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BSI Standards Publication

Guidance on the selection, use, care and maintenance of personal protective equipment (PPE) designed to provide protection for firefighters

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National foreword

This Published Document is the UK implementation of ISO/TR 21808:2021. It supersedes PD ISO/TR 21808:2009, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PH/14, Firefighters' personal protective equipment.

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TECHNICAL REPORT

ISO/TR 21808

Second edition
2021-02

Guidance on the selection, use, care and maintenance of personal protective equipment (PPE) designed to provide protection for firefighters

Lignes directices sur la sélection, l'utilisation, le soin et l'entretien des équipements de protection individuelle (PPE) conçus pour pourvoir à la protection des pompiers

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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 are noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

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

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 94, *Personal safety — Protective equipment*, Subcommittee SC 14, *Firefighters personal equipment*.

This second edition cancels and replaces the first edition (ISO/TR 21808:2009), which has been technically revised and completely rewritten.

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Introduction

The information in this document has been produced to assist firefighters, fire services and purchasers (or the person who advises the employer) in making the necessary decisions regarding the selection, use, care and maintenance of PPE for firefighters.

The purpose of this document is to establish a guidance document for PPE with the goal to evaluate and reduce the hazards and potential health risks associated with firefighting. This selection use, care and maintenance guideline provides basic answers, criteria, and options for the fire service personnel that are selecting or using PPE through its life cycle with respect to protection it provides related to heat and flame or damaged PPE.

The main topics that the fire service needs to consider are highlighted in this document. This guidance document goes through the various steps and considerations such as risk assessment, compatibility, testing, cleaning, information to be provided with the PPE so that the right management choices can be made for each fire service. Many paragraphs of the document contain bullet-lists as thought provokers or options that may need to be considered. The annexes provide additional information that if included, would make the main body of this document too complicated to read, but are necessary to describe hazards and risks, the value of the test methods for the end user, for example Annex E "Description of burn injury risks" and Annex F "Guidance on some of the items that may be addressed in labelling, subject to the required use of the PPE" provide importance guidance information.

The selection of appropriate PPE for heat and flame are based on your own risk assessment and not be copied from other procurement documents.

The compatibility in this document focused mainly on the physical compatibility between each element of PPE and the documentation.

This document is not intended for cleaning, inspection or repair of firefighter PPE. Use ISO 23616[1)] for cleaning, inspection and repair of firefighters personal protective equipment (PPE).

Currently, TC 94/WG1 works to establish a parent standard for the development of this document. In case of the parent standard publication, the consistency of this document is to be considered.

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Guidance on the selection, use, care and maintenance of personal protective equipment (PPE) designed to provide protection for firefighters

1 Scope

This document sets out guidance for the selection, use, care and maintenance of PPE designed to provide protection for firefighters while carrying out their duties.

The PPE covered in this document is intended for firefighting personnel exposed to risks associated with but not necessarily limited to the following activities:

— structural firefighting;

— wildland firefighting;

— incidents involving hazardous materials;

— incidents involving motor vehicle;

— urban search and rescue.

The purpose of this document is to highlight the main areas that a Fire service needs to consider when providing PPE to its members. This document is a supplement to the information provided in the PPE standards or used in conjunction with them. Most paragraphs of the document contain bulletlists, these lists are provided for guidance only and they are not exhaustive.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TR 19591, *Personal protective equipment for firefighters — Standard terms and definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19591 and the following apply.

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

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

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

3.1
base-layer garment
the first layer of a textile structure that is in direct contact with the skin (i.e. briefs, t-shirts, bras, socks)

3.2
care
processes and procedures for cleaning, decontamination, and storage of protective clothing and equipment

[SOURCE: ISO/TR 19591:2018, 3.30]

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3.3
cleaning
act of removing soils and contaminants from protective clothing and equipment by a mechanical, chemical, thermal, or combined processes

[SOURCE: ISO/TR 19591:2018, 3.45]

3.4
compatibility
capability of two or more items or components of personal protective equipment to exist or function in the same system without modification, adaption or mutual interference with respect to interfaces and performance

3.5
contamination
contaminate
process by which elements of PPE are exposed to hazardous materials, body fluids, CBRN agent, the products of combustion, soils and general dirt

3.6
coverall
one-piece garment that completely covers the wearer's torso, together with arms, and legs, excluding the head, hands, and feet

3.7
deterioration
downgrading of the effectiveness or physical characteristics of PPE component due to use, *care* (3.2), maintenance or storage conditions

3.8
ensemble
combination or assembly of multiple items that are individually compliant with a standard that provide protection to the head, upper torso including arms and hands and the lower torso including feet

[SOURCE: ISO 11999-1:2015, 3.24]

3.9
flame resistance
property of a material whereby combustion is prevented, terminated, or inhibited following the application of a source of ignition, with or without subsequent removal of the ignition source

[SOURCE: ISO/TR 19591:2018, 3.114]

Note 1 to entry: Usually flame resistance materials for fire fighter are Index III of ISO 14116, but flame resistance is denoted by meeting one of the Index of ISO 14416 using the flame spread test method ISO 15025.

