AEP-38
Volume 1
Final Study Draft

OPERATIONAL REQUIREMENTS, TECHNICAL SPECIFICATIONS AND EVALUATION CRITERIA FOR CBRN PROTECTIVE CLOTHING

Allied Engineering Publication

AEP-38 Volume I

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NORTH ATLANTIC TREATY ORGANIZATION

NATO STANDARDIZATION AGENCY (NSA)

NATO LETTER OF PROMULGATION

Month/Year

1. AEP-38, Volume I, Operational Requirements, Technical Specifications and Evaluation Criteria for CBRN Protective Clothing is a NATO/PfP UNCLASSIFIED publication. The agreement of nations to use this publication is recorded in….

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Juan A. MORENO
Vice Admiral, ESP (N)
Director, NATO Standardization Agency

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RECORD OF CHANGES

Change		Date Entered	Effective Date	By Whom Entered (Signature; Rank, Grade or Rate: Name or Command)
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CHAPTER 1
INTRODUCTION

SECTION I - OBJECTIVE

0101. Purpose

The purpose of this Allied Engineering Publication (AEP) is to provide the materiel acquisition community with the operational requirements, technical specifications, test methodology and acceptance criteria to be applied during the acquisition and through-life management of chemical, biological, radiological, and nuclear (CBRN) protective clothing. Equally important it will also benefit those involved in setting requirements for personal protection, and in the research and development, testing and evaluation of CBRN protective clothing.

0102. Other information

The document also provides background information and guidance to the proper selection of these requirements, specifications, test methods and criteria for specific personal protection items.

0103. Interoperability

This document sets a minimum standard for nations, in order to enhance interoperability between North Atlantic Treaty Organization (NATO) forces. AAP-6 (2006) defines interoperability as the ability of Alliance forces and, when appropriate, forces of Partner and other nations, to train, exercise and operate effectively together in the execution of assigned missions and tasks. Nations should provide at least one system that protects against the challenges defined in Allied Engineering Publication 38 (AEP-38) (Volume II).

SECTION II - APPLICABILITY

0104. User Groups

The requirements, specifications, test methods and criteria in this document are intended for use when designing and evaluating CBRN protective clothing for general combat tasks. Specialized user groups might have requirements that are not covered by this document but the selection of equipment for specialist requirements may benefit from the overall methodology defined in this document.

SECTION III - SCOPE AND LIMITATIONS

0105. Clothing

When using the expression ‘protective clothing’ all types of skin protective clothing items are referred to, including but not limited to garment(s), boots, gloves and hoods. While respiratory protection

requirements are addressed by D/103, the dermal protection requirements of AEP-38 Volume I and II should be applied to respirators and associated hood systems.

0106. Changes

New information on challenge levels, operational conditions, test methodology, and toxicological criteria, have been incorporated in AEP-38, Volume I and II including:

a. new data from the NATO Army Armaments Group / Joint Capability Group on CBRN Defence / Challenge Sub Group (CSG),

b. the changes in the operational environment for NATO, and the flexibility to adopt different configurations of IPE as the tactical situation dictates,

c. the changes in material technologies and concepts of individual protection,

d. the use of system testing as definitive qualification tool for the protection against CBRN challenges,

e. the toxicity levels described in AEP-52, and

f. detailed description of test methods against aerosol challenges, the introduction of tests against toxic industrial materials, and updated test methods for clothing properties other than CBRN and TIC protection.

0107. Limitations

During the revision process the team of experts was limited in accessing current threat information. Protection requirements are therefore based on worst-case challenge levels as calculated by CSG. Other limitations included the availability of toxicological criteria for certain challenges, and the status of scientific development.

0108. Background information

Annex A presents a more detailed description of the scope and limitations of the document.

SECTION IV - BACKGROUND HISTORY OF AEP-38

0109. First Triptych

In October 1971 an initial but incomplete NBC Protective Clothing Triptych (D/101) was issued, prepared by a panel of experts. It identified characteristics and specifications for the then existing clothing systems.

0110. 1994 Review

In 1991 changes in global power shifts and the use of CBRN agents between Iran and Iraq in the Middle East in 1990 prompted the establishment of a Working Group of Experts (WGE.5) under Panel VII to review and revise the D/101 document. This work was finalised in April 1994.

0111. STANAG 4548

The NATO Army Armaments Group (NAAG) Land Group 7 (LG7) on NBC Defense (later called the Joint Capability Group on CBRN Defence and now called the Joint CBRN Defence Working Group) decided in September 1996 to publish D/101, which is covered by STANAG 4548, to achieve a broader distribution. AEP-38 was then published in October 1998.

SECTION V - TEAM OF EXPERTS

0112. Team of Experts (ToE)

The Joint Capability Group on CBRN Defence Physical Protection Sub Group (PPSG) formed a ToE to revise the 1998 edition of AEP-38. Ten NATO countries were represented in this ToE: Belgium, Canada, Denmark, France, Germany, The Netherlands, Norway, Spain, the United Kingdom and the United States. National representatives belonged to the military, procurement and scientific communities.

0113. Scope of Activities

ToE activities started in February 2006 and lasted till February 2008. Due to the wide scope of the revisions that were needed a phase-based approach to complete all activities was decided upon. Therefore this ToE concentrated on finalizing a select number of revisions. Subjects not covered by this ToE are summarised in Annex A.

CHAPTER 2
SELECTION PROCESS

0201. Introduction

The variety in present-day clothing items, clothing materials, operational scenarios and user groups is such that no single set of requirements can be given that is entirely definitive. The following chapters describe some of the input parameters that are important when defining the requirements for CBRN protective clothing.

0202. Requirements

A step-by-step approach is needed in order to define the proper requirements for the protective clothing, starting with:

a. Identification of strategic context ……Chapter 3 Section 2

b. Identification of operational conditions……..……...Chapter 3 Section 3

This leads to identification of:

c. Environmental (test) conditions……Chapter 3 Section 3

d. Battlefield contaminants and other non-CBRN challenges……...Chapter 3 Section 3

e. User groups……...Chapter 4, Annex B

f. CBRN challenges…….Chapter 5, *Volume II (NATO CONFIDENTIAL)*

g. Necessary equipment……Chapter 6

The information thus obtained should then be translated into a selection of requirements for the clothing, in which attention also needs to be paid to:

h. Priority of the requirements……...Chapter 7 *Section 1*

i. Nature of the clothing item……...Chapter 7 *Section 2*

j. Phases in the life cycle of the clothing item……..Chapter 7 *Section 3, Annex E*

k. Whether a requirement is mandatory or desired……Chapter 8 *Section 2, Annex E*

The requirements and related test methods are described in:

l. The actual triptych…… Chapter 8 *Section 3*

m. Annexes……*Annexes F and G*

Finally, results need to be evaluated against the following criteria, whenever available:

n. Toxicological criteria…… *Chapter 5, Annex D*

o. Non-CBRN criteria……..Chapter 8 Section 3, *Annex G*

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CHAPTER 3
STRATEGIC CONTEXT AND OPERATIONAL ENVIRONMENT

SECTION I - INTRODUCTION

0301. Background

This Chapter provides a broad description of the Chemical Biological Radiological and Nuclear (CBRN) risks within the global security environment and the relationship between Force Protection principles and CBRN Defence. It does not claim to be complete and is only aimed at assisting the requirements and acquisition communities in identifying the nature of the input needed from strategic analysts.

SECTION II - STRATEGIC CONTEXT

0302. Global Instability

Whilst the Cold War has ended and the threat of Global nuclear war has receded, the world remains unstable. Current forecasts emphasise the increasingly fragmented and disparate nature of conflict. NATO nations should not only expect to confront traditional nation states of similar capability, possibly in regional conflicts, but, more commonly, will need to deal with a wide range of non-state threats. Despite sustained efforts in the field of arms control, there is firm evidence of a continuing worldwide proliferation and development of CBRN weapons and their delivery systems. At the same time, expanding urbanisation and the global distribution of nuclear, biological and chemical industries and materials increases the possibilities of the release of Toxic Industrial Materials (TIMs) into the environment as a result of neglect, natural disaster, deliberate action or collateral damage in the course of military operations.

0303. NATO Operations

NATO operations need to be planned and conducted against a background of the risk of employment of CBRN weapons and agents. Additionally, across the whole spectrum of conflict, including Peace Support Operations, there may be a risk of release of harmful substances from damaged industrial facilities or nuclear installations. Therefore, NATO forces need not only to be capable of defence against conventional attacks but also to be proficient in conducting operations over protracted periods in a CBRN environment. These latter conditions can result both from the intentional use of CBRN warfare agents and from a CBRN release other than by attack.

0304. Asymmetric Warfare

In the face of continuing NATO superiority in conventional military capabilities, adversaries may seek unconventional strategies and tactics, including the use of CBRN agents and TIMs, to reduce this advantage. Adversaries are likely to focus on perceived NATO weaknesses and vulnerabilities such as the sensitivity of public opinion to casualties and other such cultural, legal and ethical constraints.

Attempts may be made to employ the threat of CBRN use as part of an information campaign to constrain Alliance or Coalition Rules of Engagement and to detach wavering Alliance / Coalition members. Adversaries may have scant regard for international law and ethical standards, allowing them to engage in the deliberate targeting of civilian populations, including expatriates, or the deliberate positioning of military assets amongst civilian infrastructure or cultural sites.

0305. The NATO CBRN Defence Requirement

CBRN Defence should not be an end in itself but should permit operations to continue with a minimum of adverse effects on both personnel and nature of the operation.

