a brittle residue when material is exposed to thermal energy

3.1.3

collar lining

that part of the collar fabric composite that is next to the skin when the collar is closed in the raised position

¹⁾ To be published.

3.1.4**composite**

layer or layers that provide protection required of outer shell, moisture barrier, and thermal barrier

3.1.5**closure system**

method of fastening openings in the garment including combinations of more than one method of achieving a secure closure, for example a slide fastener covered by an overlap fastened down with a touch and close fastener

NOTE This term does not cover seams.

3.1.6**component assembly**

material combination found in a multilayer garment arranged in the order of the finished garment construction and including any inner liner

3.1.7**drip**

to run or fall in drops or blobs

3.1.8**firefighters' protective clothing**

specific garments providing protection for the firefighter's upper and lower torso, neck, arms, and legs, but excluding the head, hands, and feet

3.1.9**garment**

single item of clothing which may consist of single or multiple layers

3.1.10**hardware**

non-fabric components of protective clothing including those made of metal or plastic material

NOTE Examples include fasteners, rank markings, buttons, etc.

3.1.11**innermost lining**

lining found on the innermost face of a component assembly

3.1.12**integral melting**

liquefaction of a material when exposed to heat to the extent of causing a hole in its structure, either by shrinking and/or dripping away under specified test conditions

NOTE See 5.1 and 5.5.

3.1.13**interface area**

area of the body not protected by a protective garment, helmet, gloves, footwear, or self-contained breathing apparatus (SCBA) facepiece; the area where the protective garments and the helmet, gloves, footwear, or SCBA facepiece meet, i.e., the protective coat/helmet/SCBA facepiece area, the protective coat/glove area, and the protective trouser/footwear area

3.1.14**interface component**

item(s) designed to provide limited protection to interface areas

3.1.15

interlining

layer found between the outermost layer and the innermost lining in a multilayer garment, not next to the wearer's skin

3.1.16

manufacturer

entity that assumes the liability and provides the warranty for the compliant product

NOTE As used in clause 5.

3.1.17

material combination

material produced from a series of separate layers, intimately combined prior to the garment manufacturing stage

EXAMPLE A quilted fabric.

3.1.18

melt

to change from solid to liquid form, or become consumed by action of heat

3.1.19

moisture barrier

that portion of the protective garment designed to prevent the transfer of liquid water from the environment to the thermal barrier

NOTE As used in clause 5.

3.1.20

moisture barrier

fabric or membrane used in a component assembly to enable the properties of the assembly to comply with the manufacturer's claims concerning hydrostatic pressure and water vapour permeability

NOTE As used in clause 4.

3.1.21

multilayer clothing assembly

series of layers of garments arranged in the order as worn

NOTE It may contain multilayer materials, material combinations or separate layers of clothing material in single layers.

3.1.22

outer material

outermost material of which the protective clothing is made

3.1.23

outer shell

outside facing portion of the composite with the exception of trim, hardware, reinforcing material, and wristlet material

NOTE As used in clause 5.

3.1.24

protective clothing

protective garments, configured as a coat and trousers or as a coverall, and interface components that are designed to provide protection to the firefighter's body

3.1.25**protective coat**

protective garment designed and configured to provide protection to upper torso and arms, excluding the hands and head

3.1.26**protective coverall**

protective garment designed and configured to provide protection to the torso, arms, and legs, excluding the head, hands, and feet

3.1.27**protective garment**

single item of clothing which may consist of single or multiple layers, for example protective coat, protective trouser, or protective coverall

3.1.28**protective hood**

interface component that provides limited protection to the protective coat/helmet/SCBA facepiece interface area

3.1.29**protective trouser**

provides protection to lower torso and legs excluding the feet

3.1.30**protective uniform garment**

garment designed and configured to be both the thermal barrier or portion of the thermal barrier of a protective garment, and a station/work uniform

NOTE 1 As used in clause 5.

NOTE 2 The term refers specifically to station/work uniform garments that satisfy the applicable requirements of NFPA 1975, *Standard on Station/Work Uniforms for Firefighters*, and that also satisfy in part or in full the thermal barrier requirements of this International Standard.

3.1.31**protective wristlet**

interface component that provides limited protection to the protective garment/glove interface area

3.1.32**removable inner liner**

inner garment designed to be attached or to be worn separately under an outer garment in order to provide thermal insulation

3.1.33**seam**

junction of two edges of material which are permanently attached in the garment by sewing or any other method

3.1.33.1**major A seams**

outer-shell seam assemblies where rupture could reduce the protection of the garment by exposing the moisture barrier, thermal barrier, the wearer's station/work uniform, other clothing, or skin

NOTE As used in clause 5.

3.1.33.2**major B seams**

moisture barrier or thermal barrier seam assemblies where rupture could reduce the protection of the garment by exposing the next layer of the garment, the wearer's station/work uniform, other clothing, or skin

NOTE As used in clause 5.

3.1.33.3

minor seams

remaining seam assemblies that are not classified as major A or major B seams

3.1.34

thermal barrier

that portion of the composite designed to provide thermal protection

3.1.35

trim

retroreflective and fluorescent material attached to the outer shell for visibility enhancement; retroreflective materials enhance night-time visibility, and fluorescent materials improve daytime visibility

3.1.36

undergarment

garment which is worn under an outer garment

3.1.37

winter liner

optional composite layer designed to provide added insulation against cold

3.2 Symbols and subscripts

3.2.1 Symbols

A_r total retroreflective trim surface area

A_p total surface area of the plate

C_l coefficient of luminous intensity

C_r coefficient of reflectivity

H heat power input

I_m permeability index

I_Q heat transmission index

I_T thermal protection index

m mass

p water pressure

p_a water pressure of the ambient environment

p_p water pressure at the plate surface

Q_{tot} total heat loss

R_e evaporative resistance

$R_{e,in}$ intrinsic evaporative resistance of the test specimen

| | |
|-------------|---|
| $R_{e,p}$ | evaporative resistance of the bare plate |
| $R_{e,tot}$ | total evaporative resistance |
| R_T | thermal resistance |
| $R_{T,in}$ | intrinsic thermal resistance of the test specimen |
| $R_{T,p}$ | thermal resistance of the bare plate |
| $R_{T,tot}$ | total thermal resistance |
| T | temperature |
| T_a | temperature of the ambient environment |
| T_p | temperature of the bare plate |
| t_1, t_2 | time necessary to reach the levels 1 and 2 |
| w | mass fraction expressed as a percentage |
| w_w | mass fraction of water absorbed |

3.2.2 Subscripts

| | |
|-----|---------------------|
| a | ambient environment |
| f | final |
| i | initial |
| in | intrinsic |
| p | plate or bare plate |
| tot | total |
| w | water |

4 Design and performance requirements — Approach A

4.1 General

This clause specifies test methods and minimum requirements for protective clothing to be worn during firefighting and associated activities where there is a risk of heat and/or flame.

It covers the general clothing design, the minimum performance levels of the materials used, and the methods of test for determining these performance levels. Performance levels in this clause are based on EN 469^[1].