3.10
maintenance
the act of preserving PPE from loss or *deterioration* (3.8) and includes procedures for inspection, repair and ultimate removal from service

3.11
risk
probability of a specific undesired event (e.g. injury) occurring so that a hazard is realized

[SOURCE: ISO/TR 11610:2004, 3.205]

3.12
risk assessment
overall process that identifies hazards, estimates the potential severity of injury or damage to health, estimates the likelihood of occurrence of injury or danger to health

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3.13
selection
process determining/assessing what PPE is necessary for protection of fire and emergency services response personnel from an anticipated specific hazard or other activity, the procurement of the appropriate PPE, and the choice of the proper PPE for a specific hazard or activity at an emergency incident

3.14
use
application of PPE including its limitations

4 General

Fire services develop procedures for selection, use, care, and maintenance (SUCAM) of PPE for firefighters.

NOTE 1 ISO 23616[2)] is a companion to this document.

NOTE 2 ISO/TS 16975-1 is also a companion to this document.

NOTE 3 ISO/TR 18690 is an additional companion to this document.

5 Selection

5.1 General

The process for selecting appropriate PPE is predicated by the use of a risk assessment process that includes the identification of the tasks to be undertaken and the hazards associated with those tasks. The aim of this process is to ensure that firefighters are provided with PPE that is suitable for the task being undertaken and provides protection against heat and flame and other related hazards.

The process of selecting PPE is divided into several stages:

5.2 Identify and assess risk

The process of carrying out a risk assessment include the following items as a minimum but not be limited to:

— identification of the activities and work environment to be undertaken by person(s) wearing the PPE;

— type of incident (understand mitigation measures in place, organisation's knowledge, training and other control measures before the application of PPE);

— geographical location and climate (environmental temperature and conditions);

— frequency and term of use of the PPE;

— a list of the hazards present;

— thermal hazards: heat flux, (e.g. convective, radiant, mixture of heat types), and contact heat etc.;

— chemical: phase of chemical (e.g. gas, liquid, particulate or solids), and which chemical or mixtures (e.g. acids/basis, organic solvents, petrol, chlorine, etc.), combustion residue (e.g. smoke, particulates, etc);

— biological: viruses, bacteria and other biological risks;

— contaminants: smoke, particulates, asbestos;

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— hot or cold: environmental temperature or cryogenics, etc.;

— mechanical: abrasion, cut, vibration, flying object, etc.;

— other hazards (e.g. noise, electrical hazards, fall, lighting, etc.);

— other aspects;

— a quantification of the risks that would result from exposure to the hazards;

— what other factors are there to mitigate the risks/hazards;

— determination of the level and extent of protection required from the PPE (in absolute or relative terms);

— evaluation of risks resulting from the use of the PPE (frequency and term of use of the PPE);

— organisation's knowledge;

— evaluation of risks resulting from the use of the PPE;

— learning from incidents and reviews injuries and causes.

A number of risk assessment models may be used to determine the level of risk associated with the activities.

For further guidance see Annex A.

5.3 Defining the level of protection required from the PPE for each activity

When defining the level of protection required, consideration is given to the following as a minimum, but not be limited to:

— determine which parts of the body require protection;

— identify what kind of protection is required;

— identify the appropriate Standards or methods that provide the required protection;

— determine the level(s) of protection required (for the relevant parts of the body) in relative or absolute terms for each item of PPE;

— assessment of previously used PPE for meeting standards (any issues and concerns these may have caused such as comfort, incidents, improper use);

— identify compatibility issues and requirements of PPE items.

5.4 Optimal performance of personal protective equipment (PPE)

Select PPE that provides the optimal level of protection as under-protection can lead to the risk of injury through burns, or other hazards while over-protection may lead to a lack of comfort or heat stress.

Heat stress occurs when the body is no longer able to control its internal temperature. In addition to ambient air temperature, factors such as work intensity, humidity and clothing worn while working may lead to heat stress.

Although when looking at heat stress one focuses on the clothing; boots, gloves, fire hood, helmet, RPD, weight of combined PPE are all factors that lead to overexertion and to heat stress. Fire services are required to be sensitive to these factors as firefighters working in hazardous environments are more likely to behave in an unsafe manner due to their loss of ability to make sound decisions. For example

— firefighters might not wear PPE properly in hot environments increasing the risks for burn injury, and

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— firefighter's ability to concentrate on a given task may start to drop off, which increases the risk of errors occurring.

Firefighters are required to be protected from the hazards associated with the tasks they are undertaking; therefore, the fire services has to balance the health and comfort, and the long-term and short-term risks. Therefore items of PPE are to be worn as late as possible, and for as shortest period possible without exposing firefighters to potential hazards.

