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BSI Standards Publication

Personal safety — Personal protective equipment — Guidelines on compatibility testing of PPE

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Sécurité personnelle — Équipement de protection individuelle — Lignes directrices pour les essais de compatibilité des PPE

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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 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 — Personal protective Equipment*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

When, following a risk assessment, users are required to wear more than one type of personal protective equipment (PPE) to minimise the risk to their safety, health and well-being, it is important that there are no negative interactions between wearers and the PPE, between the items of PPE and between the PPE and other necessary items to the operations and processes.

Any item of PPE introduces some barrier between part(s) of the body and the environment. This barrier is essential for protection, but it is recognized that this can have unwanted side-effects on the wearer in terms of imposing additional physical effort, hindering movement, impairing sensory perception or causing discomfort. Such side-effects can reduce the efficiency and accuracy of task performance and/or discourage the user from wearing the PPE and, consequently compromising the level of protection afforded.

This document deals with the identification of issues and provides guidance for test procedures to assess the compatibility of items of PPE worn together in an ensemble and between the PPE and the operating environment and processes.

International standards for PPE and requirements and test methods are generally related to individual items of PPE and only a few, for instance ISO 10333-1, ISO 16073-2 and ISO/TS 11999-2, include the assessment of interactions with other items of PPE. For instance, the interface between PPE items at the neck, wrist and ankle needs to provide the appropriate coverage and functionality to protect the wearer from hazards.

The ultimate responsibility for protective equipment is with the wearers' employer, however there may be different levels of shared responsibility with manufacturers and/or wearers themselves. The employer is also the authority on their individual operating environment and processes

Since it is expected that a wide range of equipment may be used by personnel, it is important to note that most PPE are not approved as an ensemble. It is the responsibility of those selecting the equipment to determine if the selected PPE items are compatible and do not impair the performance of other PPE nor impede the ability of the wearer to conduct their activities safely. Given the importance of compatibility, those selecting the PPE ensemble should also be responsible for, or in close coordination with those responsible for the respiratory protection program. Suitability factors should include, but not be limited to issues such as correct use of each item of PPE, mobility, dexterity, field of view and clarity of vision. Heat stress is an issue too but it is not addressed in this document.

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Personal safety — Personal protective equipment — Guidelines on compatibility testing of PPE

1 Scope

This document describes compatibility for ensembles of personal protective equipment (PPE) to be used by personnel where operating situations and processes require more than one piece of PPE. Where there is more than one risk to health and safety, it is necessary to wear or use more than one item of PPE at the same time. Such equipment should be compatible and continue to be effective to minimise the risks.

This document includes examples of interactions between items of PPE, between PPE and the operating environment and the effects of PPE on the correct functioning of integrated sensors and electronic devices.

This document provides suggestions of test procedures to assess the effects of any interactions and identify unacceptable restrictions to safe operations.

NOTE The principles of this document are also applicable to assessment of interactions with other items in an ensemble that are necessary to the work and that are not PPE, for example cap lamps, instruments, tools.

This document is also intended to be a general guideline for writers of performance requirements standards and test methods for PPE. This document can also be used by PPE manufacturers, distributors, solutions providers, purchasers, wearers and employers as guidance in PPE design and selection.

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 374-1, *Protective gloves against dangerous chemicals and micro-organisms — Part 1: Terminology and performance requirements for chemical risks*

ISO 374-2, *Protective gloves against dangerous chemicals and micro-organisms — Part 2: Determination of resistance to penetration*

ISO 4007, *Personal protective equipment — Eye and face protection — Vocabulary*

ISO 16972, *Respiratory protective devices — Vocabulary and graphical symbols*

ISO/TR 11610, *Protective clothing — Vocabulary*

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 374-1, ISO 374-2, ISO 4007, ISO 16972, ISO/TR 11610, ISO/TR 19691 and the following apply.

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

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

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

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3.1
compatibility (of PPE)
situation where two or more elements of personal protective equipment may be used together and perform appropriately without modification, adaption or mutual interference.

