
**PPE for firefighters — Test methods
and requirements for PPE used by
firefighters who are at risk of exposure
to high levels of heat and/or flame while
fighting fires occurring in structures —**

**Part 3:
Clothing**

*Équipement de protection personnelle pour pompiers — Méthodes
d'essai et exigences pour les équipements de protection personnelle
utilisés par les pompiers qui sont à risque d'une exposition à des
niveaux élevés de chaleur et/ou de flamme quand la lutte contre les
incendies survient dans les structures —*

Partie 3: Vêtements



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#)

The committee responsible for this document is ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 14, *Firefighters' personal equipment*.

ISO 11999 consists of the following parts, under the general title *PPE for firefighters — Test methods and requirements for PPE used by firefighters who are at risk of exposure to high levels of heat and/or to flame while fighting fires occurring in structures*:

- Part 1: General
- Part 2: Compatibility
- Part 3: Clothing
- Part 4: Gloves

The following parts are under preparation:

- Part 5: Helmets
- Part 6: Footwear
- Part 7: Face and eye protection
- Part 8: Hearing
- Part 9: Firehoods
- Part 10: Respiratory protection

NOTE The number of this draft has been changed from ISO/DIS 11613-3 to ISO 11999-3. The committee agreed a new number for this project was appropriate given the scope publication of the ISO 11999 series was to cover ensemble standards. It was further agreed that ISO 11613:1999 would remain current.

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PPE for firefighters — Test methods and requirements for PPE used by firefighters who are at risk of exposure to high levels of heat and/or flame while fighting fires occurring in structures —

Part 3: Clothing

1 Scope

This part of ISO 11999 specifies the minimum design and performance requirements for clothing as part of personal protective equipment (PPE) to be used by firefighters, primarily but not solely to protect against exposure to flame and high thermal loads.

To assist with choice based on user risk assessment, a number of levels of protection are included.

The scope of this part of ISO 11999 does not include clothing for use in high-risk fire exposures where for example, reflective protective clothing according to ISO 15538 could be more appropriate, or for use in long-term firefighting operations in high ambient temperature, for example bush, wildland, or forest firefighting where clothing according to ISO 16073 or ISO 15384 could be more appropriate.

Similarly, this part of ISO 11999 does not include clothing to protect against chemical and biological hazards, other than against short-term and accidental exposure while engaged in firefighting and associated activities when fighting fires occurring in structures.

This part of ISO 11999 describes types, design, and performance of clothing, the specific requirements for clothing, marking, and manufacturer's instructions.

2 Normative references

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

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

ISO 3146:2000, *Plastics — Determination of melting behaviour (melting temperature or melting range) of semi-crystalline polymers by capillary tube and polarizing-microscope methods*

ISO 3175-1, *Textiles — Professional care, drycleaning and wetcleaning of fabrics and garments — Part 1: Assessment of performance after cleaning and finishing*

ISO 4674-1, *Rubber- or plastics-coated fabrics — Determination of tear resistance — Part 1: Constant rate of tear methods*

ISO 4920:2012, *Textile fabrics — Determination of resistance to surface wetting (spray test)*

ISO 5077:2007, *Textiles — Determination of dimensional change in washing and drying*

ISO 6330:2012, *Textiles — Domestic washing and drying procedures for textile testing*

ISO 6530:2005, *Protective clothing — Protection against liquid chemicals — Test method for resistance of materials to penetration by liquids*

ISO 6942:2002, *Protective clothing — Protection against heat and fire — Method of test: Evaluation of materials and material assemblies when exposed to a source of radiant heat*

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

ISO 9227:2012, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 11092:1993, *Textiles — Physiological effects — Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)*

ISO 11999-1, *PPE for firefighters — Test methods and requirements for PPE used by firefighters who are at risk of exposure to high levels of heat and/or flame while fighting fires occurring in structures — Part 1: General*

ISO 11999-2, *PPE for firefighters — Test methods and requirements for PPE used by firefighters who are at risk of exposure to high levels of heat and/or flame while fighting fires occurring in structures — Part 2: Compatibility*

ISO 12127-1, *Clothing for protection against heat and flame — Determination of contact heat transmission through protective clothing or constituent materials — Part 1: Contact heat produced by heating cylinder*

ISO 13688:2013, *Protective clothing — General requirements*

ISO 13934-1:2013, *Textiles — Tensile properties of fabrics — Part 1: Determination of maximum force and elongation at maximum force using the strip method*

ISO 13935-2, *Textiles — Seam tensile properties of fabrics and made-up textile articles — Part 2: Determination of maximum force to seam rupture using the grab method*

ISO 13937-2, *Textiles — Tear properties of fabrics — Part 2: Determination of tear force of trouser-shaped test specimens (Single tear method)*

ISO 13994:2005, *Clothing for protection against liquid chemicals — Determination of the resistance of protective clothing materials to penetration by liquids under pressure*

ISO 15025:2000, *Protective clothing — Protection against heat and flame — Method of test for limited flame spread*

ISO 15384:2003, *Protective clothing for firefighters — Laboratory test methods and performance requirements for wildland firefighting clothing*

ISO 15538:2001, *Protective clothing for firefighters — Laboratory test methods and performance requirements for protective clothing with a reflective outer surface*

ISO 16073:2011, *Wildland firefighting personal protective equipment — Requirements and test methods*

ISO 16604:2004, *Clothing for protection against contact with blood and body fluids — Determination of resistance of protective clothing materials to penetration by blood-borne pathogens — Test method using Phi-X 174 bacteriophage*