By identifying the hazards that firefighters might face and then engineering out or reducing the hazard level where possible, may reduce the risk. In some cases, and only after being based on a risk assessment process, the fire service can often reduce the required flame-resistant protection level needed for protective garments and therefore increase the comfort and breathability. PPE is the last line of defence for the firefighter.

Provision of optimal performance PPE depends on several factors. The following provides some examples of what can be adopted:

— The ability to layering concept especially used in garment technology to achieve a balance between comfort and level of protection needed for different tasks e.g. station wear/work wear providing limited heat and flame protection could be used for some tasks and for those tasks requiring additional protection a second heat and flame-resistant garment layer added.

— When a layered approach is used, clearly identify so it is understood that if such layered protective clothing is capable of being compliant with the required Standard.

— PPE construction can increase or decrease the perception of comfort.

NOTE 1 The more pockets, pads, etc. that are added the heavier the garment becomes, and the PPE's breathability is reduced.

— Use of liners may have a positive effect by increasing protection against hot steam, chemical, moisture, etc. but they may also decrease the breathability.

— PPE materials can be a critical factor in determining comfort.

— RPD construction can protect scratches or dents on metal surface or deterioration of rubber materials by adding protective pads or increasing thickness of materials but it may affect the ease of movement due to bulkiness and may lead to fatigue accumulation of firefighters due to added weight. Familiarize with the construction of RPD to determine correct action.

— High breathability (air permeability and/or water vapour permeability) of PPE influences strongly wearing comfort.

NOTE 2 The body produces sweat when regulating the body's core temperature back to normal temperatures. The evaporation of the sweat and breathability of the PPE allows moisture displacement from the skin. Comfort of fabric is frequently measured by its vapour resistance (Ret). Different fabric weaves will provide a difference level of air permeability. Knitted fabrics will generally be more air permeable than woven fabrics.

— When considering comfort, one needs to consider not only the PPE but the whole clothing system including underwear and base layers influence on the moisture management.

Supporting equipment which provides information such as environmental temperature, remaining air pressure of cylinders, communication, etc. are capable of increasing safety and accuracy of activities of firefighters. Adding such equipment is one of the most important factors and needs to be considered.

5.5 Collecting information on available PPE

When purchasing PPE, the fire service carry out market research to determine products that are available.

Consider that systems and innovations of protection have consequences (advantages and disadvantages) and are taken into account and that this can also cause a paradox.

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Take into account:

— sensibility;

— comfort; e.g. heavy weight;

— ergonomics;

— compatibility of all items of PPE;

— suitable for purpose;

— correct fitting;

— durability;

— guidance given regarding wash and care (including and coating re-impregnation/refurbishment);

— information obtained from the potential suppliers on performance levels and manufacturer's information including the compliance to relevant standards and certification by a recognised independent certification body.

— Information gathered from comparable organisations using similar items of PPE for similar tasks.

NOTE If after collating all available information, it is established that suitable PPE is not available, then it can be necessary for a fire service to carry out research and development work.

5.6 Considerations for practical evaluation of selection and performance parameters

When procuring PPE, practical evaluation are conducted to assess the compatibility and the ergonomics of the PPE. See also Annex B.

Structured trials with participants undertaking standardised, representative tasks are recommended. The number of participants, the diversity as well as the repeatability using the same population need to be considered.

When conducting practical evaluation, a systematic approach is adopted with the following issues considered:

— ability to protect based on expectation and the outcomes of the risk assessment;

— ease and speed of putting on and taking off;

— ease of activity;

— hindrance of use of PPE;

— durability;

— ease and extent of adjustability;

— acceptance in terms of comfort, mobility, weight and metabolic heat release;

— compatibility with all other items of PPE;

— ability to undertake all tasks expected without hindrance or difficulty;

— preservation of the protection in all working positions.

Practical evaluations are carried out under the following conditions:

— participants are selected based on a cross section of the firefighters (height, weight, age, gender, etc.);

— participants evaluate each item of the PPE on trial individually;

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— performance of the garments including fire hoods after a number of cleaning cycles according to the manufacturer's instructions;

— objective physiological measurements are used to determine thermal impact (metabolic heat release/retention);

— the number of firefighters are sufficient to ensure that the results obtained are statistically significant and representatives of the total workforce.

Evaluation feedback is obtained in a structured manner allowing for both qualitative and quantitative data collection and analysis. Using a structured questionnaire, structured or semi-structured interviews and/or group discussions may achieve this.

NOTE 1 For consistency of data the same firefighters are used to conduct the practical evaluation. Obtaining feedback from the intended firefighters is imperative at this stage, as such information will provide valuable data relating to the practical performance of the PPE and give confidence to the firefighters, thus ensuring that the selected items are suitable for use.

NOTE 2 Further guidance on the ergonomics of PPE in general can be found in EN 13921. A detailed test protocol, specifically for firefighters PPE, can be found in BS 8469. Also, selection protocol can be found in the German Fire Protection Association (vfdb) guideline 0810 (*Guideline for the selection of personal protective equipment (PPE) based on a risk assessment for operations of German fire services*).