SECTION III - OPERATIONAL ENVIRONMENT IN AEP-38

0306. Operational environment in AEP-38

1. This AEP has been revised to take into consideration not only conventional NATO operations, with forces operating for extended periods of time in contaminated environments, but also operations conducted in environments characterized by fluid, non-linear battlefields and the use of unconventional force by irregular adversaries. With CBRN Defence improvements in the areas of detection / identification / monitoring, warning and reporting, physical protection, hazard management, and medical countermeasures, commanders nowadays have options such as

   a. to continue the operation unmodified,

   b. to continue the operation but in a modified form to reduce exposure to identified hazards, and

   c. to cease the operation and withdraw forces, if hazards are too severe.

2. The wider range of options affects the nature of the CBRN protective equipment chosen.

0307. Operational conditions

1. Commanders need to reconcile the vulnerability of their forces to CBRN hazards with the concomitant restrictions imposed by the use of protective measures, and the need to pursue the mission. Threat, vulnerability, and risk analysis procedures, outlined in ATP-3.8.1 Volume 1, assist commanders in determining the defensive posture to be adopted, in order to reduce degradation while improving operational efficiency. All analysis will change with time and as the situation changes, and will need to be reviewed regularly. Factors that need to be considered are:

   a. Local CBRN Threat. Local commanders typically have the authority to determine the appropriate level of CBRN physical protection, based on their assessment of local conditions, the required associated protective measures, and the operational imperatives of the local situation. The CBRN test parameters chosen for evaluation of the clothing protective properties are contained in AEP-38 Volume II.

   b. Operational Task. The priority and urgency afforded to the operational task and an assessment of the risk is necessary to ensure that over-protection does not hinder effective and timely completion of the mission. In particular, greater risks are typically accepted in combat operations than in peace support operations.

c. Location of Personnel. While the location and function of personnel will affect their chances of being targeted with CBRN weapons or devices, the physical protection afforded by their location will often dictate their defensive posture. For example, personnel under cover, and unlikely to be exposed to surface contamination, may not need to wear CBRN overboots or gloves, while those in Collective Protection (COLPRO) in a toxic free environment should not need to wear full individual protective equipment (IPE).

d. Nature of Work Undertaken. The nature of work to be completed will have an effect on the time on task for the user. Many variables contribute to increasing and or decreasing a user's time on task, such as the threat, acceptable risk, temperature, relative humidity, solar (radiation) load, and resistance to fire, to name a few examples. STANAG 4370 / AECTP 200 is one of many publications that should be used. The chosen test conditions are presented in AEP-38 Volume II.

e. Duration. The duration of operations in a CBRN environment will depend on the whole CBRN capability of the force and/or limitations and not just on one system. The time spent wearing the IPE might be much longer than the time that protection is actually needed. For example, a cloud of biological agent may pass by quite quickly at any moment during the operation. On the other hand, it may be possible and/or desirable to change out equipment in the middle of a task (see f. below). The chosen test durations against which equipment will be evaluated are presented in AEP-38 Volume II.

f. Equipment. STANAG 2352 does not specify the quantities of equipment necessary to fulfil the task. A change of suit or other protective equipment like gloves, boots, and canisters is thus possible, which implies that protection must be guaranteed for a defined period, but that it is open to the nations whether this protection is achieved by one or more sets of Individual Protective Equipment (IPE). This option then has to be included in the doctrine / concept of operations.

Note: It is important to understand that changing the CBRN outfit with a fresh one does not reduce the already accumulated dosage or dose in/on the body to zero.

g. Non-CBRN challenges. Battlefield contaminants that personnel can be exposed to may affect the protection level offered by the IPE and thus the duration of protection. The level of contamination depends on the nature of work undertaken. The test parameters are described in Annex F. Location and nature of work also affect the environmental, physical and mechanical challenges to the clothing. These are defined in Section 8.3 (the Triptych), and Annex G.

2. Chapter 4 offers an example of an analysis for various user groups.

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CHAPTER 4
USER GROUPS

SECTION I - USER GROUPS AND TASKS

0401. Introduction

Although nations should provide at least one system / set of systems that protects against the challenges defined in this AEP-38 Volume II, certain user groups might need special (extra) requirements for their protective equipment. This chapter offers guidance in the selection process for these user groups.

0402. Tasks

The variety of tasks or the kind of missions undertaken by NATO personnel (AJP-3.8) is too varied to allow highly specific representative tasks or capabilities to be defined. However, generalized representative major user groups have been identified:

a. combat soldier, dismounted,
b. combat soldier, mounted (vehicle),
c. special operations,
d. fast jet pilot and other closed cockpit personnel,
e. helicopter pilot and other open cockpit personnel,
f. aircraft rear crew,
g. air force ground crew,
h. amphibious / maritime personnel,
i. CBRN operational specialist personnel (e.g. decontamination),
j. logistics personnel,
k. medical personnel,
l. command/staff roles, and
m. EOD and related tasks.

It should be noted that this list does not encompass all the roles that are undertaken within NATO. Certain specialist small user groups will have requirements not covered specifically in this document.

0403. Challenges

When determining the requirements for IPE for a user group, the challenges that are likely to be encountered by the specific user group have to be established, see point 0307. Challenges related to climate are generally common for all user groups but other challenges that may vary include exposure to

CBRN agents, TIMS, flame/fire, water, high wind speeds (from transport in open vehicles or from rotors) and battlefield contaminants.

0404. Analysis

If dedicated clothing is needed, a detailed analysis is necessary to determine the magnitude of the challenges identified in the operational analysis, their mutual interaction and their impact on the requirements for the clothing item. An example of such an analysis regarding CBRN threats, which can help the user in the analysis, is presented in Annex B.

SECTION II - SELECTION OF EQUIPMENT FOR USER GROUPS

0405. Selection parameters for IPE

1. Selection of any form of IPE and its required protection level must be balanced against the needs of the specific user group and will depend on numerous considerations such as:

   a. the duration of the task,

   b. the durability required,

   c. physical effort necessary to complete the task,

   d. acceptable heat stress levels,

   e. the need for specialized equipment such as self-contained breathing apparatus,

   f. the likelihood, duration, and challenge level of an expected CBRN incident,

   g. doctrine, which outlines the protective measures for soldiers at the moment of the CBRN-incident,

   h. risk, vulnerability and threat analysis, and the acceptable risk a nation will take, and

   i. a nation's CBRN Defence program, (see points 307 and 404, and Annex B.)

2. Note that to improve readability of the document, it was chosen not to reflect all these variables in the Triptych part (Chapter 8) beforehand. It is up to the user of this document to check and implement the applicability of the aforementioned selection parameters when defining the requirements.

0406. Combat soldier, dismounted

Dismounted combat soldiers are likely to have the highest physiological stress and greatest exposure to the environment, and also require the greatest degree of flexibility when wearing IPE. Their IPE should integrate with a wide range of associated personal equipment, weapons, communications, optics and vehicles. Tasks will vary from low to high intensity operations in all types of climates. Therefore, the IPE should allow usage in a wide range of environments whilst offering protection against a wide threat range.

0407. Combat soldier, mounted

The major differences in protective requirements between mounted personnel (e.g., armour, infantry, artillery, and logistics) and the dismounted soldier are driven by the constraints, hazards, and capabilities of the vehicle, and not by the operational CBRN environment. Within vehicles, mounted personnel face a reduced threat of being exposed to a liquid chemical hazard. However, the risk and threat rises when they exit their vehicle. By the nature of their surroundings, vehicles are subjected to severe fire / flame hazards, greater heat stress, and space constraints. However, mounted personnel may have COLPRO and cooling systems, which mitigate these constraints. Personnel in open vehicles might encounter CBRN challenges at elevated wind speeds, which their IPE may not have been designed against.

0408. Special operations

Special Forces may need to operate in a CBRN contaminated environment. The need for high flexibility, mobility, and low thermal burden IPE requires specialized protective concepts.

0409. Fast jet pilot and other closed cockpit personnel

In contrast to dismounted personnel, aircrew should be inside their aircraft most of the time. While entering or exiting the aircraft, aircrew may be exposed to vapour, liquid and/or aerosol challenges. Yet, inside the aircraft the contact hazard will be minimal as long as the airframe is entered initially by clean ground service and aircrew. Their clothing system must provide adequate protection for mission durations across a wide range of operations. Typically, respiratory protection is provided by powered air purifying respirators (PAPR) or self-contained breathing apparatus (SCBA), whose integration with protective clothing must be specifically addressed.

0410. Helicopter pilot and other open cockpit personnel

The situation of personnel in an open cockpit is similar to that of closed cockpit personnel, but with a potentially increased risk of exposure to vapour and aerosol challenges and high air flows during operational flights. Tactical helicopter personnel are often co-located with ground combat units, and consequently may be subject to the same level of hazards as either mounted or dismounted soldiers.

0411. Aircraft rear crew

Aircraft rear crew may experience the same and increased CBRN agent effects as personnel in open vehicles due to higher wind speeds.

0412. Air force ground crew

Unlike the dismounted soldier, ground crews may have the ability to use overhead protection in the conduct of their duties. However, like mounted and dismounted soldiers, their IPE would need to be resistant to static electricity, petroleum lubricant, and jet fuel, to name a few vital considerations.

0413. Amphibious / Maritime personnel

Naval personnel need most if not all the same considerations for IPE as ground force personnel. In addition, they are very concerned that their IPE maintains buoyancy as much as possible and hardly absorbs water. Yet another main difference is that most naval vessels have a citadel that when activated provides pressurized COLPRO protection. Three distinct categories must be considered for shipboard personnel: personnel on weather decks (potentially exposed to the full range of hazards), personnel within the ship's structure but ex-citadel (potentially exposed to vapour/aerosol hazards only), and personnel within the citadel (no exposure when the citadel is activated). All maritime personnel are liable for action damage duties including fire fighting, so their clothing must meet minimum standards of heat protection and flame retardance.