4.2 Design requirements

4.2.1 Configuration

The firefighters' protective clothing shall provide protection for the firefighter's upper and lower torso, neck, arms, and legs, but excluding the head, hands, and feet. It shall consist of:

- a) a single outer garment; or
- b) an outer two piece suit consisting of a jacket and a pair of trousers with a minimum overlap of 30 cm; or
- c) a series of outer and undergarments designed to be worn together.

If choosing to comply with Approach A of this clause — which allows an area of limited protection — the following points shall be met:

- a) the upper body shall be protected by clothing meeting requirements of Approach A of this clause;
- b) the area of limited protection shall be in the lower body area;
- c) the level of performance when tested in accordance with ISO 6942 at 40 kW/m² and ISO 9151 shall be declared.

4.2.2 Restriction of movement

The clothing shall be designed to minimize restrictions of movement. It shall be compatible with other protective equipment which may be necessary, for example boots, helmet, gloves and breathing apparatus.

4.2.3 Multilayer clothing assemblies

Where multilayer clothing assemblies are used to achieve the specified performance levels, the layers shall be either permanently attached or the various garments shall be clearly labelled that they must always be used in combination (see 4.2.6).

4.2.4 Seams

Seams shall be constructed to give the minimum loss in strength and protection and to maintain the integrity of the garment.

4.2.5 Hardware

Hardware penetrating the outer material shall not be exposed on the innermost surface of the component assembly.

4.2.6 Closure systems

Closure systems shall be constructed so as to fulfil the performance requirements of the garment.

4.2.7 Retroreflective elements

The clothing shall have retroreflective elements to the user's requirements provided that they do not affect the performance of the clothing.

4.2.8 Sleeve ends

The ends of the sleeves shall be designed to protect the wrist and to prevent the entry of burning debris. They shall not hinder the donning of the garment and shall be compatible with the wearing of protective gloves.

4.2.9 Clothing mass

The clothing shall be as light as possible while still maintaining the required performance levels.

4.2.10 Ease of cleaning

The clothing shall be designed to promote ease of cleaning.

4.2.11 Labels

Any labels or trim shall not adversely affect the performance of the garment.

4.3 Sampling and pretreatment

4.3.1 Samples

Samples shall be taken so as to be representative of the materials and garment construction employed.

4.3.2 Number and size of specimens

The number and size of specimens for the different tests shall be in accordance with the respective standards. All tests shall be carried out on materials as received unless otherwise specified (see 4.3.4).

4.3.3 Exposure surface

In all surface tests, the outermost surface shall be exposed, except for flame spread testing of the innermost lining (see 4.4.1) and testing of water vapour permeability (see 4.4.11) when the innermost surface is exposed.

4.3.4 Pretreatment

Before testing to the basic safety requirements (4.4.1, 4.4.2 and 4.4.3), the test materials shall be washed five times in a front loading horizontal drum machine with 1 g/l IEC reference detergent (annex B of ISO 6330:1984) in soft water and dried in accordance with the procedures of ISO 6330. Washing shall be carried out by procedure 2A at (60 ± 3) °C and drying by procedure E (tumble drying) unless otherwise specified in the care labelling. Drying shall be in accordance with the procedures of ISO 6330. A total of five washing and drying cycles shall be used. Materials which are labelled as dry cleanable only shall be dry cleaned five times in accordance with ISO 3175-2.

4.4 Requirements

4.4.1 Flame resistance (surface exposure)

Flame spread shall be tested in accordance with EN 532 after the pretreatment specified in 4.3.4 and the following requirements shall be satisfied.

- a) No specimen shall give flaming to top or either side edge;
- b) No specimen shall give hole formation in any layer, except the outer layer of a multilayer assembly;
- c) No specimen shall give flaming or molten debris;
- d) The mean value of afterflame time shall be ≤ 2 s;
- e) The mean value of the afterglow time shall be ≤ 2 s.

The component assembly of the outer garment shall be tested by applying the flame to the outer surface of the garment.

If the outer garment has a lining material, the component assembly of the outer garment shall also be tested with the flame applied to the innermost lining of the outer garment.

If the clothing assembly consists of several separate garments and the undergarment may be exposed to flame, the component assembly of this undergarment shall also be tested applying the flame to the outer surface of this inner garment.

If the clothing assembly incorporates wristlet material, this shall be tested separately applying the flame to the outer surface of the wristlet material.

NOTE Hole formation is permitted in moisture barrier interlinings. The following clarification is offered for 4.4.1 b): "No specimen shall give hole formation in any layer, except for a layer which is used for specific protection other than heat protection, for example, liquid penetration, high visibility, etc."

4.4.2 Heat transfer (flame exposure)

The component assembly or multilayer clothing assembly when tested in accordance with ISO 9151 after the pretreatment specified in 4.3.4 shall give a mean heat transmission index (I_Q) of $I_{Q,24} \geq 13$ and a mean $(I_{Q,24} - I_{Q,12}) \geq 4$.

4.4.3 Heat transfer (radiant exposure)

The component assembly or multilayer clothing assembly when tested in accordance with method B of ISO 6942:1993 at a heat flux density of 40 kW/m², after the pretreatment specified in 4.3.4, shall give a mean $t_2 \geq 22$ s, a mean $(t_2 - t_1) \geq 6$ s, and a mean transmission factor ≤ 60 %.

4.4.4 Residual strength of material when exposed to radiant heat

One machine and one cross machine specimen of the outer material shall be tested in accordance with ISO 5081 before and after pretreatment of the complete assembly by method A of ISO 6942:1993 at a heat flux density of 10 kW/m². Each specimen shall have a tensile strength ≥ 450 N.

4.4.5 Heat resistance

Each material used in the clothing assembly when tested in accordance with the method given in annex A at a test temperature of 180 °C, shall not melt, drip, separate, or ignite, and shall not shrink more than 5 %.

4.4.6 Tensile strength

The outer material when tested in accordance with ISO 5081 shall give a breaking load in both machine and cross direction ≥ 450 N.

4.4.7 Tear strength

The outer material when tested in accordance with method A2 of ISO 4674:1977 shall give a tear strength in both machine and cross direction ≥ 25 N.

4.4.8 Surface wetting

The outer material when tested in accordance with ISO 4920 shall give a spray rating of ≥ 4 .

4.4.9 Cleaning-shrinkage resistance

The materials of the outer garment assembly when tested in accordance with ISO 5077 using the cleansing pretreatment specified in 4.3.4 shall give a dimensional change $\leq 3\%$ in both the machine and cross machine directions.

4.4.10 Liquid-chemical penetration resistance

The component assembly or multilayer clothing assembly when tested in accordance with ISO 6530 using:

- a) 40 % sodium hydroxide (NaOH) at 20 °C;
- b) 36 % hydrochloric acid (HCl) at 20 °C;
- c) 30 % sulfuric acid (H₂SO₄) at 20 °C;
- d) white spirit;

shall give > 80 % run-off and no penetration to the innermost surface.