Table 1 — Summary on properties and wearability of Head protection. (Helmet)

Property	Consideration	Parameters (as examples)
Physiological	— Sound attenuation	— Jet style all surround shell design
	— Loss of spatial awareness	— Decrease in visual and audio sensitivity
	— Increased brain temperature (hyper-thermia)	— Heat dissipation rate, good air ventilation
Ergonomics	— Weight	— Pressure points; neck muscles fatigue
	— Weight distribution (helmet design, add-on accessories)	— Fit when running
	— Wearing height	— Area of coverage; wobbliness
	— Wearing comfort	— Heat dissipation; air circulation; sweat wicking material on headband
	— Interface with other components	— Between neck protector and jacket collar; between face shield and BA mask; between headband and BA mask; between helmet and comms system
	— Head size	— Gender specific helmets
	— Head shape	— Non-ethnocentric liner design that fits user of all ethnic groups
	— Wearing size	— Fits a wider range of head sizes; secure down-sizing kit for smaller head sizes
	— Interface with BA mask that uses mounting adaptor	— Face seal security
Durability	— Resistance to chemical	— Cleaning agents; adhesive from decals and retro-reflective trims

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Table 1 *(continued)*

Property	Consideration	Parameters (as examples)
	— Resistance to UV degradation	— Solar radiation
Wash and care	— Decontamination of internal components	— Ease of component removal and re-assembly
Protection: Thermal (convective, radiant and contact heat)	— Flame resistance — Heat resistance — Heat insulation	— Inherently FR shell; FR componentry — Level of dropping ad sagging — Increase in internal temperature
Protection mechanical & other	— Resistance to impacts — Resistance to crushing — Electrical insulation	— Shock impacts (force, acceleration) — Penetration by blunt and sharp objects — High speed particle shock impacts — Shell design — Non-conductive shell or paint

Table 2 — Summary on properties and wearability of Respiratory protection (RPD)

Property	Consideration	Parameters (as examples)
Physiological	— Comfort — Activity — Fitness	— Weight — Field test — Fatigue resistant — Movement of limbs and body — Transport — Training — Airtightness
Ergonomics	— Comfort — Environmental performance	— Size — Visibility — Conversation — Breathing — Activities — Interference with other PPE — Abrasion with other PPE
Durability	— Comfort — Environmental — Performance	— Comfort — Flame resistance — Abrasion resistance — Weatherability — Aging of materials
Wash and care	— Cleaning — Decomposition and Manual	— Materials not affected by detergent — Not to affect breathability performance — Visibility
Thermal (convective, radiant and contact heat)	— Environmental performance	— Flame resistance

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Table 2 *(continued)*

Property	Consideration	Parameters (as examples)
		— Heat resistance

Table 3 — Summary on properties and wearability of protective clothing, protective gloves, and firehoods

Property	Consideration	Parameters (as examples)
Physiological	— Breathability — Flexibility — Elasticity — Skin effects	— Air permeability — Water vapour permeability — Thermal heat loss by sweating torso or manikin test — Weight — Thickness — Surface roughness — allergy — pH value and chromium (VI) content in a case of leather PPE
Ergonomics	— While carrying out work	— Size — Fit — Weight — Freedom of movement and work — Friction against undergarments in walking — Dressing — Compatibility with another PPE — Heat stress — Discomfort
Durability	— While being worn — In storage	— Tensile strength — Tear strength — Burst strength — Abrasion resistance — Flex cracking — Seam resistance — Aging
Wash and care	— Single use — (Water) washing — Laundry — Workplace — Home — Dry cleaning	— Easy to clean — Dimensional stability — Pilling — Visual appearance — Absence of physical damages after cleaning — Performance preservation
Thermal (convective, radiant and contact heat)	— Insulation for heat — Feeling heat	— Compare exposed body parts — Protection from burns

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Table 3 *(continued)*

Property	Consideration	Parameters (as examples)
		— Skin burn risk prediction by thermal human simulator measurement

Table 4 — Summary on properties and wearability of Foot protection (Fire Boots)

Property	Consideration	Parameters (as examples)
Physiological	— Cold — Environment — Cold surface — Moist or wet conditions — Drops — splashes	— Cold insulation — Water penetration and water — Absorption of upper — Water resistance
Ergonomics	— Wearing comfort — Walking and standing — Orthopedic footwear — Stepping down from height (e.g. cab of truck)	— Energy absorption of seat — Region
Durability	— Wear and tear	— Strength (tensile, burst, etc) — Abrasion
Wash and care	— Ensure protective function — Wear and tear of garments	— Maintaining repellency (to water and chemical) washing away treatment and need for re-treatment — Potentiation re-activation of repellency — Chemicals used in cleaning (bleach and peroxide, starch) as they all have an effect on the heat and flame requirements
Thermal (convective, radiant and contact heat)	— Environment — Hot surfaces	— Heat insulation — Heat resistance of outsole — Flame resistance — Insulation against heat — Resistance to hot contact — Resistance to radiant heat
Mechanical hazards	— Falling objects — Compression — Sharp objects — Cut (by sharp objects or chain saw) — Slip potential	— Toecap — Metatarsal protection — Ankle protection — Penetration resistance — Cut resistance — Resistance to chain saw cutting — Cleated outsole slip resistance (coefficient of friction)

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Table 4 *(continued)*

Property	Consideration	Parameters (as examples)

See also ISO/TR 18690 SUCAM Footwear and other PPE offering foot and leg protection.