0414. CBRN operational specialist personnel (e.g. decontamination)

The decontamination process often involves intensive work applying decontamination solutions using high-pressure sprays. Therefore, equipment must have excellent protection against high levels of toxic agent, water and decontamination solution in vapour, liquid, and aerosol form. Total endurance time for the operators will depend on many factors such as weather and temperature, decontamination solutions and the level of decontamination required, as well as following work to rest tables. To balance protection under varying threat conditions against the physiological stress imposed by CBRN environments, nations may elect to provide waterproof/impermeable IPE for this task.

CBRN operational specialists not involved in decontamination tasks can be expected to need the same level of protection as the dismounted combat soldier.

0415. Logistics personnel

Because of the self-defence requirement that derives from operating on the non-linear battlefield, all support personnel require the same levels of protection as dismounted combat soldiers.

0416. Medical personnel

Medical personnel will be active on and off the actual battlefield. They will require various levels of protection, up to the same level of protection as dismounted soldiers.

0417. Command and staff roles

Command and staff personnel will require the same level of protection as dismounted soldiers.

0418. EOD and related tasks

Gear intended to protect against explosion is burdensome and heavy, however the many layers offer some additional CBRN protection. IPE for this application will likely be specialized.

CHAPTER 5
CHALLENGES AND TOXICOLOGICAL CRITERIA

SECTION I - CHEMICAL AND BIOLOGICAL CHALLENGE LEVELS

0501. Sources and challenge levels

1. Chemical and biological challenge levels are presented in AEP-38 Volume II, table 1-4 (NATO CONFIDENTIAL). They were derived from CSG reports:

   a. Chemical warfare agents. CSG report from September 2001.

   b. Toxic Industrial Materials. List of 17 TIC compounds presented by the CSG Chairman at the JCG CBRN meeting in February 2007. No other TIMs are considered.

   c. Biological warfare agents. Report presented at the JCG CBRN meeting in September 2007.

2. Two exposure levels have been defined, an Essential Challenge Level (P95) and a Desired Challenge Level (P99).

3. AEP-38 Volume II represents a more detailed explanation of the CSG calculations and methodology, and a translation of the challenge levels into concentration, time, particle size, and other parameters, to be used in the evaluation of the protective clothing.

0502. Limitations

The CSG does not define the current and/or expected threat. They only calculate the contamination that would occur after an attack, regardless of the likelihood of such an attack.

SECTION II - RADIOLOGICAL AND NUCLEAR CHALLENGE LEVELS

0503. Sources and challenge levels

1. Radiological and nuclear challenge levels are presented in AEP-38 Volume II. They are derived from STANAG 2473 and Radiological Aerosol Challenge Levels produced by the ToE of Nuclear Protection Sub Group (NPSG) in 2004.

2. The most relevant radiological scenarios for NATO are represented by both an outdoor and an indoor release scenario for a β-radiation source (strontium) and for a γ-radiation source (cesium).

3. AEP-38 Volume II also gives a translation of the RN challenge levels into concentration, time, particle size, and other parameters, that can be used for evaluation.

0504. Limitations

Only a limited set of scenarios have been used in the calculation of challenge levels. No threat information was available.

SECTION III - TOXICOLOGICAL CRITERIA

0505. Skin (dermal) exposure and pass/fail criteria

The level of skin exposure is determined by the combination of the level and duration of the outside challenge and the degree of protection offered by IPE. The level of actual skin exposure determines the ultimate effect of the agent. It should be noted that protective clothing pass/fail criteria for CBRN agents and TIMs are independent of challenge levels and test methodology. The only determining factor is the highest level of accepted effects on the contaminated person. This level can be used as pass/fail criterion for the clothing.

0506. Data

All toxicological data are presented in Annex D.

0507. Chemical warfare agents

1. The effect levels for classic CWAs have been defined in AEP-52 as:
   a. negligible,
   b. significant decrement in military performance, and
   c. danger of death.

2. In general, if any liquid nerve agent reached the skin, lethal dosages could be delivered, and if liquid vesicant reached the skin, significant blistering/ulceration would take place. Therefore dermal protection is generally designed to prevent liquid penetration of persistent agents, and it is only the vapour dosage delivered to the skin that is relevant (delivered by vapours, aerosols or from evaporating liquid drops). The values provided by AEP-52 for vapour toxicity of CWAs can be used directly. The permissible values (criteria) for vapour exposure to the skin have been taken as those causing negligible effects.

3. There is no toxicological information that relates an aerosol dosage to toxicological effects to the skin. Further, aerosols may also deliver a significant vapour dosage as the CWA evaporates. In the absence of alternate information, volatile liquid aerosols are treated here as equivalent to vapours, while non-volatile liquid or solid aerosol are treated as liquids deposited on the skin.

0508. TIMs

Inhalation toxicity is one of the properties common to the TICs mentioned in the CSG list, but some also pose a hazard to the skin. Skin toxicity values however are largely unknown, so criteria have been estimated based on total body toxicity. For reason of comparison toxicity data via other entry routes have been presented as well in Annex D.

0509. Biological agents

No toxicological criteria for exposure of intact skin are available for biological agents. A potential risk exists when the skin is damaged, but no toxicological data exists for this exposure either. The hazard from re-aerosolisation and/or subsequent ingestion should be considered when considering protective requirements. For these hazards respiratory or ingestion exposure criteria apply.

0510. Radiological and Nuclear agents

1. Only substances that emit β- and γ-radiation are considered as potential dermal radiological threat. Substances emitting α-radiation may pose a hazard to damaged skin. The toxicological level applicable as threshold for skin contamination can be derived from STANAG 2473 (2).

2. Also the hazard from re-aerosolisation and/or subsequent ingestion should be considered when considering protective requirements. For these hazards respiratory or ingestion exposure criteria apply.

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CHAPTER 6
EQUIPMENT

SECTION I - OVERVIEW

0601. Types of equipment

This section gives a brief description of the various examples of dermal protective IPE currently in use and a description of trends, both as of the end of 2007. This chapter does not claim to be complete, nor does it give prescriptive design requirements. New materials and systems are continuously being developed, like semi-permeable membranes, materials based on nanotechnology, and self-detoxifying materials, as well as new concepts of use, such as CBRN protective combat uniforms designed for extended, routine wear, and improved designs for lower physiological burden.

0602. Protection

The protection offered by IPE is due to a combination of

a. the protective properties of material(s),

b. the design of the equipment,

c. the manufacturing process, and

d. the intended role for the equipment.

0603. Materials

Materials/fabrics can be air permeable, selectively (moisture vapour) permeable, or air impermeable. Different materials can be layered or laminated in order to provide multiple protective functionalities. Some new materials include a reactive component, which is aimed at deactivation of CBRN agents (self-detoxification).

a. Air permeable. Air permeable materials require an adsorbing material to afford dermal protection against toxic vapours. In many cases, liquid repellence is provided by an outer layer, resistance to permeation by vapours and/or liquids by a middle layer, with comfort to the skin and structural support to the middle layer by an inner comfort layer. Current air permeable materials all contain activated carbon in the middle layer and show medium to low protection against high volatility TIC vapours. Air permeable materials are more susceptible to penetration of liquids, and typically materials used at pressure points (knees, elbows) are reinforced. Air permeable materials currently provide greater comfort and lower physiological burden for the user compared to other types of material, allowing operations to be conducted in many climates.

b. Selectively permeable. Selectively permeable materials (membranes) are based on the concept of permitting some molecules to penetrate through the material while blocking others. The selection process is often (but not always) size-based; the transmission of very

small molecules, especially water vapour, is allowed, while larger molecules like the classical chemical warfare agents are blocked. Size exclusion based membranes may not be protective against small TICs. These materials also tend to prevent bulk liquid transfer and aerosol penetration. Water vapour transmission has a limited cooling effect on the wearer. Clothing constructed from these materials can often not be worn for long-term operations without additional cooling or other comfort enhancing measures.

c. Air and moisture vapour impermeable. Air and moisture vapour impermeable materials do not allow the transmission of any water molecules through the materials. Hence clothing made from these materials also cannot be worn for long periods of time without additional cooling or other comfort enhancing measures. The materials in general prevent penetration to a very high degree.

0604. Suits

1. The main protection of the skin is by the suit. Suits can be made from one or more parts, with or without integrated hood, gloves, boots, and respiratory protection. Protective performance is determined both by the protective properties of the material and the design of the suit, as well as the seal achievable with other equipment. The relative contribution of each varies.

a. Air permeable. Historically, the majority of CBRN suits are made from air permeable carbon-containing materials, so that operations can be conducted in many climates. Current suit designs mostly involve one and two-piece suits, with attached hood but separate gloves, boots and respirator.

b. Selectively permeable. The design of selectively permeable suits plays a dominant role in the protective performance of the suit, because penetration through openings is the major or single skin exposure process.

c. Air and moisture vapour impermeable. Due to the protection offered by suits made from air and moisture vapour impermeable materials, these suits are commonly used during decontamination and for protection against TICs. Totally encapsulating suits made from these materials can offer the highest degree of protection available, albeit for a short duration, because of the thermo physiological burden.

2. Design of the equipment affects not only protection, but also human factors (e.g. ease of donning and doffing, wearability), decontaminability, and integration and system compatibility.

3. The design considerations given for the suit also apply to other clothing items.

0605. Protective underwear

Protective underwear or next-to-skin designs are usually worn under the combat uniform. These systems are commonly manufactured from air permeable (carbon containing) materials. Close skin contact reduces the air flows through the material, potentially reducing the amount of carbon needed or increasing the permissible air permeability and thus reducing the physiological burden imparted by the material. The degree of stretch and stiffness of the material determines the freedom of movement and comfort.