NOTE Fabrics shall be conditioned for 24 h at (20 ± 2) °C and (65 ± 5) % RH before testing. All tests shall be carried out with a pouring time of 10 s and at a temperature of 20 °C.

4.4.11 Water-penetration resistance and water-vapour resistance

It is recommended that the manufacturer should supply information on the behaviour of the clothing assembly when tested according to ISO 811 for hydrostatic pressure and to ISO 11092^[2] for water-vapour resistance.

4.5 Additional garment testing

If agreed between the purchaser and the manufacturer, the complete garment assembly may be additionally tested to typical scenarios encountered by a firefighter (see Table 1).

Table 1 — Additional testing

| Conditions | Exposure time | Temperature | Heat flux density |
|------------|---------------|-------------|------------------------|
| Normal | 8 h | 40 °C | 1 kW/m ² |
| Hazardous | 5 min | 250 °C | 1,75 kW/m ² |
| Emergency | 10 s | 800 °C | 40 kW/m ² |

Testing under emergency conditions must be carried out on an equipped mannequin and may involve shorter exposure at higher temperature and heat flux levels. The test will be followed by a visual inspection.

4.6 Marking

Firefighter protective clothing, for which compliance with this International Standard is claimed, shall have a label permanently and conspicuously attached marked with the number of this International Standard, i.e. ISO 11613, clause 4.

If the requirements are only met by the use of a combination of garments [see 4.2.1 c)] this must be declared on the labels of all the garments involved.

General marking requirements shall be as specified in ISO 13688.

4.7 Manufacturers' information

The manufacturer's information shall be given as specified in ISO 13688.

5 Design and performance requirements — Approach B

5.1 General

This clause specifies test methods and minimum requirements for protective clothing to be worn during firefighting and associated activities where there is a risk of heat and/or flame.

It covers the general clothing design, the minimum performance levels of the materials used, and the methods of test for determining these performance levels. Performance levels in this clause are based on NFPA 1971^[3].

5.2 Design requirements

5.2.1 Composite

Protective garments shall consist of a composite of an outer shell, moisture barrier, and thermal barrier. This composite shall be permitted to be configured as a single layer or multiple layers.

NOTE Purchasers might wish to specify additional reinforcement or padding in high-wear or load-bearing areas, such as pockets, cuffs, knees, elbows, and shoulders. Padding can include additional thermal barrier material meeting requirements as specified herein. Reinforcing material can include outer-shell material or leather. Purchasers are cautioned that additional weight caused by excessive reinforcement or padding could lead to fatigue or result in injury.

The thermal barrier or portion of the thermal barrier shall be permitted to be configured as a protective-uniform garment. When configured in this manner, the assembled protective garment shall meet all requirements specified in this International Standard.

5.2.2 Attachment of moisture barrier and thermal barrier

Protective garments shall have a means of securing the moisture barrier and thermal barrier to the outer shell.

NOTE The fastener system should be specified by the purchaser. Fastener system methods can include (but are not limited to) stitching the thermal barrier and moisture barrier into the coat in the neck, or into the trouser in the waist area with snap or hook and pile fasteners securing the remainder; entirely stitching the thermal barrier and moisture barrier to the outer shell; entirely securing the thermal barrier and moisture barrier to a component part of the outer shell with snap fasteners or fastener tape; or zipping the thermal barrier and vapour barrier to the outer shell.

5.2.3 Use of fasteners

Protective garments, including the front closure, shall be constructed in a manner that provides secure and complete moisture and thermal protection. If non-positive fasteners, such as snaps or hook and pile tape, are utilized in garment closures, a positive locking fastener, such as hooks and dees or zippers, shall also be utilized.

5.2.4 Extension of moisture and thermal barriers

The distance from the outer-shell cuffs and hems to the moisture and thermal barriers shall not exceed 76 mm. At the neck, the coat moisture barrier and thermal barrier shall extend to the neckline seam. The upper edge of the trouser moisture barrier and thermal barrier shall extend, as a minimum, to the waistline.

5.2.5 Cargo pocket requirements

Cargo pockets, where provided, shall have a means of drainage of water and shall have a means of fastening them in the closed position.

NOTE Purchasers should specify pockets large enough to carry tools and items normally carried. Placement should allow for access to the pockets while wearing SCBA. Specifying ballooned pockets will increase capacity but could interfere with manoeuvrability. Ballooning only the back edges could minimize the manoeuvrability problem. Divided pockets could be desired, as well as pockets for specific items, such as SCBA facepieces and radios.

5.2.6 Trim dimensions and coverage

Trim utilized to meet visibility requirements shall be permanently attached to the outer shell of protective garments and shall be no less than 50 mm wide and shall have both retroreflective and fluorescent surfaces. Retroreflective surface of trim shall be no less than 16 mm wide. Fluorescent and retroreflective areas of trim shall appear to be continuous for the length of the trim, with gaps between areas of retroreflectivity of no more than 4 mm.

NOTE Users of protective clothing should be aware that retroreflective trims have varying durability under field use conditions. Trim may be damaged by heat but appear to be in good condition when in fact it may have lost retroreflective properties. Trim may become soiled and lose fluorescing and retroreflective qualities. Trim may lose retroreflective qualities in rain or firefighting water exposures.

5.2.7 Excess trim

Trim affixed to protective garments exceeding the visibility requirements specified in 5.4.8 of this International Standard shall be permitted to be obscured by components such as, but not limited to, pockets, storm flaps, and reinforcing patches as long as the minimum trim required in 5.2.8. and 5.2.9 is not obscured.

NOTE Purchasers of protective clothing should realize that trim patterns can materially affect the visibility of the firefighter. Trim patterns should be evaluated on live models as the models proceed through a series of arm and leg motions, bending, stooping, and turning.

5.2.8 Additional requirements for protective coats

5.2.8.1 Area of protection

Protective coats shall provide protection as specified to the upper torso, neck, arms, and wrists, excluding the hands and head.

NOTE A protective ensemble consisting of both protective coat and protective trousers is required to be utilized for structural firefighting in order to assure better protection for the firefighter's torso and limbs by 5-2.6 of NFPA 1500^[4]. An overlap of no less than 203 mm of coat and trousers is also required by 5-2.1 of NFPA 1500 and should be specified to assure better protection.

5.2.8.2 Hardware

Protective coat hardware shall not penetrate through the outer shell, moisture barrier, and thermal barrier to contact the wearer's body when the coat is worn with closures fastened, unless the hardware is completely covered by external closure flaps.

5.2.8.3 Protective wristlets

Each protective coat sleeve shall have a protective wristlet meeting requirements specified in 5.2.12 and 5.6 of this International Standard.

NOTE Purchasers should consider specifying wristlets with a thumb hole or bartack creating a thumb hole for wearer's thumb in order to assure protection when arms are in raised position.

5.2.8.4 Composite collar

Protective coats shall have a composite collar no less than 102 mm in height at any point, with a closure system. Collar and closure system shall consist of outer shell, moisture barrier, and thermal barrier that meet all applicable performance requirements as specified in 5.2.