5.7 Additional evaluations for fire services

5.7.1 General

To assist any decision making process, additional evaluations, tests or assessments can be required to determine the strength or weakness of various items of PPE. For example, bench scale testing for clothing, firehoods and gloves.

Laboratory bench scale transferred energy tests are used to select suitable materials for a protective clothing ensemble. While these tests can allow ranking of garment or ensemble materials and components, the tests do not allow a complete assessment of a garment or ensemble made of the materials. Bench scale transferred energy test methods use small amounts of material, up to 150 mm × 150 mm in area, and hold the material initially flat, either in a vertical or horizontal plane. Multiple layers are used where appropriate (e.g. fire-fighting ensembles). In this case, the layer normally worn on the exterior is exposed directly to the energy source, while the layer normally worn on the inside is away from the energy source.

With the planar orientation and alignment of materials, shrinkage has little effect on the outcome of the test, unless the shrinkage is so severe as to cause holes to form in the material during the exposure to the energy source. Sagging, however, does directly affect the results, as an air gap can form or grow in size, adding an insulating effect. With the aforementioned test methods, it is possible to test seams, zippers, pockets, buttons or other closures, metal and plastic clips or other features that can be included in a complete garment such as heraldry, company logos, etc. However, it is often considered easier to evaluate these aspects together with the overall design features of a garment or ensemble that can affect the performance by testing complete garments or ensembles on a manikin. It is for this purpose the thermal manikin standard series was created (ISO 13506-1 and ISO 13506-2).

NOTE 1 Bench scale is not appropriate for RPD selection.

NOTE 2 For guidance of thermal manikin test, refer to ISO 13506-1.

NOTE 3 For guidance relating to the physiological performance of the garment refer to ISO 13506-2.

NOTE 4 For guidance relating to RPD refer to ISO 17420-5[3)].

5.7.2 Clothing

5.7.2.1 General

There are a number of garment standards for firefighter such as

— ISO 21942 station wear,

— ISO 11613 clothing for support activities associated with structural fire fighting, and

— ISO 17723-1 clothing for hazardous material incidents and CBRN.

For structural firefighting and wildland more detail is provided in the subclauses below.

3) Under preparation. Stage at the time of publication ISO/FDIS 17420-5:2021.

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5.7.2.2 Structural firefighting clothing

Additional requirements and information for structural firefighting clothing may be found in ISO 11999-3.

This protective clothing is designed to provide protection for the firefighter's upper and lower torso, neck, arms, and legs, but excluding the head, hands, and feet. It usually consists 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, or

— a series of outer and undergarments designed to be worn together.

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

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

To assist with the choice based on a user risk assessment, a number of levels of protection are included in ISO 11999-3:2015, Table 1.

The scope of ISO 11999-3 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.

Flame and thermal resistance performance of ISO 11999-3 conforms to all requirements for the respective performance level specified in ISO 11999-3:2015, Table 2. The firefighter protective clothing is classified for flame and thermal resistance performance to the lowest performance achieved for any performance property.

For the purpose of marking, each item of PPE, for which compliance with ISO 11999-3 is claimed, are labled permanently and conspicuously attached, upon which the following information is printed in letters at least 1,5 mm high:

— where practical, the pictogram given in ISO 11999-3:2015, Figure 1;

— the name, trademark, or other means of identifying or tracing back the manufacturer;

— the manufacturer's model number and/or user's specified number;

— the size.

For detailed requirements for marking, refer to ISO 11999-1.

5.7.2.3 Wildland firefighting clothing

Additional requirements and information for wildland firefighting clothing may be found in ISO 15384, *Protective clothing for firefighters — Laboratory test methods and performance requirements for wildland firefighting clothing*.

The purpose of ISO 15384 is to provide minimum performance requirements for protective clothing designed for use for extended periods during wildland firefighting activities. The minimum performance requirements and methods of test for personal protective equipment (PPE) covering the head, hands, feet, eyes and ears for wildland firefighting are covered in ISO 16073 (all parts).

NOTE ISO 16073 (all parts) is a placeholder and simply indicates the content is covered by existing standard, ISO 15384.

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Wildland firefighting involves work primarily in summer temperatures, for many hours in which the firefighter can develop high levels of metabolic heat. Loose-fitting clothing is as important as the fire resistance of materials in preventing serious burn injury. Clothing that is tight-fitting poses a danger to the wildland firefighter from radiant heat and heat stress, while, at the same time, diminishing the firefighter's ability to perform. Consequently, the protective clothing needs to be light, flexible and commensurate with the risks to which the firefighter can be exposed in order to be effective without introducing heat stress to the wearer.