3.2
electronic safety equipment
ESE
products that contain or have associated electronics that provide enhanced safety functions for wearers during use

3.3
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/TR 19591:2018, 3.95]

3.4
harm
injury or damage to the health of people, or damage to property or the environment

[SOURCE: ISO/IEC Guide 51:2014, 3.1]

3.5
hazard
potential source of *harm* (3.4)

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

3.6
interface
common boundary or interconnection between systems, equipment, use environment or human beings

3.7
latin square design
$n \times n$ array filled with n different symbols, each occurring once only in each row and once only in each column and which is used especially in the statistical design of experiments

3.8
personal protective equipment
PPE
any device or appliance designed to be worn or held by an individual for protection against one or more health and safety hazards

[SOURCE: ISO 11660-1:2008, 3.1.15]

3.9
practical performance test
test procedure with wearers of PPE ensembles moving under specified conditions

3.10
risk
combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: ISO/IEC Guide 51:2014, 3.9, modified — Note 1 to entry has been deleted.]

3.11
use conditions
conditions and processes for which an ensemble of PPE is used, including environmental and climatic circumstances

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4 Compatibility

4.1 General

Compatibility is an issue when different types or combinations of PPE in an ensemble are worn together. This may mean that each item of PPE will not be compatible with each other or may interfere with each other. This may lead to protection being compromised and/or restrictions caused by the PPE that may impede the ability to carry out the tasks. When considering compatibility of items of PPE, there are three main criteria that need to be evaluated in the interest of safety:

— Interfaces – interface between PPE need to ensure that whatever the movement of the person (see Clause 6) does not cause a movement restriction or a lack of protection.

— Performance – the PPE that is used needs to provide the same minimum protection and it is necessary to identify the weakest item of PPE in the ensemble and how this may affect the user (can he/she realise when an item of PPE is about to fail). There are different tests that exist to permit testing of a full ensemble to understand the weakest link (for example chemical, heat and flame). (See 4.4 and 4.5).

— Use condition are related not just to the expected movements of the user but also related to the length of time the PPE is intended to be worn, the spatial conditions the wearer is in, but also the climatic conditions (humidity, temperature, rain, etc.) of the use environment.

Compatibility is also an issue when PPE forms an interface with the user, the environment in which it is used and any integrated and external devices used including electronic.

While product standards can address the first two, the third remains an important consideration in the application of a dynamic risk assessment process and the safe use of PPE. These considerations need to cover the PPE and any ancillary or associated equipment, which is used in conjunction with each other for the holistic and overall protection of the user.

This document and other documents that cover at least partially compatibility, like ISO 16073-2, ISO 17723-1, ISO 18639-1, ISO/TS 11999-2, can only address the issue in general terms as guidance. The compatibility of a particular PPE ensemble can only be assessed by personnel familiar with the needs, processes and use conditions at which the tasks are carried out and set of activities. This will require an assessment of the required components of an ensemble and the potential compatibility issues, based on a risk assessment of the tasks and processes involved.

Any user, manufacturer or any test laboratory, that wishes to assess compatibility of a particular ensemble in a specific application under specific use conditions or compare the functioning of different ensembles, will need to be guided on the selection and design of appropriate test protocol(s) that ensure reproducibility of the results, but also includes hazards and risks to which the user is exposed including the use conditions in which the tasks and activities are carried out.

4.2 Combination of items of PPE known to create problems

The compatibility of the combination of PPE items should be tested. The easiest way to assess compatibility of your PPE items is to undertake an audit. The compatibility test should cover the items of PPE required and be cross-referenced against users' needs, use conditions at which the tasks are carried out, and the set of activities. A comprehensive audit will optimise user acceptance and wearing time. Table 1 identifies the interfaces known to create potential problems (identified as "x").