ISO 17491-4:2008, *Protective clothing — Test methods for clothing providing protection against chemicals — Part 4: Determination of resistance to penetration by a spray of liquid (spray test)*

ISO 17492:2003, *Clothing for protection against heat and flame — Determination of heat transmission on exposure to both flame and radiant heat*

ISO 17493:2000, *Clothing and equipment for protection against heat — Test method for convective heat resistance using a hot air circulating oven*

ISO 20471:2013, *High visibility clothing — Test methods and requirements*

ASTM F1868-12, *Standard test method for thermal and evaporative resistance of clothing materials using a sweating hot plate*

CIE 054.2:2001, Retroreflection: definition and measurement

NFPA 1971:2007, *Standard on protective ensembles for structural firefighting and proximity firefighting*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11999-1 apply.

4 Clothing requirements

4.1 General

Design requirements for clothing are given in 4.1 to 4.13. Sampling and pre-treatment are given in 4.14 and 4.15. Performance requirements are as required in 4.16 to 4.20. Additional requirements are given in 4.21. A comparison of performance requirements for clothing is provided in Annex A.

4.2 Clothing configuration

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 an outer garment which can be, for example

- a one-piece protective cover all designed to cover the upper and lower torso including the neck, arms, and legs,
- a protective coat and a pair of protective trousers with an overlap of sufficient length to provide protection to the wearer (see ISO 11999-2), or
- a series of outer and undergarments designed to be worn together.

4.3 Multi-layer clothing assemblies

Where multi-layer clothing assemblies are used to achieve the specified performance levels, the layers shall be either permanently attached or the various layers shall be clearly labelled:

"IN ORDER TO ACHIEVE THE CLAIMED LEVEL OF PERFORMANCE FOR THE CLOTHING ASSEMBLY, ALL LAYERS BEARING THIS LABEL SHALL ALWAYS BE WORN TOGETHER."

4.4 Component assembly

Protective garments shall consist of a component assembly that provides the necessary number and type of layers for achieving the performance specified in this part of ISO 11999.

Any component assembly reinforcement or padding used in high-wear or load-bearing areas, such as pockets, cuffs, knees, elbows, and shoulders shall meet the requirements of at least flame resistance and heat resistance contained in 4.17 equivalent to the level achieved by the garment. Padding can include additional thermal barrier material, meeting the requirements as specified in this part of ISO 11999.

4.5 Attachment of interlining and innermost layers

Component assemblies shall have a means of securing the interlining and innermost lining where present to the outer material.

4.6 Extension of interlining and innermost layers

In performance level A2 coats, the interlining and innermost layers shall extend, as a minimum, to the neckline seams, to within 75 mm of the bottom outer material hems, and to within 25 mm of the sleeve end of the outer material. The interlining and innermost layers shall be configured to overlap at all closures.

In performance level A1 coats, the interlining and innermost layers shall extend, as a minimum, to the neckline seams, to the bottom of the outer materials hems, and to within 25 mm of the sleeve end of the outer material.

The interlining and innermost layers shall be configured to overlap at all closures.

In all trousers, the interlining and innermost layers shall extend, as a minimum, to the waistline seam, and to within 75 mm of the bottom outer material hems of the legs.

The ends of the interlining and innermost layers shall be attached at or adjacent to the coat sleeves or the trouser legs. The distance between the attachment points of any mechanism used to attach the liner shall not be greater than 25 mm, and the mechanism shall not be expandable.

4.7 Garment closure systems

Closures that breach the protective integrity of the garment shall be constructed in a manner that provides secure and complete moisture and thermal protection to the requirements of this part of ISO 11999. If non-positive fasteners, such as snaps or hook and pile tape, are utilized in these closures, except where used in the collar and pocket closure system ([4.11](#)), a positive locking fastener, such as hooks and eyes or zippers, shall also be utilized.

NOTE A positive locking fastener cannot be opened by inadvertently pulling on it.

4.8 Hardware

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

4.9 External pocket requirements

External pockets, where provided, shall have a means of drainage of water, of fastening them in the closed position, and of preventing entry of burning debris, excluding radio pockets.

4.10 Garment sizing

Garment sizes shall fit to the measures indicated in ISO 13688.

4.11 Neck protection

Protective clothing shall have a collar no less than 75 mm in height at any point, with a closure system. Collar and closure system shall meet at least the flame and thermal requirements specified in [4.17](#), equivalent to the level achieved by the garment.

4.12 Wrist protection

Each protective garment sleeve shall have a protective wristlet or other means of protection at the wrist which is so designed with the intention of preventing the ingress of both water and burning debris.

4.13 High-visibility materials

4.13.1 General

Firefighter's clothing shall have high-visibility materials fitted which shall meet the following requirements in either [4.13.2](#) or [4.13.3](#).

4.13.2 Option 1 — Placement based on minimum area of coverage

The minimum area requirements for high-visibility materials shall be as specified in [4.13.2.1](#) for retroreflective materials and as specified in [4.13.2.2](#) for fluorescent or combined retroreflective/fluorescent materials.

4.13.2.1 Retroreflective material

Retroreflective material shall be attached to the outermost surface of the protective clothing with a minimum area of not less than 0,13 m². All-around visibility shall be ensured by having at least one band encircling each of the arms, legs, and torso regions of the garments.