5.2.8.5 Trim location

Protective coat trim configuration shall include a circumferential band around the coat and each wrist. No vertical trim shall be allowed on the front of the protective coat.

NOTE A possible configuration for trim on coats or coveralls, in addition to the minimum requirements specified herein, is two 635 mm vertical stripes on the coat back intersecting the circumferential stripe (forming a "U"). Use of vertical trim on protective garment fronts has been shown to be capable of detrimentally affecting the performance of SCBA in flashover heat/flame conditions.

5.2.8.6 Trim minimum area

Protective coat trim shall have no less than 2 100 cm² of fluorescent area.

5.2.8.7 Visible trim minimum areas

Protective coat trim shall include no less than 1 050 cm² of fluorescent area visible from the front and 1 050 cm² of fluorescent area visible from the rear when the coat is properly closed and is laid on a flat inspection surface.

5.2.9 Additional requirements for protective trousers

5.2.9.1 Area of protection

Protective trousers shall provide protection as specified to the lower torso and legs, excluding the ankles and feet.

NOTE A protective ensemble consisting of both protective coat and protective trousers is required to be utilized for structural firefighting in order to assure better protection for the firefighter's torso and limbs in accordance with 5-2.6 of NFPA 1500. An overlap of no less than 203 mm of coat and trousers is also required by 5-2.1 of NFPA 1500 and should be specified to assure adequate protection.

5.2.9.2 Hardware

Protective trouser hardware shall not penetrate through the outer shell, moisture barrier, and thermal barrier to contact the wearer's body when trouser is worn with closure fastened, unless the hardware is located on or above the waistline or hardware is completely covered by external closure flaps.

5.2.9.3 Trim location

Protective trouser trim shall include a circumferential band around each leg between the hem and knee.

5.2.9.4 Trim minimum area

Protective trouser trim shall have no less than 520 cm² of fluorescent area.

5.2.9.5 Visible trim minimum areas

Protective trouser trim shall include no less than 260 cm² of fluorescent area visible from the front and no less than 260 cm² of fluorescent area visible from the rear when the trouser is properly closed and is laid on a flat inspection surface.

5.2.10 Additional requirements for protective coverall

That portion of the protective coverall that corresponds to the protective coat shall meet all requirements of 5.2.8.

That portion of the protective coverall that corresponds to the protective trouser shall meet all requirements of 5.2.9.

5.2.11 Specific requirements for protective hoods

The protective hood shall be designed to cover and provide the limited protection specified in 5.5 to the head, face, and neck, which are not protected by the protective coat, helmet, or SCBA facepiece.

The protective hood shall be designed to contact the sides of the SCBA facepiece, when worn, to cover all exposed facial areas. The protective hood shall be designed so that it does not interfere with the proper use of SCBA and the SCBA facepiece-to-face seal, as specified by the SCBA manufacturer.

The protective hood shall be designed so that it does not interfere with the proper use and fit of helmets, as specified by the helmet manufacturer.

5.2.12 Specific requirements for protective wristlets

The protective wristlet shall be designed to cover and provide the limited protection specified within this subclause to the wrist areas.

The protective wristlet shall be permanently attached to the protective coat.

5.3 Sampling and pretreatment

5.3.1 Sampling levels

Sampling levels for testing and inspection shall be established by the responsible testing laboratory and the manufacturer to assure a reasonable and acceptable reliability at a reasonable and acceptable confidence level that products certified as being compliant with this International Standard are compliant.

5.3.2 Inspection

Inspection for determining compliance with the design requirements specified in 5.2 shall be performed on a completed garment.

5.3.3 Testing

Testing for determining material and component compliance with the requirements specified in 5.4 shall be performed on samples representative of materials and components used in the actual construction of the protective clothing. The responsible testing laboratory organization shall be permitted to also use sample materials cut from a representative protective garment.

5.3.4 Pretreatment

When pretreatment is specified as part of the test procedure or performance requirement, the test materials shall be washed five times in a front loading horizontal drum machine with 1 g/l IEC reference detergent (annex B of ISO 6330:1984) in soft water and dried in accordance with the procedures of ISO 6330. Washing shall be carried out by procedure 2A at (60 ± 3) °C and drying by procedure E (tumble drying) unless otherwise specified in the care labelling. Drying shall be in accordance with the procedures of ISO 6330. A total of five washing and drying cycles shall be used. A laundry bag shall not be used.

5.4 Performance requirements

5.4.1 Protective garment requirements

5.4.1.1 Heat transfer (combined radiant and flame exposure)

The protective garment composite consisting of outer shell, moisture barrier, and thermal barrier shall have a heat transfer burn time of no less than 17,5 s when tested for heat transfer (combined radiant and flame exposure) in

accordance with ISO 17492, using the thermal protection index (I_T) analysis method with the specimens in the contact configuration, before and after the pretreatment specified in 5.3.4.

5.4.1.2 Seam strength

All seams shall be tested for breaking strength and shall demonstrate a seam strength equal to or greater than 675 N force for major A seams, 337 N force for major B seams, and 180 N force for minor seams when tested as specified in ISO 5082, with the test machine operated at a rate of 305 mm/min. Seam breaking strength shall be considered acceptable when the fabric strength is less than the required seam strength specified above, providing the fabric fails without failure of the seam below the applicable forces specified above.

5.4.1.3 Breathability

It is recommended that the manufacturer supply information on the behaviour of the composite when tested in accordance with ISO 11092 as modified by annex B for total heat loss.

5.4.2 Textiles

5.4.2.1 Flame resistance (edge exposure)

Outer shell, moisture barrier, thermal barrier, collar linings, winter liner fabric, and trim shall be individually tested for flame resistance and shall have an average char length of no more than 102 mm, an average afterflame of no more than 2 s, and shall not melt or drip when tested in accordance with ISO 15025 as modified by annex D, before and after the pretreatment specified in 5.3.4.

5.4.2.2 Thermal-shrinkage resistance

Outer shell, moisture barrier, thermal barrier, collar linings, and winter liner fabric shall be individually tested for thermal-shrinkage resistance and shall not shrink more than 10 % in any direction when tested in accordance with ISO 17493, using the procedure for flat textile and other sheet materials at a test temperature of 260 °C, before and after the pretreatment specified in 5.3.4.

5.4.2.3 Heat resistance

Outer shell, moisture barrier, thermal barrier, collar linings, and winter liner fabric, and other materials used in construction — including but not limited to padding, reinforcement, garment labels, interfacing, binding, hanger loops, and emblems, but excluding trim, elastic and hook and pile fasteners when not placed in direct contact with the body — shall be individually tested for heat resistance and shall not melt, separate, or ignite when tested in accordance with ISO 17493, using the procedure for flat textile and other sheet materials at a test temperature of 260 °C, before and after the pretreatment specified in 5.3.4.

Moisture barrier seam seal materials shall be tested for heat resistance and shall not drip or ignite when tested in accordance with the method given in ISO 17493 when tested at a temperature of 260 °C.