The general clothing designs of wildland clothing are capable of satisfying the levels of performance specified in ISO 15384 and protect the wearer's body, except the head, hands, and feet. It may be comprised of

— a coverall,

— a protective suit provided with an interface overlap area, or

— a number of inner and/or outer garments designed to be worn together.

Ensure the clothing does not restrict the wearer in any of the movements expected to be made during wildland firefighting, for example bending, reaching, twisting, and crouching.

Closure systems, label accessories, touch and close fasteners, retro-reflective and/or fluorescent materials etc. attached to the personal protective clothing is designed to not adversely affect the clothing's performance.

All closure systems are designed to prevent the entry of burning debris.

Conformity to these requirements include an assessment by visual inspection and practical testing, such as to check sizing and correct fit by donning and doffing of the garment.

Compliance marking for each item of PPE for which compliance with ISO 15384 is claimed, the label is permanently and conspicuously attached, upon which the following information is printed in letters at least 2,0 mm high:

— designation of the type as appropriate;

— name, trademark or other means of identifying the manufacturer;

— style/model designation;

— size;

— a reference to this document, i.e. ISO 15384:2018;

— material composition.

In addition to the marking, the following information is provided to the firefighter, it is appropriate that the manufacturer gives as much information as possible on known factors of durability, especially on durability to cleaning:

— the name and address of the manufacturer or its authorized representative;

— the intended use of the product;

— a reference to this document, i.e. ISO 15384:2018;

— test to be carried out by the user before use, if necessary;

— the instructions explaining how to put on and take off the garment, if necessary;

— the limits of use (e.g. scale of temperatures);

— the storage and maintenance instructions;

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— the instructions for cleaning and/or decontamination;

— the method of drying;

— a warning against problems which might arise, if necessary;

— any illustrations, if these might be useful;

— the type of packaging suitable for transport.

5.7.3 Gloves

5.7.3.1 General

Additional requirements and information for structural firefighting gloves may be found in ISO 11999-4.

These gloves consist of a component assembly meeting the design and performance requirements of ISO 11999-4. The component assembly is permitted to be configured as a continuous or joined single layer or as continuous or joined multiple layers. The component assembly may be different for the palm, back and fingers.

5.7.3.2 Additional marking for gloves

The gloves are marked with the number of the relevant part of this International Standard, i.e. ISO 11999-4.

Where practical, the pictogram given in ISO 11999-4:2015, Figure 1 and requirements within ISO 11999-4:2015, Table 1 can be used.

In the case that the gloves have flame and thermal category rating A1, then “ISO 11999-4 Type 1” is written underneath the pictogram given in ISO 11999-1:2015, Figure 1

In the case that the gloves have flame and thermal category rating A2, then “ISO 11999-4 Type 2” is written underneath the pictogram given in ISO 11999-1:2015, Figure 1

At the bottom right of the pictogram given in ISO 11999-1, the following letter designation is used to represent the different performance category levels for gloves:

— heat and flame performance category;

— mechanical performance category;

— barrier performance category;

— ergonomic performance category.

The performance level achieved by the gloves can be found next to the letter for each performance category, for example, a_2,b_3,c_2,d_2.

Other requirements are set in various firefighter standards such as:

— ISO 16073-4 for wildland;

— ISO 18639-4 for rescue operation (both USAR and RTC).

NOTE USAR stands for Urban Search and Rescue, RTC for Road Traffic Crash incidents.

5.7.4 Helmets

Additional requirements and information for structural firefighting helmets may be found in ISO 11999-5.

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They may consist of at least the following assembled components as detailed in ISO 11999-5:

— shell;

— energy absorbing system;

— retention system.

The retention system includes a chinstrap having a minimum width of 19 mm. (Optional for Type 1 helmets, area 3a according to EN 443:2008).

— Neck protector

— Ear covers (Optional for Type 1 helmets, area 1b according to EN 443:2008).

— Face shield or goggles or both (Optional for Type 1 helmets, area 3b or area 2 according to EN 443:2008).

Where a faceshield is selected, the faceshield is attached to and tested with the helmet.

Where goggles are selected, the goggles are permitted to be unattached.

The following is an example of the marking that can be found on Type 1 ISO 11999-5 certified helmets:

Every helmet carries visible, legible and unambiguous, permanent and durable marking giving the following information:

— a reference and year of this part of ISO 11999, i.e. ISO 11999-5:2015;

— name or identification mark of the manufacturer;

— year of manufacture;

— type of helmet, e.g. Type 1;

— model of helmet (manufacturer's designation);

— size or size range (in cm).

Every helmet claimed to conform to the optional requirements of ISO 11999-5 carries visible, legible and unambiguous, permanent and durable marking on the shell or carry durable self-adhesive label, stating that the optional requirements have been complied with.