4.13.2.2 Fluorescent material or combined retroreflective/fluorescent material

When fluorescent or combined retroreflective and fluorescent material is applied, the minimum area of fluorescent material shall not be less than 0,2 m². All-around visibility shall be ensured by having at least one band encircling each of the arms, legs, and torso regions of the garments.

4.13.3 Option 2 — Placement based on standard pattern

4.13.3.1 General

The minimum pattern requirements for high-visibility materials shall be as specified in [4.13.3.2](#) to [4.13.3.6](#).

4.13.3.2 Type of high-visibility materials

High-visibility trim utilized to meet retroreflectivity and fluorescence requirements shall be permanently attached to the outermost surface of protective garments and shall have both retroreflective and fluorescent surfaces. The width of the retroreflective surface of trim shall not be less than 16 mm. 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 3 mm.

4.13.3.3 Minimum amount of fluorescence for standard pattern

High-visibility materials used to meet the standard pattern shall have a minimum fluorescent surface of 50 mm²/linear mm.

4.13.3.4 High-visibility materials exceeding standard pattern

High-visibility material affixed to protective garments exceeding the standard pattern requirements illustrated in [Figures 1](#) and [2](#) 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 high-visibility material required in [4.13.3.5](#) and [4.13.3.6](#) is not obscured.

4.13.3.5 Standard pattern for garments covering the upper torso including arms

The configuration for high-visibility materials on garments covering the upper torso including the arms shall be as illustrated in [Figure 1](#). The standard pattern of high-visibility material for the garments covering the upper torso including the arms shall have one circumferential band of high-visibility material or a staggered 360-degree visibility pattern meeting or exceeding the surface areas of a continuous circumferential band around the bottom of the coat. The lower edge of the circumferential

band on the lower part of the coat shall be within 25 mm of the coat hem's highest point. The front of the coat shall also have at least one horizontal band of high-visibility material at the chest level. No vertical strips of high visibility shall be permitted on the front of the coat.

The back of the coat shall also have a minimum of either two vertical strips of high-visibility material perpendicular to the bottom band with one strip located on both the left and right sides of the back of the coat or a minimum of one horizontal band of high visibility material at the chest/shoulder blade level.

The minimum high-visibility material configuration for each sleeve, between the wrist and elbow area, shall be one circumferential band or a staggered 360-degree visibility pattern meeting or exceeding the surface area of a continuous circumferential band. Where trim on the garment covering the upper torso including the arms intersects a zipper, a maximum gap in the trim of 25 mm shall be permitted.

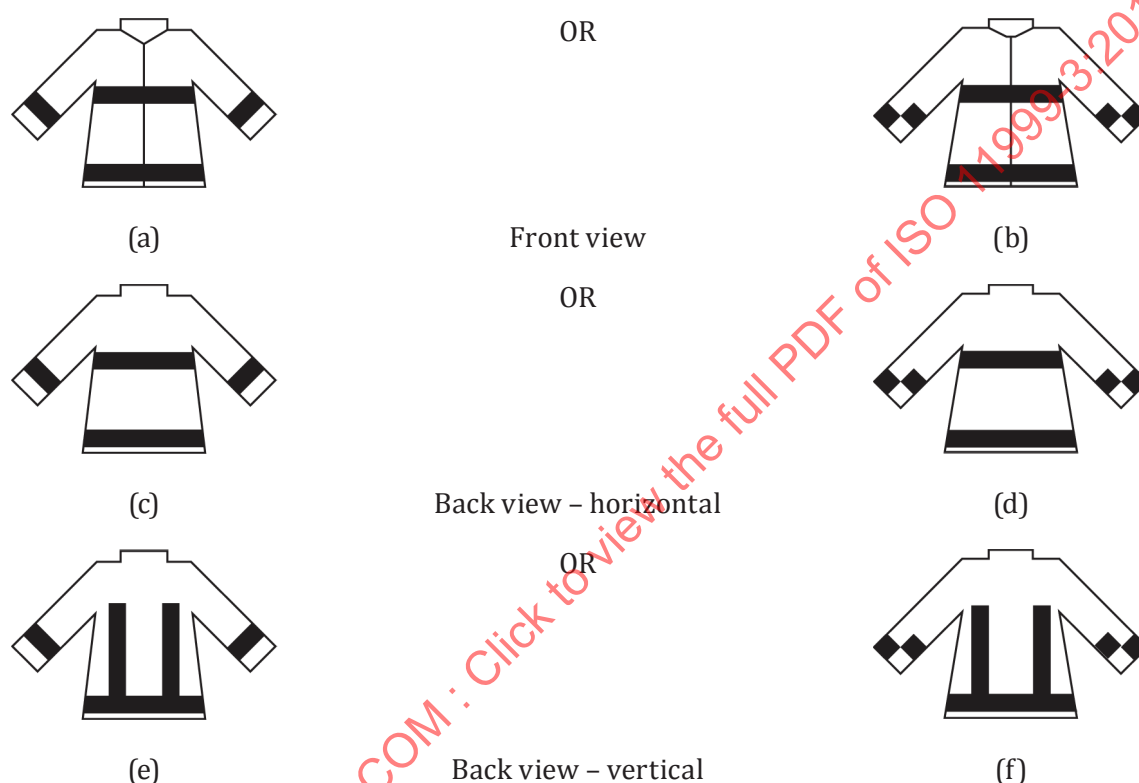


Figure 1 — Minimum pattern for placement of high-visibility materials on garments covering the upper torso including the arms

NOTE Diagrams (a) and (b) represent alternative placement for the front of the coat; Diagrams (c), (d), (e), and (f) represent alternative placement for the back of the coat.