5.4.2.4 Cleaning-shrinkage resistance

Outer shell, moisture barrier, thermal barrier, collar linings, and winter liner fabric shall be individually tested for cleaning-shrinkage resistance in accordance with ISO 5077 using the cleansing pretreatment specified in 5.3.4 and shall not shrink more than 5 % in any direction. Knit fabric specimens shall be pulled to original dimensions and shall be allowed to relax for 1 min prior to measurement.

5.4.3 Outer shell requirements

5.4.3.1 Tear resistance

Outer-shell and collar-lining fabrics shall be tested for tear resistance and shall have a tear strength of no less than 100 N when tested as specified in accordance with ISO 9073-4.

5.4.3.2 Char resistance

Outer-shell and collar-lining fabrics shall be tested for char resistance and shall not char when tested in accordance with the method given in ISO 17493 when tested at a temperature of 260 °C, before and after the pretreatment specified in 5.3.4.

5.4.3.3 Water-absorption resistance

Outer-shell and collar-lining fabrics shall be tested for water-absorption resistance and shall have no more than 30 % water absorption when tested in accordance with ISO 4920 as modified by annex E, before and after the pretreatment specified in 5.3.4.

5.4.4 Moisture barrier requirements

5.4.4.1 Tear resistance

Moisture barriers shall be tested for tear resistance and shall have a tear strength of no less than 22 N when tested in accordance with ISO 9073-4.

5.4.4.2 Water-penetration resistance (high pressure)

The moisture barrier fabric shall be tested for high pressure range water-penetration resistance and shall have a minimum water-penetration resistance of 172 kPa when tested in accordance with ISO 811 using a rate of water pressure increase of 60 cm/min, before and after the pretreatment specified in 5.3.4. Appearance of water drops shall constitute failure.

5.4.4.3 Water-penetration resistance (low pressure)

The moisture barrier fabric and seams shall be tested for low pressure range water-penetration resistance and shall show no appearance of water drops when tested in accordance with ISO 811 at 7 kPa for a period of 5 min, before and after the pretreatment specified in 5.3.4.

5.4.5 Thermal barrier requirement

Thermal barrier shall be tested for tear resistance and shall have a tear strength of no less than 22 N when tested in accordance with ISO 9073-4.

5.4.6 Winter liner requirement

When provided, the winter liner shall be tested for tear resistance and shall have a tear strength of no less than 22 N when tested in accordance with ISO 9073-4.

5.4.7 Thread requirement

All thread utilized in the construction of the protective garments shall be tested for heat resistance and shall not ignite, melt, or char when tested in accordance with ISO 3146 when tested at a temperature of 260 °C.

5.4.8 Visibility requirements for trim

Protective coat-trim shall have a total coefficient of luminous intensity (C_l) of no less than 25 cd/lx (270 cd/foot-candle) when tested in accordance with ASTM E 809 and the test parameters given in annex C.

Protective trouser-trim shall have a total coefficient of luminous intensity (C_l) of no less than 7 cd/lx (75 cd/foot-candle) when tested in accordance with ASTM E 809 and the test parameters given in annex C.

5.4.9 Hardware requirements

5.4.9.1 Surface finish

All hardware finish shall be free of rough spots, burrs, or sharp edges.

5.4.9.2 Corrosion resistance

All metal hardware and hardware that includes metal parts shall be tested for corrosion resistance when tested in accordance with ISO 9227 using a 5 % saline solution and 20 h test exposure followed by immediately rinsing the specimens under warm, running tap water and drying with compressed air. Metals inherently resistant to corrosion, including but not limited to stainless steel, brass, copper, aluminium, and zinc shall show no more than light surface-type corrosion or oxidation. Ferrous metals shall show no corrosion of the base metal.

5.4.9.3 Heat resistance

All hardware shall be tested for heat resistance and shall not ignite and shall remain functional when tested in accordance with the method given in annex A when tested at a temperature of 260 °C.

5.5 Protective hood requirements

5.5.1 Heat transfer (combined radiant and flame exposure)

The protective hood fabric or component assembly shall have a heat transfer burn time of no less than 10 s when tested for heat transfer (combined radiant and flame exposure) in accordance with ISO 17492, using thermal protection index (I_T) analysis method with the specimens in the contact configuration, before and after the pretreatment specified in 5.3.4.

5.5.2 Flame resistance (edge exposure)

The protective hood material(s), including labels, but excluding hook and pile fasteners and elastic when not placed in direct contact with the body, shall be individually tested for flame resistance and shall have an average char length of no more than 102 mm, an average afterflame of no more than 2 s, and shall not melt or drip when tested in accordance with ISO 15025 as modified by annex D, before and after the pretreatment specified in 5.3.4.

5.5.3 Thermal-shrinkage resistance

The protective hood material(s), including labels, but excluding hook and pile fasteners and elastic when not placed in direct contact with the body, shall be individually tested for thermal-shrinkage resistance and shall not shrink more than 10 % in any direction when tested in accordance with ISO 17493, using the procedure for flat textile and other sheet materials at a test temperature of 260 °C, before and after the pretreatment specified in 5.3.4.

5.5.4 Heat resistance

The protective hood material(s), including labels, but excluding hook and pile fasteners and elastic when not placed in direct contact with the body, shall be individually tested for heat resistance and shall not melt, separate, or ignite when tested in accordance with ISO 17493, using the procedure for flat textile and other sheet materials at a test temperature of 260 °C, before and after the pretreatment specified in 5.3.4.

5.5.5 Cleaning-shrinkage resistance

The protective hood material(s), including labels, but excluding hook and pile fasteners and elastic when not placed in direct contact with the body, shall be individually tested for cleaning-shrinkage resistance in accordance with ISO 5077 using the cleansing pretreatment specified in 5.3.4 and shall not shrink more than 5 % in any direction. Knit fabric specimens shall be pulled to original dimensions and shall be allowed to relax for 1 min prior to measurement.

5.5.6 Thread heat resistance

All thread utilized in the construction of the protective hood shall be tested for heat resistance and shall not ignite, melt, or char when tested in accordance with ISO 3146.

5.6 Protective wristlet requirements

5.6.1 Heat transfer (combined radiant and flame exposure)

The protective wristlet shall have a heat transfer burn time of no less than 10 s when tested for heat transfer (combined radiant and flame exposure) in accordance with ISO 17492, using thermal protection index (I_T) analysis method with the specimens in the contact configuration, before and after the pretreatment specified in 5.3.4.

5.6.2 Flame resistance (edge exposure)

The protective wristlet material(s) shall be individually tested for flame resistance and shall have an average char length of no more than 102 mm, an average afterflame of no more than 2 s, and shall not melt or drip when tested in accordance with ISO 15025 as modified by annex D, before and after pretreatment specified in 5.3.4.