The following is an example of the marking that can be found on Type 2 Helmets certified to NFPA 1971:

The following information is printed legibly on each product label with all letters at least 1,5 mm (1/16 in.) in height:

a) manufacturer's name, identification, or designation;

b) manufacturer's address;

c) country of manufacture;

d) manufacturer's element identification number, lot number, or serial number;

e) month and year of manufacture, not coded;

f) model name, number, or design;

g) size or size range;

h) principal material(s) of construction — For principal materials of construction of helmets, generic terminology for the shell material be provided;

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i) cleaning precautions.

Compliance statements are printed legibly on the product label, example as follows for Type 2 helmets:

"THIS STRUCTURAL FIRE FIGHTING PROTECTIVE HELMET MEETS THE HELMET REQUIREMENTS OF NFPA 1971:2013 EDITION. . DO NOT REMOVE THIS LABEL."

All product label letters and figures be at least 2,5 mm (3/32 in.) in height.

For helmets only, the helmet manufacturer places a unique manufacturer's part number, the symbol of the certification organization, and the words "NFPA 1971:2013 ED." permanently on each replaceable performance critical part of the goggle lens or face shield.

5.7.5 Footwear

Additional requirements and information for footwear may be found in ISO 11999-6.

Examples of types of footwear for firefighters are:

— Type 1: Outdoor interventions, fire and wildland firefighting; no protection against penetration, no toe protection, no protection against chemical hazards.

— Type 2: All fire suppression and rescue interventions where protection against penetration and toe protection are needed, no protection against chemical hazards.

— Type 3: All fire suppression and rescue interventions where protection against penetration and toe protection are needed, including protection against chemical hazards.

For Type 1 firefighters' footwear only, the presence of a safety toe cap is denoted by the marking T. The marking code R indicates the presence of a rigid toe puff offering protection against compression forces not exceeding 500 N for protection against minor mechanical risks.

Type 3 firefighters' footwear may offer resistance to chemicals and this protection is indicated by the marking code CH

Type 3 firefighters' footwear be constructed from all-rubber (i.e. entirely vulcanized) or all polymeric (i.e. entirely moulded) footwear

The level of heat insulation properties of the product is given by the marking codes HI1, HI2 and HI3. The performance of these products will be as described in Table 5.

Table 5 — Insulation against heat: requirements for footwear degradation and thermal insulation

Performance level	Test temperature Thp (°C)	Temperature rise (°C) inside the footwear	Degradation not occur
HI1	150	<42 after 10 min	20 min exposure
HI2	250	<42 after 10 min	30 min exposure
HI3	250	<42 after 10 min	40 min exposure

Other additional protection categories are denoted by the appropriate marking codes as given in EN 15090.

Footwear be marked with the marking codes for the main protective categories as given in Table 6.

Table 6 — Marking symbols

Footwear type	Symbol	Additional categories of protection
For Type 1:	F1A	Antistatic properties
	F1PA	Penetration resistance and antistatic properties

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Table 6 *(continued)*

Footwear type	Symbol	Additional categories of protection
	F1I	Electrical insulating properties
	F1PI	Penetration resistance and electrical insulating properties
For Type 2:	F2A	Antistatic properties
	F2I	Electrical insulating properties
For Type 3:	F3A	Antistatic properties
	F3I	Electrical insulating properties

5.7.6 Respiratory Protective Devices (RPD)

When Fire service procures RPD and deploys it to firefighters, fire service will confirm whether the construction and performance of the RPD are appropriate for the firefighting activities tactics and activities by having firefighters use the RPD during firefighting training. Confirmation that the RPD does not become a hindering factor to firefighting activities will ensure risk elimination and safety. If there is mismatch between the tactic and RPD, it is necessary to secure time to implement tactic change and equipment modification.

5.7.7 Other considerations

To establish the overall performance and total cost of ownership of the PPE, consideration is given to the following:

— the training offered as part of the procurement package (including training provided by third parties);

— the quality control measures that are in place prior to the delivery;

— the quality control procedures used by subcontractors e.g. care and maintenance of the PPE;

— the requirements for cleaning and decontamination;

— the specific inspection and maintenance requirements;

— the replacement requirements relating to the life cycle of the PPE;

— the delivery lead time for standard and special sizes;

— the range of sizes available;

— the level of stock held by the supplier;

— the collection and delivery arrangements;

— the level of stock to be held within the organisation;

— how the internal distribution to the firefighters will be managed;

— how the corporate/role identity (e.g. badges on garments) can be incorporated without adversely affecting performance;

— compliance and certification;

— how the end of life and contaminated PPE will be disposed of.

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5.8 Thermal manikin testing

5.8.1 General

The thermal manikin test method (ISO 13506-1) uses a stationary, upright adult-sized manikin which is dressed in a complete garment and exposed to a laboratory simulation of a fire with controlled heat flux, duration and flame distribution. The average heat flux to the exterior of the garment is 84 kW/m2, a value similar to those used in ISO 9151, ISO 6942 (maximum level) and ISO 17492. Heat flux sensors fitted to the surface of the manikin are used to measure the heat flux variation with time and location on the manikin and to determine the total energy absorbed over the data-gathering period.