4.13.3.6 Standard pattern for garments covering the lower torso including the legs

The minimum high-visibility material pattern for garments covering the lower torso including the legs shall consist of one circumferential strip of high-visibility material around each leg at least 50 mm from the bottom hem in accordance with [Figure 2](#).



Figure 2 — Minimum pattern for placement of high-visibility materials on garments covering the lower torso including the legs (front and back)

4.14 Sampling

4.14.1 Samples

Testing for determining the material and component compliance with the requirements specified in [4.17](#) 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.

4.14.2 Sampling levels

Unless otherwise specified, the number and size of specimens for the different tests shall be in accordance with the respective standards.

4.14.3 Exposure surface

In all surface tests, the outermost surface of the component assembly shall be exposed, except for flame spread testing of the innermost lining (see [4.17.1](#)) and testing of water vapour resistance (see [4.20.1](#)) and total heat loss (see [4.20.2](#)) when the innermost surface is exposed.

4.15 Pre-treatment

4.15.1 General

Pre-treatments are done to provide uniformly treated materials for test.

Unless otherwise specified in the specific test methods, all specimens shall be conditioned for a minimum of 24 h by exposure to a temperature of $20\text{ °C} \pm 2\text{ °C}$ and a relative humidity of $65\% \pm 5\%$ prior to testing.

Unless otherwise specified in the specific methods, all specimens shall be tested within 5 min after removal from the pre-treatment.

4.15.2 Pre-treatment by laundering or dry cleaning

In order to ensure consistency of testing, pre-treatment by laundering or dry cleaning is done to remove contaminants, finishes, or dressings from the manufacturing process.

NOTE Ageing and life expectancy is not to be confused with these pre-treatments.

For materials that are labelled as washable, test samples shall be subjected to five cleaning cycles in a front-loading horizontal drum machine using 1 g/l IEC detergent in soft water in accordance with the procedures of ISO 6330. Washing shall be carried out by Procedure 2A at $60\text{ °C} \pm 3\text{ °C}$ and drying by Procedure E (tumble drying) unless otherwise specified in the care labelling.

Materials that are labelled as dry cleanable only shall be dry cleaned five times in accordance with ISO 3175-1. A laundry bag shall not be used.

4.16 Clothing — Performance requirements

The performance of firefighter protective clothing shall be classified in each performance category as specified in [Table 1](#).

Table 1 — Classification of performance

Performance category	Applicable subclause	
	Performance level A1	Performance level A2
(Letter code “A” for marking according to ISO 11999-1:2013, Clause 6)		
Flame and thermal resistance	4.17.2 Flame resistance surface ignition; 4.17.4 (Heat resistance at 180 °C) Either 4.17.5 Heat transfer (flame exposure) ($HTI_{24} \geq 13$ and $HTI_{24} - HTI_{12} \geq 4$) and 4.17.6 Heat transfer (radiant exposure) ($RHTI_{24} \geq 18$ and $RHTI_{24} - RHTI_{12} \geq 4$) or 4.17.7 Heat transfer (combined flame and radiant exposure) ($TTI \geq 1\,050$) 4.17.8 Residual strength (≥ 450 N after 10 kW/m ²) 4.17.9.1 (CCHR at 180 °C) 4.17.10 (Thread heat resistance at 260 °C)	4.17.3 Flame resistance edge ignition; 4.17.4 (Heat resistance at 260 °C) Either 4.17.5 Heat transfer (flame exposure) ($HTI_{24} \geq 17$ and $HTI_{24} - HTI_{12} \geq 6$) and 4.17.6 Heat transfer (radiant exposure) ($RHTI_{24} \geq 26$ and $RHTI_{24} - RHTI_{12} \geq 8$) or 4.17.7 Heat transfer (combined flame and radiant exposure) ($TTI \geq 1\,400$) 4.17.8 Residual strength (≥ 600 N after 20 kW/m ²) 4.17.9.2 (CCHR at 260 °C) 4.17.10 (Thread heat resistance at 260 °C)

Table 1 (continued)

Performance category	Applicable subclause	
Additional	4.21.1 Cleaning shrinkage resistance 4.21.2 Hardware corrosion resistance 4.21.3 Photometric requirements of high-visibility retroreflective/combined performance materials 4.21.4 Colour requirements of high-visibility fluorescent/combined performance materials 4.21.5 Heat resistance of high-visibility materials used on garments 4.21.6 Flame spread of high-visibility materials used on garments 4.21.7 Protective wristlets 4.21.8 Optional clothing test using an instrumented manikin NOTE Applicable requirements under review. 4.21.9 Optional drag rescue device (DRD)	4.21.1 Cleaning shrinkage resistance 4.21.2 Hardware corrosion resistance 4.21.3 Photometric requirements of high-visibility retroreflective/combined performance materials 4.21.4 Colour requirements of high-visibility fluorescent/combined performance materials 4.21.5 Heat resistance of high-visibility materials used on garments 4.21.6 Flame spread of high-visibility materials used on garments 4.21.7 Protective wristlets 4.21.8 Optional clothing test using an instrumented manikin NOTE Applicable requirements under review. 4.21.9 Optional drag rescue device (DRD)
(Letter code “b” for marking according to ISO 11999-1:2013, Clause 6)	Performance level b₁	Performance level b₂
Strength and physical hazard resistance	4.18.1 (≥ 450 N) 4.18.2 (≥ 25 N for outer shell) 4.18.3 (≥ 225 N for major A seams)	4.18.1 (≥ 800 N) 4.18.2 (≥ 40 N for outer shell) 4.18.2 (≥ 10 N for moisture management component, thermal liner, etc.) 4.18.3 (≥ 450 N for major A seams) 4.18.3 (≥ 330 N for major B seams) 4.18.3 (≥ 180 N for minor seams) 4.18.4 (≥ 180 N for knit materials)
(Letter code “c” for marking according to ISO 11999-1:2013, Clause 6)	Performance level c₁	Performance level c₂
Water and liquid penetration resistance	4.19.2 (spray rating of ≥ 4) 4.19.3 (water absorption ≤ 30 %) 4.19.4 water penetration (≥ 20 kPa) 4.19.5 liquid penetration resistance (runoff method)	4.19.2 (spray rating of ≥ 4) 4.19.3 (water absorption ≤ 30 %) 4.19.4 water penetration (≥ 175 kPa) 4.19.6 liquid penetration pressure resistance (hydrostatic method) 4.19.7 viral penetration 4.19.8 shower test 4.19.9 light degradation
(Letter code “d” for marking according to ISO 11999-1:2013, Clause 6)	Performance level d₁	Performance level d₂