5.6.3 Thermal-shrinkage resistance

The protective wristlet material(s) shall be individually tested for thermal-shrinkage resistance and shall not shrink more than 10 % in any direction when tested in accordance with ISO 17493, using the procedure for flat textile and other sheet materials at a test temperature of 260 °C, before and after the pretreatment specified in 5.3.4.

5.6.4 Heat resistance

The protective wristlet material(s) shall be individually tested for heat resistance and shall not melt, separate, or ignite when tested in accordance with ISO 17493, using the procedure for flat textile and other sheet materials at a test temperature of 260 °C, before and after the pretreatment specified in 5.3.4.

5.6.5 Cleaning-shrinkage resistance

The protective wristlet material(s) shall be individually tested for cleaning-shrinkage resistance in accordance with ISO 5077 using the cleansing pretreatment specified in 5.3.4 and shall not shrink more than 5 % in any direction. Knit fabric specimens shall be pulled to original dimensions and shall be allowed to relax for 1 min prior to measurement.

5.6.6 Thread heat resistance

All thread utilized in the construction of the protective wristlet shall be tested for heat resistance and shall not ignite, melt, or char when tested in accordance with ISO 3146.

5.7 Marking

5.7.1 Label

Each separable layer of each protective garment shall have a label permanently and conspicuously attached to each layer upon which at least the information given in Figure 1 is printed in letters at least 1,5 mm high. At least one label shall be conspicuously located inside the garment in all possible configurations of garment utilization.

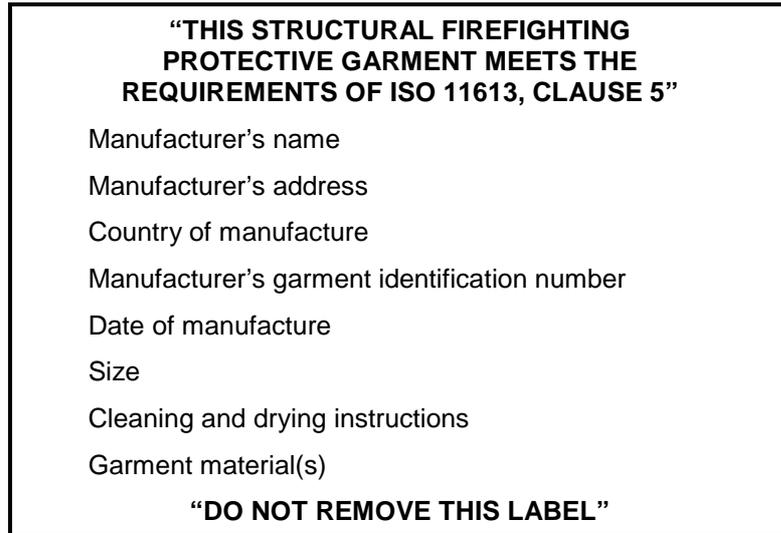


Figure 1 — Label

5.7.2 Label legibility

All garment labels shall be clearly legible to the eye both before and after being subjected to the pretreatment specified in 5.3.4. Garment labels not meeting specimen size requirements for the procedure specified in 5.3.4 shall be sewn to a support fabric of required size.

5.8 Manufacturers' information

5.8.1 Instructions and information

Protective-clothing manufacturers shall provide the following instructions and information with each garment:

- a) cleaning and instructions;
- b) maintenance criteria;
- c) methods of repair;
- d) warranty information.

5.8.2 Training materials

Protective-clothing manufacturers shall furnish training materials that address, but are not limited to:

- a) safety considerations;
- b) storage conditions;
- c) decontamination procedures;
- d) retirement considerations.

Annex A (normative)

Heat resistance test

A.1 Principle

Specimens of the material shall be suspended in a hot air circulating oven for 5 min at the specified test temperature. Any ignition, melting, dripping, separation or shrinking of the specimen shall be recorded.

A.2 Apparatus

A.2.1 Forced-air circulating oven, capable of maintaining the test temperature over a period of 5 min and of sufficient internal volume to allow the test specimen (see A.3) to be suspended as specified in A.4.

A.2.2 Rigid-square template, 150 mm by 150 mm.

A.2.3 Ruler, graduated in millimetres.

A.3 Specimens

Condition the material for at least 24 h in a standard atmosphere at (20 ± 2) °C and (65 ± 5) % RH. Mark and cut out a square specimen using the template (A.2.2). If the material or item for test is narrower than 150 mm, cut the specimen 150 mm in the length direction by the width of the material. If the item for test is less than 150 mm by 150 mm, test the complete item.

A.4 Procedure

Attach a metal clip to the top centre of the specimen. Heat the oven to the test temperature. Open the oven door and quickly insert the specimen so that it hangs in the centre of the oven and is no less than 50 mm from any inner surface of the oven. Close the door and time the exposure from the door closure. After 5 min, open the oven door and remove the specimen.

The oven temperature will drop when the door is opened. The temperature throughout the 5 min exposure period should remain above the test temperature. If the temperature falls below this level, repeat the test.

A.5 Report

The report shall include the following observations:

- a) any ignition of the specimen;
- b) any melting of the specimen: hole formation, dripping;
- c) any separation of the specimen: splitting, delamination;
- d) any shrinkage of the specimen in either length or width direction, if the shrinkage is greater than 5 % and the specimen was originally 150 mm in that direction.

Annex B (normative)

Total heat-loss test

B.1 Principle

This test method involves the measurement of evaporative heat transfer through the component assembly using a hot plate. The thermal resistance of the component assembly is first measured using a hot plate with the capacity for measuring heat loss through the multiple layers. The evaporative resistance is then measured using the same hot plate with water added to simulate sweating. The thermal resistance and evaporative resistance are then used to calculate total heat loss.

NOTE This is a unique test for firefighter protective clothing which has been taken from NFPA 1971. It differs from ISO 11092 by conducting the evaluation under non-isothermal conditions.

B.2 Apparatus

The test apparatus shall consist of a test plate with temperature controller and power-input measuring capability. The test plate shall be surrounded by a guard ring and bottom plate that can be controlled to eliminate lateral and downward heat transfer from the test plate. The test plate and guard ring shall have a wettable surface. The test plate, guard ring, and bottom plate shall be in an environmental chamber that can control the temperature, relative humidity, and air flow over the test plate. These properties shall be continuously measured in the free flow air stream uninfluenced by the boundary of the test plate. Apparatus used to measure temperature shall be accurate to within $\pm 0,25$ °C. Apparatus used to measure relative humidity shall be accurate to within ± 4 % RH.

B.3 Specimens

Total heat-loss testing shall be conducted on at least three specimens. Specimens shall consist of all layers in the protective garment component assembly arranged in the order and orientation as worn.

B.4 Procedure

B.4.1 The test plate shall have a temperature of $(35 \pm 0,5)$ °C.

B.4.2 The local environmental climate shall be $(25 \pm 0,5)$ °C and (65 ± 4) % RH.

B.4.3 The air flow shall be the same for all calibrations and tests.