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Table 1 — Possible interfaces between items of PPE worn together as an ensemble

x indicates those items of an ensemble that may have compatibility issues. This is not an exhaustive list of all possible interfaces and PPE items

Item of PPE	Head/ skull physical impact protective devices	Head/ face protective devices	Eye/face protective devices	Hearing protective devices	Respiratory protective devices	Torso and arms protective devices	Hand protective devices	Foot and leg protective devices	Protective clothing	Fall arrest devices	Personal flotation devices	Electronic safety equipment
Electronic safety equipment	x	x	x	x	x	x	x	x	x	x	x	x
Personal flotation devices	x	x	x	x	x	x	x	x	x	x	x	
Fall arrest devices	x	x	x	x	x	x	x	x	x			
Protective clothing	x	x	x	x	x	x	x	x	x			
Foot and leg protective devices						x		x				
Hand protective devices						x	x					
Torso and arms protective devices	x	x	x		x	x						
Respiratory protective devices	x	x	x	x								
Hearing protective devices	x		x									
Eye/face protective devices	x	x	x									
Head/face protective devices	x											
Head/skull physical impact protective devices												

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NOTE ISO 19734 contains advice on compatibility between prescription spectacles and eye/face protection.

4.3 Multiple hazard compatibility

Establish whether a combination of PPE (for example, harness, RPD) has the potential for a negative effect on other items of PPE (for example, garment) and the protection that the other PPE needs to provide (for example, chemical, heat and flame) or presents other risks due to compression, creation of folds, etc.

4.4 Consideration of environmental compatibility

— Establish appropriate PPE compatibility in the use environment based on an environmental risk assessment to achieve a sufficient level of protection.

— In the case of using a combination of PPE in a certain use environment, establish that each item of PPE and/or combination of PPE meets the appropriate level of protection to avoid interference between items of PPE and with the use environment.

— Combinations of items of PPE should be ergonomically appropriate (not too hot, not too humid, not too heavy, etc.) for the wearer to complete the mission objective or practical performance test

4.5 Thermal protection compatibility

The thermal protective properties of a different PPE should be reviewed so that the overall protection is not disproportional for one part of the body or cause a risk of failure of critical equipment. In addition, overprotection of certain body parts would increase the thermal physiological impact of the PPE on the wearer. Wearers should also be aware of the materials of the underclothing when using protective clothing against heat and flame to consider the probable melting properties of underwear.

ISO 13506-1 and ISO 13506-2 can be used to assess heat and flame ensembles to identify any weaknesses to the full system.

4.6 Chemical protection compatibility

The chemical protective properties of the outer layer are critical in providing chemical protection for the user whether this is purely chemical or dual protection (for example, chemical in combination with heat and flame).

Repellency of chemicals, in garment such as for structural firefighting, station wear, rescue clothing, needs to be ensured after cleaning through re-impregnation. If not, the garment could absorb or let through chemicals during an incident or cleaning operations. Some chemicals (for example, solvent, oil) may have a negative impact the heat and flame protection of the garment, glove, boot, etc.

Wear and tear, and specifically abrasion, can negatively impact the chemical protection of boots, gloves and garments. Helmets may lose their robustness if exposed to chemicals (for example, solvents, acids).

Chemical protection of the ensemble needs to ensure that, if one part for example, gloves, protect against a specific chemical, set of chemicals or mixtures, then the other parts (for example, boots, garments, RPD, visor) provide smaller protection.

— ISO 17491 series can be used to assess chemical protection of ensembles against liquids, gases and particulates to identify weaknesses in the full system.

— ISO 17491-1 for gas ingress.

— ISO 17491-2 for particulates testing.

— ISO 17491-3 Liquid jet resistance.

— ISO 17491-4 (Method B) Liquid spray (high level spray) resistance.

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— ISO 17491-4 (Method A) Liquid mist (low level spray) resistance.

— ISO 17491-5 Manikin liquid spray resistance.

These tests should not be seen as being hierarchical. Tests from ISO 17491-3 through ISO 17491-5 are water-based tests at various pressures, liquid volumes, angles and surface tensions.

4.7 Mechanical protection compatibility

The mechanical protective properties of the outer layer are critical to providing protection of user. The mechanical properties can have different functions:

— Mechanical protection;

— Longevity of the PPE (maintaining the integrity of the PPE);

— Avoidance of snagging.

Therefore, the specific function of the mechanical properties is critical when assessing them as a user.

4.8 Examples of issues

4.8.1 General

It is important that each item of PPE complies with the relevant requirements in the specific product standard(s) and is selected and used in accordance with the relevant document(s) (if published). ISO 11999-1, ISO 16073-1, ISO/TR 21808 refer to PPE in general and Table 2 contains examples of standards and documents published by ISO and IEC applicable to components of an ensemble. This list is not guaranteed to be exhaustive nor current.