Table 1 (continued)

Performance category	Applicable subclause	
Thermal comfort:		
Water vapour resistance or	4.20.2 ($\leq 40 \text{ m}^2 \text{ Pa/W}$)	4.20.2 ($\leq 30 \text{ m}^2 \text{ Pa/W}$)
Total heat loss	4.20.3 ($\geq 200 \text{ W/m}^2$)	4.20.3 ($\geq 300 \text{ W/m}^2$)

The performance level for each performance category shall be determined by the performance achieved for each requirement in the respective performance category. For many properties within each performance category, different minimum performance is established. For example, where performance levels 1 and 2 exist in the same garment or multilayer assembly within a performance category, it shall be classified as level 1.

Different performance levels shall be permitted for each performance category with the exception of the “additional” category. The “additional” category shall achieve the same level of classification as the flame and thermal resistance performance category.

The garments achieving the performance level A1 for the flame and thermal resistance category and the “additional” category shall be type 1 garments.

The garments achieving the performance level A2 for the flame and thermal resistance category and the “additional” category shall be type 2 garments.

All garments shall achieve at least performance level 1 for all categories.

The performance level achieved for the strength and physical hazard category, the water and liquid penetration resistance category, and the thermal comfort category shall be reported as required in [Clause 5](#) and 11999-1.

4.17 Flame and thermal resistance performance

4.17.1 General

Flame and thermal resistance performance of firefighter protective clothing shall conform to all requirements for the respective performance level specified in [Table 2](#). The firefighter protective clothing shall be classified for flame and thermal resistance performance to the lowest performance achieved for any performance property.

Table 2 — Marking code “A” — Flame and thermal resistance performance

Property	Applicable subclause	
	Performance level A1	Performance level A2
Flame resistance	4.17.2	4.17.3
Heat resistance	4.17.4	4.17.4
Heat transfer	4.17.5 and 4.17.6 or 4.17.7	4.17.5 and 4.17.6 or 4.17.7
Residual strength following radiant exposure	4.17.8	4.17.8
Conductive compressive heat transfer	4.17.9	4.17.9
Thread heat resistance	4.17.10	4.17.10

4.17.2 Flame resistance (surface ignition) for performance level A1

Flame resistance shall be tested in accordance with ISO 15025:2000 Procedure A, after pre-treatment by laundering or dry cleaning as specified in [4.15.2](#), and shall satisfy the following requirements.

- a) No specimen shall give flaming to the top or either side edge.
- b) No specimen shall give hole formation in any layer except for a layer providing performance other than flame protection, e.g. moisture management component.
- c) No specimen shall give flaming or molten debris.
- d) The mean value of afterflame time shall be ≤ 2 s.
- e) Any afterglow shall not spread from the carbonized area to the undamaged area after the cessation of flaming.

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 can 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.

4.17.3 Flame resistance (bottom-edge ignition) for performance level A2

Each layer of the component assembly, including the outer material, moisture management component, thermal barrier, collar linings, and winter linings shall be tested individually for flame resistance in accordance with ISO 15025:2000, Procedure B, both before and after pre-treatment by laundering or dry cleaning as specified in [4.15.2](#) and shall satisfy the following requirements, noting that testing shall be performed on the edge and not on the seam.

- a) No specimen shall give flaming to the top or either side edge.
- b) No specimen shall give flaming or molten debris.
- c) The mean value of the afterflame time shall be less than 2 s.
- d) The char length shall be less than 100 mm when measured, as specified in Annex C of ISO 15025:2000.
- e) Any afterglow shall not spread from the carbonized area to the undamaged area after the cessation of flaming.

Zippers, hook and pile fasteners, and seam-sealing materials shall be tested only where located on the exterior of the garment or located where they will directly contact the wearer's body.

Elastic shall be tested only when used in locations where they will directly contact the wearer's body.

Small specimens that are not large enough to meet the specimen size requirement in ISO 15025:2000 shall be sewn or attached onto a layer of the component assembly as representative of the construction of the clothing and shall not be consumed and shall satisfy requirements b), c), and d) only.