B.4.4 The total thermal resistance ($R_{T,tot}$) of the specimen shall be calculated from the following equation:

$$R_{T,tot} = \frac{(T_p - T_a) \times A_p}{H}$$

where:

$R_{T,tot}$ is the total thermal resistance of the specimen and surface air layer (°C m²/W);

T_p is the temperature at the plate surface (°C);

T_a is the temperature in the ambient environment (°C);

A_p is the area of the test plate (m²);

H is the power input (W).

B.4.5 Measurement of thermal resistance shall be done when equilibrium is reached.

B.4.5.1 Data used to calculate the thermal resistance shall be collected at least every 5 min.

B.4.5.2 Equilibrium shall be a rate of change of less than 3 %/h of the calculated thermal resistance over a period no less than 30 min.

B.4.5.3 The standard deviation of calculated thermal resistance shall be less than 1 %.

B.4.6 The average bare plate thermal resistance, including the air layer and any apparatus contribution ($R_{T,p}$) shall be an average of at least three measurements with nothing mounted on the test plate.

B.4.7 The average intrinsic thermal resistance of the sample alone ($R_{T,in}$) shall be determined by subtracting the average bare plate resistance ($R_{T,p}$) from the average of the total thermal resistance ($R_{T,tot}$) of the specimens tested.

B.4.8 For thermal resistance measurements, the apparatus shall be calibrated as follows:

B.4.8.1 One layer of 255 g/m² Nomex duck shall be mounted on the test plate and the total thermal resistance ($R_{T,tot}$) shall be measured.

B.4.8.2 Two layers of 255 g/m² Nomex duck shall be mounted on the test plate and the total thermal resistance ($R_{T,tot}$) shall be measured.

B.4.8.3 Three layers of 255 g/m² Nomex duck shall be mounted on the test plate and the total thermal resistance ($R_{T,tot}$) shall be measured.

B.4.8.4 Four layers of 255 g/m² Nomex duck shall be mounted on the test plate and the total thermal resistance ($R_{T,tot}$) shall be measured.

B.4.8.5 The apparatus shall meet the following constraints:

- a) a graph of total thermal resistance versus number of layers of 255 g/m² Nomex duck shall be linear for the bare plate value, one, two, three, and four layers;
- b) the slope of the linear regression shall be $0,0206 \times (1 \pm 10 \%) \text{ } ^\circ\text{C} \cdot \text{m}^2/\text{W}$;
- c) no individual data measurement shall be outside $\pm 10 \%$ of the value predicted by the linear regression;
- d) the intrinsic thermal resistance of four layers of 255 g/m² Nomex duck shall be $0,082 \times (1 \pm 10 \%) \text{ } ^\circ\text{C} \cdot \text{m}^2/\text{W}$.

B.4.8.6 If the apparatus cannot meet any one of these constraints, no specimens shall be tested until the apparatus is adjusted to meet these constraints.

B.4.9 The specimen to be tested shall be mounted on the test plate in the orientation it has in the finished garment from the skin surface (plate surface) to the outside and the total thermal resistance ($R_{T,tot}$) shall be measured.

B.4.10 Water shall be fed to the test plate and guard ring so that water uniformly wets the test plate and guard ring surface.

B.4.11 The test plate and guard ring shall be covered with a liquid barrier that prevents wetting of the test specimen by the liquid water.

B.4.12 Apparent total evaporative resistance ($R_{e,tot}$) shall be calculated from the following equation:

$$R_{e,tot} = \frac{(p_p - p_a) \times A_p}{H - \frac{(T_p - T_a) \times A_p}{R_{T,tot}}}$$

where:

$R_{e,tot}$ is the apparent total evaporative resistance of the specimen and air layer (kPa m²/W);

p_p is the water vapour pressure at the test plate surface (kPa);

p_a is the water vapour pressure in the ambient environment (kPa);

A_p is the area of the test plate (m²);

H is the power input (W);

T_p is the temperature at the test plate surface (°C);

T_a is the temperature in the ambient environment (°C);

$R_{T,tot}$ is the total thermal resistance of the specimen and surface air layer (°C·m²/W).

NOTE The term "apparent" is used as a modifier for evaporative resistance to reflect the fact that condensation may occur within the specimen.

B.4.13 Measurement of apparent evaporative resistance shall be done when equilibrium is reached.

B.4.13.1 Data to calculate apparent evaporative resistance shall be collected at least every 5 min.

B.4.13.2 Equilibrium shall be a rate of change of less than 3 %/h of calculated apparent evaporative resistance over a period no less than 30 min.

B.4.13.3 The standard deviation of the calculated apparent evaporative resistance shall be less than 1 %.

B.4.13.4 If data collection cannot be completed within 4 h after mounting the specimen on the test plate, the specimen shall be removed from the test plate and allowed to dry at least 24 h at (20 ± 5) °C before retesting. Subsequent data reporting shall state that drying was required. If the retest of the specimen still cannot be completed within 4 h, then it shall be reported that the specimen cannot be tested by this method.

B.4.14 The average bare plate evaporative resistance, including the air layer, the liquid barrier, and any apparatus contribution, ($R_{e,p}$) shall be an average of at least three measurements with only the liquid barrier mounted on the plate. The local environmental climate shall be permitted to increase above 25 °C if necessary to maintain test plate temperature at 35 °C.

B.4.15 The average apparent intrinsic evaporative resistance of the sample alone ($R_{e,in}$) shall be the apparent total evaporative resistance ($R_{e,tot}$) minus the average bare plate evaporative resistance ($R_{e,p}$).

$$R_{e,in} = R_{e,tot} - R_{e,p}$$

NOTE The term "apparent" is used as a modifier for evaporative resistance to reflect the fact that condensation may occur within the specimen.

B.4.16 For evaporative resistance measurements, the apparatus shall be recalibrated as follows:

B.4.16.1 The permeability index of the liquid barrier alone on the wetted test plate shall be greater than 0,7. The permeability index shall be calculated from the following equation:

$$I_m = 0,061 \times \frac{R_{T,p}}{R_{e,p}}$$

where:

I_m is the permeability index;

$R_{T,p}$ is the average bare plate thermal resistance (without liquid barrier) described in B.4.6 ($^{\circ}\text{C} \cdot \text{m}^2/\text{W}$);

$R_{e,p}$ is the average bare plate evaporative resistance (with liquid barrier in place) described in B.4.14 ($\text{kPa} \cdot \text{m}^2/\text{W}$).

NOTE One material that will meet this requirement is uncoated cellophane from Flexel, Inc., Atlanta, GA 30346, USA.

B.4.16.2 One layer of 255 g/m² Nomex duck shall be mounted on the test plate and the apparent evaporative resistance ($R_{e,\text{tot}}$) shall be measured.

B.4.16.3 Two layers of 255 g/m² Nomex duck shall be mounted on the test plate and the apparent evaporative resistance ($R_{e,\text{tot}}$) shall be measured.

B.4.16.4 Three layers of 255 g/m² Nomex duck shall be mounted on the test plate and the apparent evaporative resistance ($R_{e,\text{tot}}$) shall be measured.