0606. Poncho

Ponchos are commonly made from low cost air impermeable materials, and are generally intended for short-term use, offering temporary additional liquid protection against water and CBRN agents. Ponchos also offer some local protection against aerosol and vapour, but a poncho alone will not offer full protection against these challenges.

0607. Gloves

CBRN gloves are designed to protect the hands and wrists. Given the repeated donning and doffing, high level of wear and tear, and the likelihood of exposure to liquid challenges, gloves are traditionally made from air impermeable, polymeric materials resistant to tearing. To retain dexterity, new gloves are being developed from membranes, leather(like), and / or carbon containing materials, in combination with air impermeable materials for contact points. Gloves can be worn alone or in combination with an inner and / or outer shell glove system.

0608. Boots

Boots are used to protect the feet and ankles. They are manufactured from rugged impermeable materials because they may be in direct contact with liquid agents. Typically, overboots are worn over footwear. However, with new innovative materials it is expected that CBRN protection will be integrated into regular combat footwear.

0609. Socks

Another method to protect feet is to wear CBRN socks inside footwear. Wearing socks instead of overboots may increase comfort, but the capability of the combat boot to withstand appropriate contamination levels and decontamination must be assured. Socks are susceptible to wear and tear, even to a higher degree than the materials used in protective (under)garments.

0610. Other devices

1. Although not designed to protect skin from CBRN agents, other equipment can influence the performance of IPE as well.

    a. Extra clothing layers, such as load carriage systems and combat gloves and boots, all contribute to reducing the flow of wind through the clothing and provide a physical barrier, resulting in reduced agent penetration.

    b. Conversely, these systems do create weak points at pressure points and closures of the IPE, potentially increasing agent penetration.

    c. The physiological burden is usually increased by the addition of these devices.

2. Protective materials and IPE should be tested and evaluated in combination with any of the above mentioned devices commonly worn with the garment, to ensure they do not impact on IPE performance.

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CHAPTER 7
SELECTION OF REQUIREMENTS AND TEST METHODS

SECTION I - PRIORITY OF REQUIREMENTS

0701. Introduction

1. To enable NATO interoperability in a CBRN environment, each nation should field at least one general-purpose protective system (or combination of protective systems) that complies with Chapter 8 (Operational Requirements) in order to achieve national desired protection levels, Chapter 1, 103, and Chapter 3, 307.

2. Even if one general-purpose system is fielded, prioritization of requirements is needed. To the extent possible, this chapter defines and summarises the minimum level of tests that need to be conducted.

3. The complete Triptych is presented in Chapter 8, Section 8.3.

4. Selection of equipment and requirements for specialized tasks or operational environments is possible only if more systems are fielded. This must be based on individual requirements, be they national or user group based.

0702. Priority of requirements and applicability of tests

1. Protection relies on both the protection offered by the material(s) from which the equipment is made, and the protection offered by the design and manufacturing of the equipment. Definitive tests for both the properties and the approval of protective clothing systems are tests at the system level, whenever

   a. a validated test on system level is available for the clothing property under investigation, and

   b. system testing has an added value over swatch (material) testing.

2. For most properties swatch tests are also included because these can be applied in various phases of the life cycle of the clothing. Both system level and swatch tests are required for full evaluation and understanding of a system's performance.

3. Manufacturing precision and consistency is essential and must be routinely evaluated.

0703. Selection process

The selection process for requirements and test methods is based on the selection process for IPE, described in Chapter 4, and the nature of the clothing item, described in Chapter 6. Based on this process tests can be selected from Chapter 8 that are applicable to the clothing item to be tested.

SECTION II - TEST SELECTION AS DETERMINED BY CLOTHING ARTICLE

0704. Introduction

1. The essential function of CBRN protective clothing is to provide protection against toxic compounds and materials that NATO forces may encounter during operations. The protective properties against CWA challenges must be assessed by whole system testing. This test must be performed with CWA or accepted simulant challenges (vapour test is mandatory).

2. Protection against various other challenges –including non-CBRN related- must be determined either by system or swatch testing. Not all of these tests are mandatory.

3. Although not explicitly mentioned per item, all items shall be durable and comfortable enough to withstand normal use and allow for all operations envisioned. Implicitly, related non-CBRN evaluations are to be taken into account as well.

0705. Suits and related clothing items

1. Air permeable. The existence of (convective) air flow through the suit material(s) is one of the major characteristics of suits made from air permeable materials.

   a. The higher susceptibility for agent penetration under incident wind conditions should be reflected in the requirements. Priority must therefore be given to agent penetration swatch (or whole system) tests under incident wind situations.

   b. For selection/qualification CWA vapour protection must be evaluated using a system test. However, CWA vapour swatch tests are useful during this and other phases for reasons such as screening, ranking, background information, production monitoring, or economy. For all other challenges, system or swatch tests are needed.

   c. Special attention should be given to pressure points (knee, elbow) where the resistance against liquid contamination under pressure should be evaluated with the actual combination of layers at that design point, the expected contamination drop size and density, and relevant pressure duration.

   d. Agent tests under diffusive conditions, without pressure, are less challenging and therefore of less importance.

   e. The existence of air flow enhances comfort and allows for easy water vapour transport through the materials. Comfort properties can be evaluated on either system or on swatch level; however for selection/qualification purposes system level tests (either human or mannequin) are preferred.

   f. Although the suit materials allow for easier water vapour transport, sweating will still result in high humidity inside suits.

2. Selectively Permeable and Impermeable. Air flow through the material is absent in both selectively permeable and impermeable materials and parts of air permeable suits worn close to the skin (e.g. top of shoulders).

   a. During whole system tests incident wind situations should be applied.

b. During swatch testing diffusive flow conditions can be applied for these materials. Some of these materials might show enhanced penetration when challenged under pressure conditions.

c. Since comfort is in general expected to be lower in suits made from these materials, tests related to comfort properties are of special importance, both on swatch and system level.

d. The quick rise in humidity expected inside suits made from these materials should be reflected in the test conditions.

0706. Protective underwear

Evaluation of the undergarments on a system level should be performed in combination with daily wear clothing or other protective equipment that is always worn with the undergarment, e.g. Explosion Ordinance Disposal (EOD) suit. Swatch testing should mimic the actual wear situation as closely as possible. Only agent tests under diffusive flow conditions are needed when no flow through the materials exists (worn close to the skin), otherwise for air permeable materials testing under incident wind conditions might also be needed. These evaluations should also be performed after wear and tear and at high humidity and sweat load.

Note: It should be noted that no standard method mimicking the actual air flow through the material in this situation is given in this document.

0707. Poncho

1. Evaluation of the poncho should reveal whether liquid chemical agent penetrates as liquid. Protection against vapour or aerosols –which should not be expected from the poncho itself– can only be evaluated with whole systems in the actual wearing combination.

2. Test conditions should reflect the short time use of this IPE, both in the duration of tests and in providing limited or no priority of requirements aimed at long time use, like laundering and wear and tear.

0708. Gloves

1. Gloves are usually worn close to the skin, and even gloves made from air permeable materials need only be evaluated under diffusive flow conditions, unless the design clearly gives rise to convective flows. Special attention should be paid to penetration at pressure points, for those materials that show enhanced penetration under pressure conditions, and to challenges with larger droplets. Especially for liquid tests under pressure conditions not only the level of protection after a predetermined period (AEP-38 Volume II) should be part of the evaluation but also the actual protection time.

2. High emphasis should be placed on requirements involving touch and dexterity, wear and tear, especially at seams and thinner parts (for example in between the fingers, tearing at finger tops), both in physical stability and agent penetration tests.

3. Humidity inside gloves is in general high and this should be reflected in the test conditions. Even tests using water or sweat soaked inner gloves might be considered.

0709. Boots

The same requirements as those for gloves apply, except for dexterity and touch. Tests using severe liquid challenges under pressure conditions and durability tests are of even higher importance than with gloves.

0710. Socks

1. Evaluation of the socks should be performed on the actual combination with the designated footwear. Similar considerations as those for protective underwear can be used for socks, keeping in mind that sweating will occur, even in moderately hot or cold environments. Less emphasis can be placed on comfort parameters like moisture vapour transmission, if the socks are to be worn in footwear not having these capabilities.

2. Evaluations should also be performed after wear and tear at high humidity and sweat load.

SECTION III - TEST SELECTION AS DETERMINED BY LIFE CYCLE PHASE

0711. Phases in the life cycle

Five major phases in the life cycle of the clothing item have been distinguished:

a. Research and Development (R&D),

b. selection/qualification (evaluating performance while new, and after use and/or decontamination),

c. pre-production (validation of selection and manufacturability),

d. production control, and

e. storage (assessment of shelf-life).

Note. The requirements presented in the Triptych are aimed at the selection/qualification phase. Guidance for the five phases is presented in Annex E.

CHAPTER 8 OPERATIONAL REQUIREMENTS, TECHNICAL SPECIFICATIONS, EVALUATION TESTS

SECTION I - INTRODUCTION

0801. Organization

In this Triptych section the specifications are presented in three columns: “Operational requirements”, “Explanation, Technical specification and criteria” and “Tests”. More background explanatory information is presented compared to the previous edition of the Triptych.

0802. Challenge conditions and toxicological criteria

Challenge conditions are presented in AEP-38 Volume II, Section V (NATO CONFIDENTIAL), for general-purpose use, and also the asymmetric operational environment. These are translated into test conditions in AEP-38 Volume II, Section VI (NATO CONFIDENTIAL). Toxicological criteria are given in Annex D.

0803. Test methods

Details of the test methods to determine the CBRN protective properties of the clothing are described in Annex F. Details of non-CBRN test methods are given in Annex G.