4.17.4 Heat resistance

Each layer of the component assembly when tested in accordance with ISO 17493, before and after pre-treatment by laundering or dry cleaning as specified in [4.15.2](#), shall not melt, drip, separate, ignite, or shrink more than the permissible percentage at the respective test temperatures specified in [Table 3](#).

Each material shall be exposed to the test temperature for 5 min +15/-0 s.

Table 3 — Heat resistance

Test parameter or measurement	Performance level A1	Performance level A2
Test temperature	180 °C +5/-0 °C	260 °C +5/-0 °C
Permissible shrinkage	≤ 5 %	≤ 5 %

Shrinkage shall not be measured for materials or components that are smaller than the required specimen dimensions specified in ISO 17493.

The following requirements shall also apply.

- The outer shell and collar lining shall not char.
- Moisture management component seams shall also be tested and shall not drip or ignite.
- Clothing hardware shall be tested and shall not ignite and shall remain functional.

4.17.5 Heat transfer (flame exposure)

The component assembly or multi-layer clothing assembly when tested in accordance with ISO 9151, after pre-treatment by laundering or dry cleaning as specified in 4.15.2, shall achieve the performance levels specified in Table 4.

Table 4 — Heat transfer (flame exposure)

Heat transfer index	Performance level A1	Performance level A2
HTI ₂₄	≥ 13 s	≥ 17 s
HTI ₂₄ – HTI ₁₂	≥ 4 s	≥ 6 s

4.17.6 Heat transfer (radiant exposure)

The component assembly or multi-layer clothing assembly when tested in accordance with Method B of ISO 6942:2002, at a heat flux density of 40 kW/m² after pre-treatment by laundering or dry cleaning specified in 4.15.2, shall achieve the performance levels specified in Table 5.

Table 5 — Heat transfer (radiant exposure)

Heat transfer factor	Performance level A1	Performance level A2
RHTI ₂₄	≥ 18 s	≥ 26 s
RHTI ₂₄ – RHTI ₁₂	≥ 4 s	≥ 8 s

4.17.7 Heat transfer (combined flame and radiant exposure)

As an alternative to meeting the requirements of 4.17.5 and 4.17.6, the component assembly or multi-layer clothing assembly when tested in accordance with ISO 17492, using the TTI analysis procedure, before and after pre-treatment by laundering or dry cleaning as specified in 4.15.2, shall achieve the performance levels specified in Table 6.

Table 6 — Heat transfer (combined flame and radiant exposure)

Performance measurement	Performance level A1	Performance level A2
TTI (kJ/m ²)	≥ 1 050	≥ 1 400

4.17.8 Residual strength of material following radiant heat exposure

The outer material shall be tested in accordance with ISO 13934-1 after pre-treatment of the complete assembly by Method A of ISO 6942:2002 at the respective heat flux density and shall achieve the performance levels specified in [Table 7](#).

Table 7 — Residual strength following radiant exposure

Test parameter or measurement	Performance level A1	Performance level A2
Heat flux density	10 kW/m ²	20 kW/m ²
Tensile strength	≥ 450 N	≥ 600 N

Testing shall be performed on a minimum of three specimens from the machine direction and three specimens from the cross-machine direction. A 50-mm-wide tensile specimen shall be obtained by cutting the exposed specimen on both sides so that the exposed specimen area is in the middle of the tensile specimen.

Tensile strength shall be separately determined in the machine and cross-machine directions. The average tensile strength for each direction shall be calculated and used to determine compliance with this requirement.

4.17.9 Conductive compressive heat resistance

Testing shall follow the procedures in ISO 12127-1 with the following exceptions:

- An applied contact pressure of 55 kPa shall be used for testing the reinforced samples representing the knee region of the firefighter protective clothing.
- An applied contact pressure of 14 kPa shall be used for testing the reinforced samples representing the shoulder region of the firefighter protective clothing.
- t_t shall be based on a 24 °C temperature rise. This measurement shall be reported as the CCHR rating.

4.17.9.1 Conductive compressive heat resistance level A1

For performance level A1, regions of firefighter protective clothing shoulder and knee areas reinforced for the reason of conductive compressive heat resistance, when tested in accordance with ISO 12127-1 using a contact temperature of 180 °C +5/-0 °C, shall have a conductive compressive heat resistance (CCHR) rating ≥ 13,5.

4.17.9.2 Conductive compressive heat resistance level A2

For performance level A2, regions of firefighter protective clothing shoulder and knee areas reinforced for the reason of conductive compressive heat resistance, when tested in accordance with ISO 12127-1 using a contact temperature of 260 °C +5/-0 °C, shall have a conductive compressive heat resistance (CCHR) rating ≥ 13,5.

Samples of the reinforced region shall include the component assembly plus any additional internal or external layers provided. Samples shall be prepared as 200 mm² that are sewn along the periphery. Samples shall be subjected to pre-treatment by laundering or dry cleaning as specified in [4.15.2](#).

Samples shall be tested both dry and wet. Samples shall be wet by placing the innermost layer between two sheets of blotting paper that has been saturated and subjected to a roller at a pressure of 10 kPa. The innermost layer and blotting paper sandwich shall be placed in a sealed bag for a period of 24 h. The sample shall be tested within 5 min after removal from the bag.

4.17.10 Thread heat resistance

For performance level A1 and A2, all thread utilized in the construction of protective garments, when tested in accordance with ISO 3146 at a temperature of 260 °C +5/-0 °C, shall not ignite, melt, or char.

4.18 Strength and physical hazard resistance performance

The strength and physical hazard resistance performance of firefighter protective clothing shall conform to all requirements for the respective performance level specified in [Table 8](#).