B.4.16.5 Four layers of 255 g/m² Nomex duck shall be mounted on the test plate and the apparent evaporative resistance ($R_{e,\text{tot}}$) shall be measured.

B.4.16.6 The apparatus shall meet the following constraints:

- a) a graph of apparent total evaporative resistance ($R_{e,\text{tot}}$) versus number of layers of 255 g/m² Nomex duck shall be linear for the bare plate value, one, two, three, and four layers;
- b) the slope of the linear regression shall be $0,005 \times (1 \pm 10 \%) \text{ kPa} \cdot \text{m}^2/\text{W}$;
- c) no individual data measurement shall be outside $\pm 10 \%$ of the value predicted by the linear regression;
- d) The apparent intrinsic evaporative resistance ($R_{e,\text{in}}$) of four layers of 255 g/m² Nomex duck shall be $0,020 \times (1 \pm 10 \%) \text{ kPa} \cdot \text{m}^2/\text{W}$.

B.4.16.7 If the apparatus cannot meet any one of these constraints, no specimens shall be tested until the apparatus is adjusted to meet these constraints.

B.4.17 The specimen to be tested shall be mounted on the wetted test plate with the liquid barrier in place in the orientation it has in the finished garment from the skin surface (plate surface) to the outside.

B.5 Report

B.5.1 The average intrinsic thermal resistance ($R_{T,\text{in}}$) of the sample shall be reported. The average intrinsic thermal resistance ($R_{T,\text{in}}$) of the specimens shall be determined by averaging all values obtained over the equilibrium period (minimum of six). The average intrinsic thermal resistance ($R_{T,\text{in}}$) of the sample shall be determined by averaging the values for all specimens. If the results for any of the three individual specimens vary

more than 10 % from the average of all three, then the test shall be repeated on the specimen(s) lying outside the ± 10 % limit. If the retest produces a value(s) within the ± 10 % limit, then the new value(s) shall be used instead. If the retest remains outside the ± 10 % limit, then an additional three specimens shall be tested, and all original and retest results shall be reported along with the average and standard deviation of intrinsic thermal resistance and a statement identifying this sample as having a high variability.

B.5.2 The average apparent intrinsic evaporative resistance ($R_{e,in}$) of the sample shall be reported. The average apparent intrinsic evaporative resistance ($R_{e,in}$) of the specimens shall be determined by averaging all values obtained over the equilibrium period (minimum of six). The average apparent intrinsic evaporative resistance ($R_{e,in}$) of the sample shall be determined by averaging the values for all specimens. If the results for any of the three individual specimens vary more than 10 % from the average of all three, then the test shall be repeated on the specimen(s) lying outside the ± 10 % limit. If the retest produces a value(s) within the ± 10 % limit, then the new value(s) shall be used instead. If the retest remains outside the ± 10 % limit, then an additional three specimens shall be tested, and all original and retest results shall be reported along with the average and standard deviation of apparent intrinsic evaporative resistance and a statement identifying this sample as having a high variability.

B.5.3 The average total heat loss (Q_{tot}) of the sample shall be determined and reported, subject to the reporting requirements in B.5.1. and B.5.2. The total heat loss of the sample shall be calculated from the following equation:

$$Q_{tot} = \frac{T_1}{R_{T,in} + 0,04} + \frac{p_1}{R_{e,in} + 0,0035}$$

where:

Q_{tot} is the total heat loss (W/m^2);

T_1 is the temperature equal to 10 °C;

p_1 is the pressure equal to 3,57 kPa;

$R_{T,in}$ is the average intrinsic thermal resistance of the sample determined in B.5.1 ($^{\circ}C \cdot m^2/W$);

$R_{e,in}$ is the average apparent intrinsic evaporative resistance of the sample determined in B.5.2 ($kPa \cdot m^2/W$).

Annex C (normative)

Retroreflective photometric performance test parameters

C.1 Test parameters

| | |
|---|---|
| Test distance: | 15,2 m |
| Observation angle: | 0,2° |
| Entrance angle: | -4,0° |
| Photoreceptor angular aperture and source angular aperture: | 0,1° |
| Projector exit aperture: | circle with 25 mm diameter |
| Retroreflector reference angle: | 90° |
| Datum mark: | as specified by trim manufacturer |
| Trim specimen size: | 305 mm × 305 mm made from multiple strips of trim |

C.2 Calculation

The coefficient of luminous intensity for trim shall be calculated by the following equation where the coefficient of reflectivity, C_r , is measured in accordance with the above:

$$C_l = C_r \times A_r$$

where

C_l is the coefficient of luminous intensity expressed as cd/lx;

C_r is the coefficient of reflectivity expressed as cd/(lx · m²);

A_r is the total retroreflective trim area expressed as m².

Annex D (normative)

Measurement of char length — Procedure

D.1 Flame resistance

Outer shell, moisture barrier, thermal barrier, collar linings, winter liner fabric, and trim shall be individually tested for flame resistance.

D.2 Char length measurement

D.2.1 Char length

The char length shall be the distance from the end of the specimen, which was exposed to the flame, to the end of a tear (made lengthwise) of the specimen through the centre of the charred area.

D.2.2 Measurement procedure

D.2.2.1 The specimen shall be folded lengthwise and creased by hand along a line through the highest peak of the charred area. A hook, made with steel wire, using a 76 mm length of wire and bent 13 mm from one end to form a 45° hook, shall be inserted in the specimen (or a hole 6 mm diameter or less, pinched out for the hook) at one side of the charred area 6 mm from the adjacent outside edge and 60 mm from the lower end. A weight of sufficient mass such that the weight and hook together shall equal the total tearing load required.

D.2.2.2 A tearing force shall be applied gently to the specimen by grasping the corner of the specimen at the opposite edge of the char from the load, and raising the specimen and weight clear of the supporting surface. The end of the tear shall be marked off on the edge and the char length measurement made along the undamaged edge.

D.2.2.3 The specific load applicable to the mass of the test specimen shall be in accordance with values given in Table D.1.

Table D.1

| Mass of specimen material before any fire retardant or coating <i>m</i> (g/m ²) | Total tearing mass for determining the charred length (kg) |
|--|--|
| 50 < <i>m</i> ≤ 200 | 0,1 |
| 200 < <i>m</i> ≤ 500 | 0,2 |
| 500 < <i>m</i> ≤ 800 | 0,3 |
| > 800 | 0,45 |

Annex E (normative)

Measurement of water-absorption resistance — Procedure

The following modifications will be used when testing the outer shell for water absorption resistance in accordance with ISO 4920.

The blotter paper shall be weighed before and after the water spray exposure. An analytical balance accurate to 0,01 g shall be used. Measurements of mass shall be made to the nearest 0,01 g. The percent water absorption shall be determined using the following equation:

$$w_w = \frac{m_f - m_i}{m_i} \times 100$$

where:

w_w is the water absorbed, expressed as a percentage by mass;

m_f is the final mass, expressed in grams, of the blotter paper;

m_i is the initial mass, expressed in grams, of the blotter paper.

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