SECTION II - MANDATORY AND DESIRED TESTS

0804. Mandatory and desired tests

The TRIPTYCH indicates which tests are mandatory and which are not. This is aimed at the **selection/qualification process for general-purpose protective clothing**. Guidance regarding the other life cycle phases is presented in Annex E.

SECTION III - TRIPTYCH

0805. Abbreviations

1. Explanation of the abbreviations

   MS = mandatory system test MM = mandatory material (swatch) test

   DS = desirable system test DM = desirable material (swatch) test

2. Whenever a test is mandatory the requirement is mandatory as well.

Table 8-1: Triptych

Operational requirements	Explanation, technical specifications and criteria	Test
1. PROTECTION		
1.1 Whole system protection		
The clothing system including auxiliary equipment shall be capable of protecting the skin of the whole body continuously against CBRN agents and (as desired) TICs during the performance of typical operational activities.	The system shall not permit the penetration, permeation or leakage of physiologically significant quantities of challenge agents, as described in AEP-38 Volume II and Annex F. Toxicological criteria are presented in Annex D. The system consists of the garment(s) and all auxiliary equipment. Footwear, gloves, hood and respirator (only in terms of dermal protection) are commonly used auxiliary equipment, but any other auxiliary equipment commonly worn with the garment shall be included as well. Simulants for warfare agents can be used in the test, provided they show behaviour similar to warfare agents towards the clothing system. This includes all materials used in the clothing system, which shall have been tested separately using both the stimulant and the warfare agent.	**MS**. A vapour test simulating chemical exposure is required on the system according to the test procedure described in Annex F.2. **DS**. Additional aerosol and/or liquid tests are desirable. Suggested methods are presented in Annex F.3.
1.2 Material chemical agent protection		
The clothing materials (fabrics) shall protect against all practical field challenges (liquid, vapour and aerosol) of chemical agents under normal operational conditions.	Material tests cannot be used as a sole qualification tool for protective clothing systems because the results are not directly comparable to whole system performance. Whenever applicable, swatch tests shall include swatches containing seams and closures. Challenge conditions are described in AEP-38 Volume II. For all the methods in this section, the data in Annex D can be used as a benchmark for the penetration dosage.	
1.2.i CWA vapour protection	Protective clothing materials shall protect against HD and GD vapours under incident wind conditions (also covered by 1.1). Air impermeable materials can be expected to offer sufficient protection when they protect against neat liquid agents.	**DM**. Vapour tests against HD and GD are described in Annex F.4. For guidance on testing underwear and socks see Section 7.2.
1.2.ii TIC vapour protection	Protective clothing materials should protect against TIC vapour under incident wind conditions.	**DM**. Vapour tests against TICs are described in Annex F.4

Operational requirements	Explanation, technical specifications and criteria	Test
1.2.iii Liquid CWA protection	All clothing material combinations, including seams and closures, shall protect against liquid HD, GD and VX under incident wind conditions, *and* in the absence of air flow through the materials. The liquids HD and GD can be used both in neat and thickened form. The drops can be applied either at terminal velocity (falling drops, resembling on-target attack) or laid (touch-off or spray, resembling brushing against contaminated vegetation). On materials which are used in parts of the clothing system to which pressure is applied when in use, respectively 20 kPa (for buttocks) and 200 kPa (for knees, elbows) pressure shall be applied on the drops after application on these materials.	**MM**. Liquid tests are required according to Annex F.5 to F.8. For guidance on kind of test see Section 7.2. Different tests consist of all combinations of: -diffusive or incident wind -neat or thickened agent for HD and GD -application: touch-off or fallen - with pressure applied after contamination: for thickened agents only. Next to these seams, seals and closures shall also be tested with a laid droplet test using neat VX.
1.2.iv Liquid CWA aerosol protection	Clothing materials should protect against liquid chemical aerosols under incident wind conditions. Air impermeable materials can be expected to offer sufficient protection when they have been shown to protect against neat liquid agents. Simulants for liquid chemical aerosols can be used in this test provided they show similar volatility, penetration behaviour and particle size distribution as the chemical agent.	**DM**. A liquid aerosol test is described in Annex F.9.
1.2.v Solid CWA aerosol protection	Clothing materials should protect against solid aerosols under incident wind conditions. Air impermeable materials can be expected to offer sufficient protection when they have been shown to protect against the agents in liquid form. Simulants for solid chemical aerosols can be used in this test provided they show similar volatility (also in case of solid aerosols impregnated with CWAs), penetration behaviour and particle size distribution as the chemical agent.	**DM**. A solid aerosol test is described in Annex F.9.
1.3 Biological Agent Protection		
The clothing system should protect against all practical field concentrations of biological agents under normal	Biological agents are disseminated as particulate material (aerosols). There are no requirements (yet) for dermal protection against	

Operational requirements	Explanation, technical specifications and criteria	Test
operational conditions.	B agents, but reduction of skin contamination is desirable. Challenge conditions are described in AEP-38 Volume II, criteria are discussed in Annex D.	
1.3.1 System and material protection The clothing system should prevent the penetration of biological agents.	The clothing system should reduce skin exposure to biological agents to below physiologically significant levels. When 1.2v is met for the specified particle size, further particulate penetration testing is unnecessary.	**DS**. A suggested method is presented in Annex F.3. **DM**. The test method in Annex F.9 can be applied to biological agent protection.
1.3.2 Spread of biological contamination The clothing system should not allow the spread of biological contamination.	The clothing system should not permit the easy spread of biological contamination by means of re-aerosolisation.	**DS**. A test method to evaluate re-aerosolisation, is suggested in Annex F.10
1.4 Radiological and Nuclear Protection		
The clothing system should protect against all practical field challenges by radiological and nuclear agents and against the fallout and heat flash effects of a nuclear explosion.	Challenge conditions are described in AEP-38 Volume II, the toxicological data in Annex D.	
1.4.1 Radiological particulates The clothing system should protect against and not increase the hazard posed by radiological and nuclear fall-out particulates.	The clothing system should provide protection against penetration by radiological and nuclear fall-out particulate and should not increase the total radiological dose received compared with the unprotected individual. When 1.2v is met for the specified particle size, further particulate penetration testing is unnecessary. QSTAG 747 may be used as a guide.	**DS**. A suggested method is presented in Annex F.3. **DM**. The test method in Annex F.9 can be applied to radiological and nuclear fall-out particulate penetration. **DM**. A method for dose evaluation is not provided.
1.4.2 Spread of radiological and nuclear contamination The clothing system should not allow the spread of radiological contamination.	The clothing system should not permit the easy spread of radiological and nuclear contamination by means of re-aerosolisation.	**DS**. Annex F.10 describes a test method for re-aerosolisation.
1.4.3 Thermal Radiation - nuclear heat flash The clothing system should protect personnel against the effects of thermal radiation.	When the clothing system is subjected to a heat flash of 60 J/cm^2 required (120 J/cm^2 highly desirable) delivered in 2 seconds required (1 second highly desirable) (square pulse) corresponding to a standard fission 30 kT nuclear explosion in air at a distance of 2.2 km (1.6 km for desired level) in clear weather conditions, it should be self-extinguishing with less than 1 second of afterburn and show no skin threatening melt.	**DS**. The complete clothing system on a mannequin may be tested using a Thermal Radiation Source (TRS) and the integrity of the clothing is examined using the criteria of Annex F.11. Preferably, the thermal radiation under the clothing may be measured in accordance with AEP-9 Volume 3 and Volume 4 in order to determine the total skin area

Operational requirements	Explanation, technical specifications and criteria	Test
	The total skin area receiving 2nd and 3rd degree burns should not exceed 21 percent as indicated in Annex A to AEP-4.	burned. **DM**. A nuclear heat flash test is described in Annex F.11.
1.5 Influence of use characteristics on protection	The clothing system shall retain its protective properties in and after all use conditions. The challenge conditions are presented in AEP-38 Volume II and the toxicological criteria in Annex D. The protective performance shall be evaluated with test methods as described in Annex F.	**MS/DS/MM/DM** as appropriate on worn/used garments, and depending on national operational directives and philosophy
1.5.1 Extended Wear The clothing system shall be suitable for extended periods of wear without an unacceptable decrease in protection.	Clothing systems intended for extended wear shall still provide adequate protection after the expected period of wear of the clothing.	**MS/MM**. Field trials or ageing as described in Annex F.1 shall be completed. The protective performance shall be evaluated in accordance with the appropriate standards, described in Annex F. Results shall be compared to those of the new clothing system.
1.5.2 Climate The clothing system shall protect in all operationally relevant climatic conditions.	The clothing system shall offer adequate protection in all operationally relevant climatic conditions. AECTP 200 gives an overview of the different climates.	**DS/MM.** Protective properties which are highly dependent on environmental conditions shall also be determined at the extremes of the climatic conditions relevant to those properties, additional to the conditions described in AEP-38 Volume II.
1.5.3 Non-CBRN Contaminants The protection against CBRN agents offered by the clothing system after being exposed to task-relevant non-CBRN contaminants shall remain at acceptable levels.	The protection of the clothing system shall at least be tested after exposure to task-relevant non-CBRN contaminants in liquid or vapour form. A list of various possible non-CBRN contaminants is contained in Annex F.1.	**MM**. After contamination, materials of the clothing system are tested in accordance with the appropriate standards, described in Annex F. Tests selected are the same as those carried out on new systems. Annex F.1 describes the contamination process.
1.5.4.i Laundering For clothing systems intended to be re-used after laundering, the level of protection offered by the clothing shall remain at acceptable levels after laundering.	The clothing system shall comply with the protection requirements after the number of laundering cycles for which it is designed.	**DS/MM.** Repeatedly worn and laundered (preferred) or repeatedly laundered garments shall be tested in accordance with the appropriate standards, described in Annex F. Tests selected are the same as those carried out on new systems. Annex F.1 describes the laundering process. Results shall be compared to those of the new clothing system.