Table 8 — Marking code “b” — Strength and physical hazard resistance performance

Strength or physical hazard resistance property	Applicable subclause	
	Performance level b ₁	Performance level b ₂
Tensile strength — outer material	4.18.1 (≥ 450 N)	4.18.1 (≥ 800 N)
Tear strength — outer material	4.18.2 (≥ 25 N)	4.18.2 (≥ 40 N)
Tear strength — moisture management component, thermal barrier, and other component assembly layers	Not required	4.18.2 (≥ 10 N)
Seam strength — major A seams	4.18.3 (≥ 225 N)	4.18.3 (≥ 450 N)
Seam strength — major B seams	Not required	4.18.3 (≥ 330 N)
Seam strength — minor seams	Not required	4.18.3 (≥ 180 N)
Seam strength — knit material seams	Not required	4.18.4 (≥ 180 N)

4.18.1 Tensile strength

The outer material, when tested in accordance with ISO 13934-1, shall achieve the performance levels specified in [Table 8](#) for both machine and cross-machine directions.

4.18.2 Tear strength

The outer material, when tested in accordance with Method B of ISO 13937-2, shall achieve the performance levels specified in [Table 8](#) for both machine and cross-machine directions.

For performance level b₂, the moisture management component, thermal barrier, or any other layer in the component assembly shall be tested in accordance with Method B of ISO 4674-1 and shall achieve the performance levels specified in [Table 8](#) for both machine and cross-machine directions.

4.18.3 Seam strength (woven materials)

Seams joining at least one woven material, when tested in accordance with ISO 13935-2, shall achieve the performance levels specified in [Table 8](#).

4.18.4 Seam strength (knit or stretch woven materials)

Seams joining knit or stretch woven materials, when tested in accordance with ISO 13935-2, shall have a seam strength of ≥ 180 N.

4.19 Water and liquid resistance performance

4.19.1 General

Water and liquid resistance performance of firefighter protective clothing shall conform to all requirements for the respective performance level specified in [Table 9](#). The firefighter protective

clothing shall be classified for water and liquid resistance performance to the lowest performance achieved for any performance property.

Table 9 — Marking code “c” — Water and liquid penetration resistance performance

Property	Applicable subclauses	
	Performance level c ₁	Performance level c ₂
Surface wetting	4.19.2	4.19.2
Water absorption resistance	4.19.3	4.19.3
Water penetration resistance	4.19.4	4.19.4
Liquid penetration resistance	4.19.5	4.19.6
Viral penetration resistance	Not required	4.19.7
Overall garment liquid penetration	Not required	4.19.8
Light degradation resistance	Not required	4.19.9

4.19.2 Surface wetting

The outer material after pre-treatment according to [4.15.2](#), when tested in accordance with ISO 4920, shall give a spray rating of ≥ 4 .

4.19.3 Water absorption resistance

The outer material and collar lining fabrics when tested in accordance with ISO 4920 as modified below, both before and after pre-treatment by laundering or dry cleaning as specified in [4.15.2](#), shall have water absorption of ≤ 30 %.

Testing shall be performed using ISO 4920 with measurement of the specimen weight change. The specimen 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 percentage water absorption shall be determined using the following formula:

$$w_w = \frac{m_f - m_i}{m_i} \times 100 \quad (1)$$

where

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

m_f is the final mass, in grams, of the specimen;

m_i is the initial mass, in grams, of the specimen.

4.19.4 Water penetration resistance

The moisture management component and its seams where present when tested in accordance with ISO 811, using the specified rate of water pressure increase, shall achieve the performance levels specified in [Table 10](#).

Table 10 — Water penetration

Observation	Performance level c ₁	Performance level c ₂
Rate of water pressure increase	0,98 ± 0,05 kPa/min	5,9 ± 0,1 kPa/min
Appearance of water drops	≥ 20 kPa	≥ 175 kPa

4.19.5 Liquid penetration resistance (runoff method) for performance level c₁

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

- a) 40 % sodium hydroxide (NaOH) at 20 °C ± 2 °C,
- b) 36 % hydrochloric acid (HCl) at 20 °C ± 2 °C,
- c) 37 % sulfuric acid (H₂SO₄) at 20 °C ± 2 °C, or
- d) o-xylene 100 % at 20 °C ± 2 °C,

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

All tests shall be carried out with a pouring time of 10 s ± 1 s and at a temperature of 20 °C ± 2 °C.

4.19.6 Liquid penetration pressure resistance (hydrostatic method) for performance level c₂

The moisture management component including seams when tested in accordance with ISO 13994, Procedure C, using the liquids listed in 4.19.5, shall show no penetration of the test liquids for at least 1 h.

Moisture management component seams shall be tested by preparing a 380 mm² sample of the component assembly with an extra layer of outer material against the innermost layer. The moisture management component layer within the sample shall include a centre seam that extends across the entire 380 mm² width of the sample. The samples shall be stitched along the peripheral edge.

The samples shall first be subjected to pre-treatment by laundering or dry cleaning as specified in 4.15.2 and then be subjected to pre-treatment by oven exposure as specified in ISO 17493 at a temperature of 140 °C +5/−0 °C for 5 min, except that no measurement or observation shall be made.

This sequence of pre-treatments shall be repeated a second time. Testing following the last oven exposure shall take place within 5 min of the oven exposure.

Following the last pre-treatment, specimens shall be taken from the moisture management component seam for liquid penetration resistance testing.