The data gathering period is selected to ensure that the total energy transferred has been completed. The information obtained can be used to assist in evaluating the performance of the garment or protective clothing ensembles under the test conditions. It can also be used to estimate the extent and nature of skin damage that a person would suffer if wearing the test garment under similar exposure conditions (ISO 13506-2).

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

5.8.2 Benefits of thermal manikin testing

The thermal manikin test is not designed to measure material properties directly, but to evaluate the interaction of material behaviour and garment design. One can compare relative material behaviour by making a series of test garments out of different materials using a common pattern.

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

The protection offered by the test specimens is evaluated through quantitative measurements and observations such as:

— enables the materials used to construct the PPE ensemble to be compared;

— enables PPE ensemble designs to be compared;

— enables PPE ensemble prototypes produced for a particular application to be evaluated;

— takes into consideration air gaps where small scale bench top heat transfer testing is limited;

— may provide more realistic results when compared to bench top heat transfer testing;

— provides the opportunity for male or female specific garments to be tested on gender specific manikins (ISO 13506 series only covers a male manikin; a number of labs have female manikins, but the shape and size has not yet been standardised).

NOTE In the revision of ISO 13506-1 it is intended to have a female form manikin and respective measurements.

5.8.3 Repeatability and variation of thermal manikin testing (and with bench scale tests)

The fire simulations are dynamic. As such, the exposure is more representative of an actual industrial accident fire than the exposures used in bench scale tests. The heat flux resulting from the exposure is neither constant nor uniform over the surface of the manikin/garment. Under these conditions, the results are expected to have more variability than carefully controlled bench scale tests. In addition, the garment is not constrained to be a flat surface but is allowed to have a natural drape on the manikin.

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The effect these variables have on a garment can be seen in several ways: ignition and burning of the garment and heraldry, sagging or shrinkage in all directions after flaming, hole generation, smoke generation and structural failure of seams. Many of these failures rarely appear in the bench scale testing of the materials because they are a result of garment design variables, interaction between material properties and design variables, construction techniques and localized exposure conditions that are more severe.

Fit of the garment on the manikin is important, thus variations in garment design and how the manikin is dressed by the operator can influence the test results. A test garment or specimen size is selected by the laboratory from the size range provided by the manufacturer to fit the laboratory's manikin.

Experience suggests that testing a garment one size larger than the standard will reduce the total energy transferred and percentage body burn by about 5 %. A number of control measures can be taken to reduce the uncertainty of measurement or improve the reproducibility of the results:

— One test laboratory is used for all testing associated with the garment procurement process. This applies to all PPE, including both male and female garments, and also same design of comparing the composition of the ensemble (determine use of under garments and if the garments are washed or not).

— The same technician will be used for the manikin dressing and testing processes for all garments being tested for comparison purposes, clear specification are given regarding the closure, how the PPE provides an overlap.

— Testing is carried out on the same day under the same conditions where practical (take pictures of PPE before and after on the manikin, take video as well of the test).

— A maximum acceptable burn prediction is determined for use as a pass or fail criteria. Determine the exposure time and the measurement time:

— for industrial/single layer garments 4 s and a 120 s measurement time is usually used under ISO, see ISO 11612 note (NFPA uses 3 s),

— for turn out gear usually 8 s and a 240 s measurement time is used.

— Testing is overseen by fire service PPE specialist where possible

— Information and how it is to be reported will utilise a common template

In the last round robin on ISO 13506-1 and ISO 13506-2, the following results of reproducibility was achieved. Further work is on-going including a revision of the standards, to further improve the reproducibility of the test method. Different garments were tested by the twelve labs that included 3 coveralls (A, B, and C) and a firefighter ensemble (D). The coveralls and firefighter ensemble were exposed for 4 s or 8 s respectively at a heat flux of 84 kW/m^2. The overall inter-laboratory test results for transferred energy and burn risk predictions (2nd and 3rd) are listed in the Table 7 below.

Table 7 — Summary of results from the Interlaboratory study on ISO 13506-1 and ISO 13506-2 in 2016

Garment	Transferred energy in kJ (according to ISO 13506-1)				Burn risk prediction in % of covered area (according to ISO 13506-2)			
	avg.	S_r	S_R	No of labs	avg.	S_r	S_R	No of labs
A	271,2	11,0	69,3	12	50,3	4,3	21,7	12

Statistical analysis according ISO 5725 was applied:

avg. is the mean of the mean total transferred energy reported by each laboratory based on the area covered by sensors.

S_r is the repeatability standard deviation (for intra-laboratory precision).

S_R is the reproducibility standard deviation (for inter-laboratory precision).

For garment D for the burn prediction one lab is excluded from the statistical assessment as an outlier.

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