Operational requirements	Explanation, technical specifications and criteria	Test
1.5.4.ii Decontamination For clothing systems intended to be re-used after decontamination, the level of protection offered by the clothing shall remain at acceptable levels after the complete decontamination procedure.	Decontamination is the cleaning of contaminated clothing in specially designed facilities after it has returned from field use. The clothing system shall comply with the protection requirements after the number of decontamination cycles for which it is designed. The method of decontamination to be applied shall be specified.	**DS/MM**. The evaluation shall include artificial contamination followed by completion of the prevailing decontamination procedures. Use methods from Annex F.
	Moreover, the clothing system shall not desorb hazardous vapour or hazardous aerosol above acceptable levels during further use (in absence of an outside challenge).	**DS/MM.** The levels of residual vapour or aerosol hazard shall be measured The methods described in Annex F can be applied without further application of contamination.
1.5.4.iii Immediate Decontamination After immediate decontamination in the field, the level of protection offered by the clothing system shall remain at acceptable levels.	Immediate decontamination is the removal of visible contamination from the clothing in the field. The entire clothing system shall comply with the protection requirements after immediate decontamination in the field. Not all kinds of clothing are suitable for immediate decontamination. Still, agents and decontaminants can spill onto these kinds of clothing in the immediate decontamination process of other parts of the clothing or of equipment. Both situations shall be evaluated for decontaminable materials, the spilling process only for materials not meant to be decontaminated.	**DS/MM**. The methods described in Annex F.7 and F.8 can be applied, with the immediate decontamination procedure applied after contamination (Annex F.1). For non-decontaminable material the decontaminant shall be applied without pressure (mimic “spill”).
1.5.5 Emergency repairs The clothing system shall be maintainable and repairable by an individual with a minimum amount of special tools under normal operational conditions. After repair the protection afforded by the repaired areas shall be at acceptable levels.	The individual shall be able to easily and quickly make emergency repairs to the clothing system with a minimum amount of special tools under normal operational conditions. The emergency repairs shall provide the necessary protection obtained for a reasonable task-related period.	**DS.** The evaluation is to include a subjective assessment by subjects as to the ease of repair and tools required to make repairs. **MM**. After repairs, the protection afforded over the desired time period shall be assessed on critical sites such as the edge and directly over the damaged area. The test methods are described in Annex F.
1.5.6 Storage Life The protection properties of the clothing system shall be maintained by the packaging during storage, handling and transit at all supply levels for the storage life of the clothing system.	Items must be stored in accordance with national requirements and the manufacturer’s guidance (see Annex E). Random samples shall be withdrawn from inventories at periodic intervals and tested to ensure that protective	**DS/MM**. The protective performance shall be evaluated with test methods as described in Annex F.

Operational requirements	Explanation, technical specifications and criteria	Test
	properties are maintained.	
2. USE CHARACTERISTICS		
2.1 Packaged State		
The clothing shall be easy to transport when not worn. Packaging shall be easy to open.		
2.1.1 Weight The clothing system shall be as light as possible.	The clothing system excluding all auxiliary equipment shall not *exceed* the weight of other operational clothing of the same size and for the same environmental condition by more than 1.5 kg essential (1 kg desirable). A higher weight can be accepted for specialist user groups.	**MS**. Weight is determined by weighing representative samples of the clothing system. Weights are averaged and compared to operational clothing. ISO 3801 can be used as guidance.
2.1.2 Packaged Volume The clothing system shall have the smallest volume possible.	The packaged volume of the clothing system excluding auxiliary equipment shall not exceed 10 dm^3 essential (3 dm^3 desirable). A higher volume can be accepted for specialist user groups.	**MS**. Volume may be determined by a water displacement test on representative packaged samples of the clothing system and averaging the results.
2.1.3 Packaging Individual item packaging shall maintain lightweight non-bulky characteristics and permit easy opening without special tools while wearing gloves. It shall maintain its integrity during shipping and storage.	Packaging material shall be durable, disposable, and not increase the total weight by more than 100 grams (excluding desiccant if required). The final packaged clothing system shall be compatible with load carriage equipment. The time required to unpack the packaged clothing system while wearing gloves shall not exceed one minute and shall not require the use of specialist tools. These requirements may not be necessary for specialist user groups.	**MS**. The weight of the packaging material is to be determined by weighing representative samples and averaging results. ISO 3801 can be used as guidance. **MS**. An evaluation shall be completed. The evaluation shall include a subjective assessment completed by the subjects as to ease of unpacking with and without gloves.
2.2 Donning and doffing		
The clothing shall be easy to don, open, close and doff, both without and while being contaminated.		
2.2.1 Donning/Doffing uncontaminated clothing The clothing system shall be easy to don and doff unassisted for most user groups.	Donning and doffing of the clothing system by trained personnel shall take a minimum amount of time, preferably unassisted. For some clothing items buddy assistance might be part of the donning/doffing procedure.	**MS**. The evaluation shall include users repeating donning and doffing procedures protective clothing system.

Operational requirements	Explanation, technical specifications and criteria	Test
2.2.2 Open and closed state The clothing system shall allow the wearer to go from the Open State to the Closed State quickly and easily.	The time required to complete unassisted donning for the clothing system from the Open State to the Closed State shall not exceed 30 seconds. The definition and use of dress states is a national responsibility. A longer time period required to complete donning for specialist user groups may be acceptable.	**MS**. An evaluation shall be completed with trained subjects repeating opening and closing procedures. ATP-65 gives guidance.on dress states. Dress Category Medium a or b might be used as Open State and Dress Category High might be used as Closed State.
2.2.3 Doffing contaminated clothing It shall be possible to doff the clothing system with minimum risk to the user of contacting contaminated surfaces or of contamination being transferred to the skin.	Contamination of the skin or other under layers resulting from doffing of contaminated components of the clothing system shall be avoidable. For some clothing items buddy assistance might be part of the doffing procedure.	**MS**. Users will perform national decontamination and doffing procedures with suits contaminated with simulant liquid challenge (e.g. methyl salicylate with fluorescent tracers in contamination density equal to real challenges) and show no contamination on skin/equipment after these procedures.
2.2.4 Contamination Control Area (CCA) Procedures The clothing system shall be compatible with CCA procedures.	Personnel wearing the clothing system shall be able to complete all necessary Contamination Control Area procedures specified in STANAG 2941. Specialized clothing might need procedures not covered by STANAG 2941.	**MS**. Field trials using the procedures from STANAG 2941 shall be completed.
2.2.5 Removal of clothing system from casualties	It should be no more difficult for medical personnel to remove the CBRN IPE from casualties (e.g. using standard casualty scissors) than for standard combat clothing.	**DS.** Trials using standard casualty handling procedures should be completed in comparison with standard combat clothing.
2.3 Comfort		
The clothing shall be comfortable to wear.		
2.3.1 Fit The clothing system shall fit.	The clothing system shall be provided in a range of off-the-shelf sizes to fit the 5th to the 95th percentile of the user population (both females and males). However, nations shall aim at 100%. For correlation of the anthropometrical sizes with the clothing system, the NATO clothing sizing system (STANAG 2177) shall be used. STANAG 2335 will govern the interchangeability of the clothing system.	**MS**. User trials using the full range of sizes shall be completed with a representative panel of users and ensure users successfully perform routine operational activities or a range of standard motions thus confirming that the clothing system conforms to and is in compliance with STANAG 2177 and 2335. National body scanning systems may be used as well.
2.3.2 Comfort The clothing system shall impose	The clothing system shall impose minimum physical hindrance to any part of the body, including the neck, elbows,	**MS**. Field trials to assess the comfort requirements shall be completed with users. Simulated obstacle and/or wear courses may be employed.

Operational requirements	Explanation, technical specifications and criteria	Test
minimum physical hindrance.	wrists, knees and ankles, and be flexible. Clothing systems directly into contact with the skin need to be soft to the skin.	Questionnaires shall be completed by the users to evaluate and comment on the comfort of the clothing system. Results will be scored and shall be at least equal to national requirements.
2.3.3 Skin Irritation and Toxicity The clothing system shall not cause irritation of the skin or be toxic to the wearer.	The clothing system shall be non-toxic and non-irritant to the wearer when in direct contact with the skin during periods of prescribed use. All chemical additives need to be non-toxic for the user. Remark: Chemicals can be toxic without giving instantaneous signs of dermatitis (e.g. carcinogenic) or respiratory problems.	**MM**. All previously unproven additives to material systems shall be evaluated to ensure that they are not toxic using standard laboratory toxicity test methods or by examining Material Safety Data Sheets or similar documents. Users wearing the clothing system over an extend period of time shall be checked for skin damage responses (direct and again in a period of 48 hours) and questioned regarding this requirement. Results will be scored and shall be at least equal to national requirements.
2.3.4 Odour The clothing system shall not have obnoxious odour.	The clothing system, whether new or re-used shall not have obnoxious odour.	**MS**. Users in field tests or test facility will be questioned confirming that no obnoxious odours were present.
2.3.5 Noise The degree of noise emanating from the clothing system shall impose minimal hindrance to the wearer.	The noise, caused by the clothing system, shall not be uncomfortable to the wearer.	**MS**. Users in field tests or test facility will be questioned confirming that the noise level was acceptable.
2.4 Performance		
The user of the clothing system shall be able to perform operational tasks.		
2.4.1 Performance reduction	Degradation caused by the clothing system while performing operational activities such as marching, digging, firing weapons, driving vehicles, operating field equipment, operating communications equipment, maintaining equipment and other task related activities shall be minimal when compared to the efficiency of the same tasks performed in other operational clothing. STANAG 2499 (ATP-65) may be used as guidance.	**MS**. Field trials shall include trained subjects to assess the ability to perform all types of relevant activities in task related environment during extended period of wear. The trial is to include a subjective assessment by the subjects of the effectiveness of the clothing system as compared to comparable combat clothing.
2.4.2 Heat stress The clothing system shall not subject the	The clothing system shall be capable of being worn in all operationally relevant climatic conditions while performing	**MS**. Climate chamber trials shall be completed including users to assess the heat stress related to a