4.19.7 Viral penetration resistance for performance level c₂

The moisture management component including seams, when tested in accordance with ISO 16604, shall show no penetration of the Phi-X174 Bacteriophage for at least 60 min when tested at 0 kPa for 5 min, followed by 14 kPa for 1 min and 0 kPa for ≥54 min. A retaining screen shall not be used to support the specimen.

Moisture management component seams shall be tested by preparing a 380 mm² sample of the component assembly with an extra layer of outer material against the innermost layer. The moisture barrier layer within the sample shall include a centre seam that extends across the entire 380 mm width of the sample. The samples shall be stitched along the peripheral edge.

The samples shall first be subjected to pre-treatment by laundering or dry cleaning as specified in 4.15.2 and then be subjected to pre-treatment by oven exposure as specified in ISO 17493 at a temperature of 140 °C +5/−0 °C for 5 min, except that no measurement or observation shall be made.

This sequence of pre-treatments shall be repeated a second time. Testing following the last oven exposure shall take place within 5 min of the oven exposure.

Following the last pre-treatment, specimens shall be taken from the moisture management component seam for viral penetration resistance testing.

4.19.8 Overall garment liquid penetration resistance for performance level c₂

Firefighter protective clothing, when tested in accordance with ISO 17491-4 after five cycles of laundering or dry cleaning as specified in 4.15.2, shall allow no liquid penetration. The use of a human subject shall be allowed in place of the manikin, taking all necessary safety and health precautions. The human subject shall conform to the size, shape, posture, and motions of the manikin.

4.19.9 Light degradation resistance for performance level c₂

Moisture management component shall be tested for light degradation in accordance with 8.62 of NFPA 1971:2007, and water shall not appear on the surface of the specimen.

4.20 Thermal comfort performance

4.20.1 General

The thermal comfort performance of the component assemblies used in firefighter protective clothing shall conform to all the requirements for the respective performance levels specified in Table 11.

Table 11 — Marking code “d” — Thermal comfort performance

Observation	Performance level d ₁	Performance level d ₂
Water vapour resistance	4.20.2 ≤ 40 m ² Pa/W	4.20.2 ≤ 30 m ² Pa/W
Total heat loss	4.20.3 ≥ 200 W/m ²	4.20.3 ≥ 300 W/m ²

NOTE 1 Both methods assess heat transfer permitted by the clothing component assembly. The measurement of water vapour resistance involves measurement of evaporative heat (simulating sweating) while the measurement of total heat loss measures heat loss by both evaporation and conduction. Water vapour resistance is measured isothermally (no difference in temperature between the skin and the air), whereas total heat loss measures heat transfer at a 10 °C temperature gradient between air and skin surface. The listed methods are intended to provide comparable results between similar but slightly different test approaches.

NOTE 2 Other factors, such as clothing design and fit, can modify the impact of these results on actual physiological performance. Consequently, consideration should be given to conducting comprehensive thermo-physiological assessments such as those found in BS 8469:2008.

NOTE 3 This table ranks the best (least stressful) performance as level d₂ and the worst (most stressful) performance as level d₁, just like all the other tables.

NOTE 4 Material for special purpose, such as reinforcement materials for shoulder pads, knee pads, or materials with heat-reflective surface or liquid-repellent surface or reflective tapes for visibility and/or pockets may adversely impact on actual physiological performance.

4.20.2 Water vapour resistance

The component assembly, when tested in accordance with ISO 11092, shall achieve the performance levels specified in Table 11.

4.20.3 Total heat loss

The component assembly, when tested in accordance with ASTM F 1868, Part C, shall achieve the performance levels specified in [Table 11](#).

4.21 Additional requirements

4.21.1 Cleaning shrinkage resistance

The materials of the outer garment assembly, when tested in accordance with ISO 5077 using the pretreatment by laundering or dry cleaning as specified in [4.15.2](#), shall give a dimensional change $\leq 5\%$.

4.21.2 Hardware corrosion resistance

All metal hardware and hardware that includes metal parts, when tested in accordance with ISO 9227 using a 5 % saline solution and 20 h test exposure, shall satisfy the following requirements.

- 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.

Hardware shall be examined for corrosion by immediately rinsing the specimens under warm, running tap water and drying with compressed air after being removed from the salt spray chamber.

4.21.3 Photometric requirements of high-visibility retroreflective/combined performance materials used on garments

Photometric requirements of retroreflective/combined performance materials shall be determined according to CIE 054.2:2001 following the procedures described in 7.3 of ISO 20471:2013. The coefficient of retroreflection shall be calculated taking into account the width of the retroreflective material.

4.21.3.1 New materials

The minimum coefficient for new retroreflective/combined performance material shall be in accordance with [Table 12](#) or [13](#), as appropriate.

Table 12 — Minimum coefficient of retroreflection in $\text{cd}/(\text{lx}\cdot\text{m}^2)$ for separate performance material

Observation angle	Entrance angle β_1 ($\beta_2 = 0$)			
	5°	20°	30°	40°
12'	330	290	180	65
20'	250	200	170	60
1°	25	15	12	10
1°30'	10	7	5	4

Table 13 — Minimum coefficient of retroreflection in $\text{cd}/(\text{lx}\cdot\text{m}^2)$ for combined performance material

Observation angle	Entrance angle β_1 ($\beta_2 = 0$)			
	5°	20°	30°	40°
12'	65	50	20	5
20'	25	20	5	1,75