Table 2 — Possible interfaces between items of PPE worn together as an ensemble

PPE component	Requirements	Guidance
Head/skull physical impact protective devices	ISO 3873, ISO 11999-5, ISO 16073-5, ISO 18639-5	
Head/face protective devices	ISO 11999-9, ISO 16073-9, ISO 16602 and ISO 17723-1	
Eye/face protective devices	ISO 16321-1 to ISO 16321-3, ISO 16073-7, ISO 19818-1, IEC 61331-3	ISO 19734
Hearing protective devices	ISO 16073-8,	
Respiratory protective devices	ISO 16975-3, ISO 17420 series,	ISO/TS 16975-1 & 2
Torso and arms protective devices	ISO 11393-6	
Hand protective devices	ISO 374-1, ISO 374-2, ISO 374-4 and ISO 374-5, ISO 11393-4, ISO 11999-4, ISO 13999-1 and ISO 13999-2, ISO 15383, ISO 16073-4, ISO 18639-4, ISO 18889, ISO 21420, ISO 23407, ISO 23388	
Foot and leg protective devices	ISO 4643, ISO 11393-2, ISO 11393-5, ISO 11999-6, ISO 16073-6, ISO 17249, ISO 18639-6, ISO 20345, ISO 20346, ISO 20347, ISO 20349-1 and ISO 20349-2	ISO/TR 18690
Protective clothing	ISO 11611, ISO 11612, ISO 11613, ISO 11999-3, ISO 13688, ISO 13982-1, ISO 14116, ISO 14877, ISO 15384, ISO 15538, ISO 16073-3, ISO 16602, ISO 17723-1, ISO 18639-3, ISO 20471, ISO 21942, ISO 27065, IEC 61331-3, IEC 61482-2	ISO/TR 2801
Fall arrest protective devices	ISO 10333-1	
Personal flotation devices	ISO 12402-2 to ISO 12402-6,	ISO 12402-10

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NOTE Users of this document should check that these documents are current or if further relevant standards have been created since publication.

For some applications, there are other guidance documents related to compatibility that should be read in conjunction with this document. These include ISO 16703-2, ISO 17723-1, and ISO/TS 11999-2.

If there is an issue that donning and doffing the PPE with appropriate convenience and speed, it may require the creation of instructions on the method and, in particular, the orders of donning or doffing the PPE.

4.8.2 Examples of compatibility situations

In the following figures several examples of compatibility are given to illustrate possible issues.

Figure 1 — Respirator, head/skull impact and eye protection

a) **b)**

Figure 2 — Respirator and head/skull impact

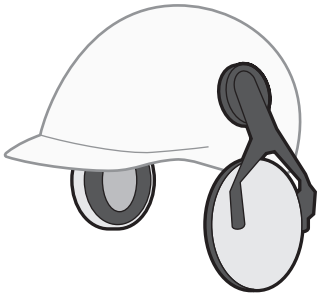

Figure 3 — Head/skull impact and hearing protection

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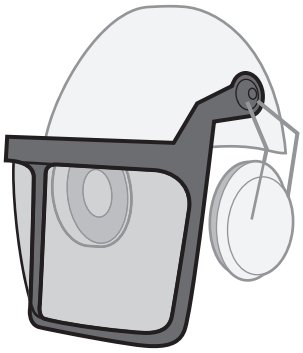

Figure 4 — Head/skull and eye/face protection

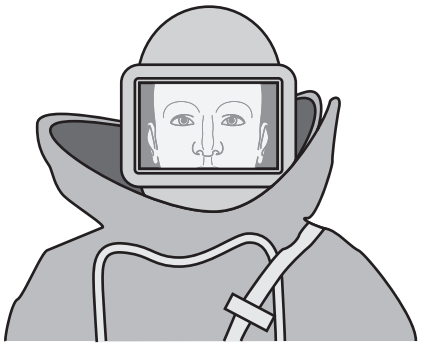

Figure 5 — Head/skull and body protection

Figure 6 — Respiratory and hearing protection

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