Operational requirements	Explanation, technical specifications and criteria	Test
wearer to an unacceptable level of heat stress.	normal operational activities without causing unacceptable heat stress. AECTP 200 gives an overview of the different climates. STANAG 2499 (ATP-65) shall be used.	certain workload at the relevant climatic conditions (ATP-65, ISO 7243). Numerical data may be obtained through mannequin testing, and compared to human responses/data. **DS**. During the field trial determining comfort (2.3.2) questionnaires could also address heat stress (ISO 10551). **MM**. Air permeability of materials can be determined with ISO 9237, water vapour permeability and heat transfer with ISO 11092. Their impact on the total heat load shall be determined. Guidance to acceptable loads, methods and calculations are found in NATO ACCP-1.
2.4.3 Vision The clothing system shall not reduce, when compared to other operational clothing, the field of view provided by the respiratory protection when the clothing system is worn in the Closed State.	The unobstructed natural field of vision of the clothing system in the Closed State shall not be less than when wearing the respiratory protection alone	**MS**. When tested in accordance with the Field of Vision Test identified in D/103, the unobstructed natural field of vision in the Closed State shall not be less than when wearing the respiratory protection alone.
2.4.4 Hearing The clothing system shall interfere as little as possible with direct hearing when compared to comparable operational clothing.	When in the Closed State the ability to differentiate between sounds and to comprehend words shall not be less than 95% of that in the Open State. Additional listening equipment might be needed for specialist clothing.	**MS**. When tested in accordance with the Modified Rhyme Test identified in D/103, the ability to differentiate between sounds and to comprehend words shall not be less than 95 percent of that in the Open State.
2.4.5 Touch The clothing system shall allow the user to maintain a sense of touch.	The clothing system shall not significantly reduce the sensation of touch or being touched in all areas.	**MS**. Tactility with or without wearing the CBRN system shall be evaluated with ASTM F2010. **DS.** CBRN footwear will be compared against other operational footwear and should not degrade traction too much, in accordance with national guidelines. **DS.** The subjects should be touched at different pressures (three or more pressures should be considered) on points covering the whole body. The subject should indicate when the touch has been felt. The subject should don operational clothing

Operational requirements	Explanation, technical specifications and criteria	Test
		and follow the same procedure. The sensation of being touched in all areas should not be significantly different from operational clothing.
2.4.6 Identification The clothing system shall allow for identification.	The clothing system shall allow being identified. National guidelines or STANAG 2429 can be used as guidance.	**MS**. The identification on the clothing is compared to national guidelines or the guidelines in STANAG 2429.
2.4.7 Respiratory Detection The clothing system shall allow a wearer to detect if another wearer is breathing.	Respiratory detection actions shall not be hindered by the clothing. Respiratory detection might not be possible in all suits (e.g. clothing systems for special function/tasks).	**MS.** Two subjects wearing the clothing system shall mutually perform a hand check - feel for chest movement, occlude canister briefly, look for fogging of eyepieces - and be able to detect breathing.
2.4.8 Urination/Defecation The clothing system should permit the unassisted user to urinate and defecate.	When in the Open State, the user should be capable of performing urination and defecation procedures easily and rapidly. When in the Closed State without toxic challenge, the user should be capable of performing urination and defecation procedures with minimal risk.	**DS**. An evaluation should be completed with trained male and female subjects repeating Open state and Closed state urination and defecation procedures. A questionnaire completed by the subjects may be used to obtain subjective comments regarding ease of use.
2.5 Equipment compatibility		
The clothing system shall be compatible with all in-service equipment used during normal operational conditions.		
2.5.1 Compatibility	The clothing system shall be fully compatible with and integrated to the greatest extent possible with other items of protective clothing systems and operational equipment (e.g. ballistic protection, load carriage gear) and shall maintain coverage of the body under normal operational conditions. The hood - respiratory protection system interface is particularly critical. The protection and intake of fluid shall not be degraded by the presence of the clothing.	**MS.** Field trials including a subjective assessment by the subjects to establish the compatibility of the complete clothing system shall be completed. The principles governing the design of load-carrying equipment in STANAG 2311 shall be followed. Parallel evaluation of the respiratory protection and intake of fluid shall be performed according to D/103 (man test for face seal leakage), wearing the full protective system.
2.5.2 Static electricity The clothing system should not produce an unacceptable static electrical discharge.	The system should not produce static electrical discharge which will cause sparks or explosions when working with POL products (e.g. refuelling), sensitive electronic equipment (e.g. sights), entering or exiting vehicles, or cause discomfort to the wearer. The most critical layer is the outermost.	**DS.** The clothing system should be tested for the decay time and resistivity. Decay time - When charged with 5,000V, the clothing system should accept a minimum of 4,000 V and dissipate 90 percent of the acquired charge in

Operational requirements	Explanation, technical specifications and criteria	Test
		less than 0.5 seconds. Resistivity - The different material layers used in the clothing system should have a maximum surface resistivity of 10^{9} ohm and a volume resistivity of 10^{-6} to 10^{-8} ohm/m at 20 and 60 percent humidity respectively.
2.5.3 Magnetic properties The clothing system should not be unacceptably magnetic.	Use of magnetic instruments should not be affected by the clothing system	**DS**. It should be demonstrated that the presence of the clothing system does not influence the operation of a compass or other magnetic instruments regardless of orientation.
2.6 Protection against non-CBRN contaminants and fire The clothing system shall prevent skin contact with non-CBRN contaminants and fire.		
2.6.1 Liquid resistance The clothing system shall prevent water and POL contact to the skin to the greatest extent possible.	Contact to the skin by water and POL can be reduced by applying repellency treatment. Where multiple items are layered, only the outermost layer need be repellent. The liquid resistance of re-usable clothing systems shall remain at an acceptable level after the intended laundering/decontamination cycles. When other means are introduced to prevent water and POL penetration through the clothing, evaluations shall then be adjusted accordingly.	**MM**. Only for water repellent material samples, water repellency shall be tested in accordance with EN-ISO 24920. The water resistance shall meet a value of 3 or higher on the ISO scale. Only for POL repellent material samples, POL repellency shall be tested according to ISO 14419, and liquid resistance shall meet a value of 5 or higher on the ISO scale.
2.6.2 Flame and fire The clothing system should protect personnel against the effects of flame and fire.	The clothing should be self-extinguishing with less than 1 second of after burn and show no skin threatening melt.	**DM**. A material test can be performed according to EN-ISO 15025
2.7 Counter surveillance		
2.7.1 Camouflage The clothing system shall not reduce the camouflage characteristics of the user when compared to operational clothing.	Because these are operational uniforms intended for wear while carrying out combat duties, national camouflage standards for regular operational clothing for the same environment shall be met.	**MM.** National camouflage standards shall be followed. STANAGs 2138 and 2333 may be used as reference.

Operational requirements	Explanation, technical specifications and criteria	Test
2.7.2 Silhouette The clothing system should not significantly increase the silhouette of the wearer when compared to comparable operational clothing.	The increase in silhouette of the user while wearing the clothing system when compared to comparable operational clothing should be less than 10 percent.	**DS.** The clothing system including auxiliary equipment is checked for its silhouette property in comparative tests. Subjects that are representative of the national sizing system should be employed for this testing. The subjects will be photographed in shadow using a scaled background. Subjects will don the clothing system including auxiliary equipment and be photographed in front of the grid background. Subjects will change to operational clothing and be photographed in the same pose. The shadow produced by the subject with each donned system will be compared by overlapping the shadows or by area calculations.
2.7.3 Noise The degree of noise emanating from the clothing system shall not lead to detection.	The allowed degree of noise emanating from the clothing depends on the operational environment. The noise characteristics of the CBRN suit system should be comparable to operational clothing systems while performing the same activities.	**MS.** See Annex G, included in controlled trial, with trained observers questioned. The noise levels for the protective clothing system shall be no higher than for the operational clothing system.
2.8 Training		
Training of personnel in the correct usage of the clothing system should be simple and easy to follow.	STANAGs 2150 and 2353 will govern the implementation and evaluation of training with the clothing system. It is important to train in similar conditions as operational conditions with all the necessary auxiliary equipment.	**DS**. In conjunction with STANAGs 2150 and 2353, an evaluation shall be completed with subjects. The training conditions are similar to the operational conditions. A questionnaire completed by the subjects may be used to obtain subjective comments regarding ease of training.
3. PHYSICAL AND MECHANICAL PROPERTIES		
3.1 Durability		
The clothing system shall be durable under normal operational and environmental conditions and after laundering.		
3.1.1 Operational wear and tear	All physical and mechanical properties of the clothing shall	**MS**. Field trials (STANAG 2138) shall be completed

Operational requirements	Explanation, technical specifications and criteria	Test
The clothing system shall be durable under normal operational wear and tear and maintain its physical and mechanical properties.	remain at acceptable levels after operational use.	to assess the durability of the clothing system. Field trials shall be representative of all types of activities and environments related to the user group of the clothing system. Regular inspections shall be conducted during the trial to obtain information regarding wear and tear. **MM.** At regular intervals and upon conclusion of the field trial, laboratory evaluation of trial items are to be compared to the new state for all relevant properties to the system being tested with the relevant task-related physical and mechanical properties, see Annex G. Some examples of material properties are tensile strength, tear strength, puncture resistance, resistance to abrasion / pilling, cold flex, crack, adhesion, colour fastness (to light, rubbing, perspiration).
3.1.2 Environmental conditions The clothing system shall be durable under all relevant environmental conditions, both when used and under storage and transport conditions.	All physical and mechanical properties of the clothing shall remain at acceptable levels in all relevant environmental conditions.	**MM.** Material properties (where environment could have an impact) are described in Annex G. Some relevant properties are colour fastness (to light, artificial weathering), and resistance to microorganisms.
3.1.3 Laundering The clothing system shall be durable during laundering.	For those clothing items designed to be laundered all important properties shall be maintained after the intended number of laundering/drying cycles.	**MM**. All relevant tests shall be repeated after washing, see Annex G. Material properties like dimensional stability and colour fastness (to washing, rubbing, bleaching) shall be maintained within acceptable levels.
3.2 Disposal Uncontaminated clothing should allow for disposal in accordance with normal operational practices.	Normal disposal procedures for uncontaminated garments should be possible, e.g. landfill, incinerator, rendering to rags prior to landfill, etc.	**DS.** National guidelines apply.
3.3 Labelling Packaging and garments shall be labelled briefly and clearly.	Labels shall facilitate interoperability and shall declare essential use instructions such as the number of times laundering is allowed.	**MS.** The label shall contain as a minimum: NATO size; NATO stock number (NSN); laundering/drying instructions including the number allowed and space for notification washings; and the date of manufacture.

SOURCE DOCUMENTS

The table below identifies the source documents like STANAGs, civilian standards and other references used in the main text. In all cases, the most recent version of the standard should be used, and test results should cite the edition/date. If a standard has been revised, results should be correlated across the old and new standards.

Table 9-1: Source Documents

Section	Document	Title
This document	AEP-38 Vol I (Original dated 1998)	Operational requirements, technical specifications and evaluation criteria for NBC protective clothing.
1.1 (point 0103)	AAP-6 Ed. 2007 (dated April 2007); covered by STANAG 3680 Ed 5, (dated 2 December 1998). Both UNCLASSIFIED.	NATO Glossary of Terms and Definitions (dated 2007).
1.3 (point 0105) 8.3 Triptych (point 2.4.3, 2.4.4, and 2.5.1)	D/103 Respiratory triptych (draft, dated 2006)	Breathing Protection: Combined operational characteristics; technical specifications and evaluation criteria
1.3 (point 0106) 5.3 (point 0507)	AEP-52 Ed.1 (September 2003; covered by STANAG 4625 Ed.1 (dated 8 August 2006). Both UNCLASSIFIED.	Assessment of effect levels of classical chemical warfare agents applied to the skin to be used in the design of protective equipment.
1.4 (point 0109)	D/101 (dated 1971)	Combined Operational Requirements, Technical Specifications and Evaluation Criteria (Triptych) for NBC Protective Clothing
3.3 (point 0307)	ATP-3.8.1, Volume 1	Allied Joint Tactical Doctrine for CBRN Defence
3.3 (point 0307) 8.3 Triptych (1.5.2 and 2.4.2)	AECTP 200 covered by STANAG 4370	STANAG 4370 Environmental Testing covering AECTP series 100 - 600 (replaces STANAG 2895)
3.3 (point 0307)	STANAG 2352 (dated 22 September 2005) UNCLASSIFIED	Nuclear, biological and chemical (NBC) defence equipment - operational guidelines
4.1 (point 0402)	AJP-3.8 Ed.1 (dated July 2003; covered by STANAG 2451 Ed.3, (dated 5 February 2004) Both UNCLASSIFIED	Allied Joint Doctrine for CBRN Defence

Section	Document	Title
5.1 (point 0501)	(AC/225(LG/7)D(2001)5)	Chemical warfare agents. CSG report from September 2001
5.1 (point 0501)	NATO Army Armaments Group Sub Groups of the Chemical and Biological Challenge/Threat to NATO Forces Minutes of the 21st Meeting of the JCG CBRN CSG (dated 3 May 2007)	Toxic Industrial Materials. List of 17 TIC compounds presented by the CSG Chairman at the JCG CBRN (dated February 2007)
5.1 (point 0501)	Report presented at the JCG CBRN meeting (dated 07 September 2007.	Biological warfare agents.
5.2 (point 0503) 5.3 (point 0510)	STANAG 2473 Ed.2 (dated 6 October 2004) UNCLASSIFIED	Commander's guide to radiation exposures in non-article 5 crisis response operations
5.2 (point 0503)	Report ToE NPSG (dated 2004)	Radiological aerosol challenge levels
8.3 Triptych (point 1.4.1)	QSTAG 747, Ed.2 (dated 1998)	NBC Survivability Acceptance Criteria, Design Guidelines, and Test Procedures for Defence Equipment (dated 1998).
8.3 Triptych (point 1.4.3)	AEP-4 Ed. 1 CLASSIFIED; covered by STANAG 4145 Ed.2, (dated 29 January 1991) UNCLASSIFIED	Nuclear survivability criteria for armed forces material and installations, Covered by: STANAG 4145 Ed.2
8.3 Triptych (point 1.4.3)	AEP-4 Vol Annex A Ed. 4 CLASSIFIED covered by STANAG 4145 Ed.2, (dat5ed 29 January 1991) UNCLASSIFIED	Nuclear hardening criteria for armed forces material and installations.
8.3 Triptych (point 1.4.3)	AEP-4 Vol Annex B Ed. 2 (classified; covered by STANAG 4145 Ed.2, (dated 29 January 1991, UNLCASSIFIED	Nuclear survivability criteria for naval material and installations.
8.3 Triptych (point 1.4.3)	AEP-4 Vol Annex C Ed. 1 (classified; covered by STANAG 4145 Ed.2, (dated 29 January 1991, UNCLASSIFIED	Nuclear survivability criteria for aviation material and installations.
8.3 Triptych (point 1.4.3)	AEP-9 Vol III Ed. 3 CLASSIFIED	NATO manual of simulators of nuclear weapons effects. Simulators of thermal and optical effects.
8.3 Triptych (point 1.4.3)	AEP-9 Vol IV Ed. 4 CLASSIFIED	NATO manual of simulators of nuclear weapons effects. Simulators of nuclear radiation effects.
8.3 Triptych (point 2.1.1 and 2.1.3)	ISO 3801:1997	Textiles. Woven fabrics. Determination of mass per unit length and mass per unit area.
8.3 Triptych (point 2.2.2, point 2.4.1 and point 2.4.2)	ATP-65:2008 (edited July 2008; covered by STANAG 2499) Both UNCLASSIFIED	The effect of wearing NBC individual protection equipment on individual and unit performance during military operations.
8.3 Triptych (point 2.2.4)	STANAG 2941 Ed.2 (dated 19 June 1992; UNCLASSIFIED	Guidelines for Air and Ground Personnel Using Collective Structures on Permanent Air Base Installations

Section	Document	Title
8.3 Triptych (point 2.3.1)	STANAG 2177 Ed. 1 (dated 31 May 1994) UNCLASSIFIED, Ed. 2 (ratified draft)	Methodology for anthropometric data.
8.3 Triptych (point 2.3.1)	STANAG 2335 Ed. 2 (dated 13 May 1976); UNCLASSIFIED, Ed. 3 (ratified draft)	Interchangeability of combat clothing sizes
8.3 Triptych (point 2.4.2)	ISO 7243:1989	Hot environments. Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature).
8.3 Triptych (point 2.4.2)	ISO 10551:1995	Ergonomics of the thermal environment. Assessment of the influence of the thermal environment using subjective judgement scales.
8.3 Triptych (point 2.4.2)	ISO 9237:1995	Textiles. Determination of the permeability of fabrics to air.
8.3 Triptych (point 2.4.2)	ISO 11092:1993	Textiles. Physiological effects. Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test).
8.3 Triptych (point 2.4.2)	NATO ACCP-1 (NATO unclassified document; AC/301-D/277)	Heat transfer and physiological evaluation of clothing.
8.3 Triptych (point 2.4.5)	ASTM F2010-00(2005).	Standard test method for evaluation of glove effects on wearer hand dexterity using a modified pegboard test.
8.3 Triptych (point 2.4.6)	STANAG 2429 Ed.3 (dated 9 December 2005; UNCLASSIFIED	Personnel identification while in NBC individual protective equipment (IPE).
8.3 Triptych (point 2.5.1)	STANAG 2311 Ed.4 (dated 31 May 1996; UNCLASSIFIED	Principles governing the design of the individual load carrying equipment of the combat soldier.
8.3 Triptych (point 2.6.1)	EN 24920:1992	Textiles. Determination of resistance to surface wetting (spray test) of fabrics.
8.3 Triptych (point 2.6.1)	ISO 14419:1998	Textiles. Oil repellence. Hydrocarbon resistance test.
8.3 Triptych (point 2.6.2)	ISO 15025:2000	Protective clothing. Protection against heat and flame. Method of test for limited flame spread.
8.3 Triptych (point 2.7.1 and point 3.1.1)	STANAG 2138 Ed.4 (dated 31 May 1996; UNCLASSIFIED	Troop trials principles and procedures. Combat clothing and personal equipment.

Section	Document	Title
8.3 Triptych (point 2.7.1)	STANAG 2333 Ed.4 (dated 12 November 1992) UNCLASSIFIED	Performance and protective properties of combat clothing.
8.3 Triptych (point 2.8)	STANAG 2150 Ed. 7	NATO standards of proficiency for NBC defence
8.3 Triptych (point 2.8)	STANAG 2353 Ed.5 (dated 6 March 2000) UNCLASSIFIED	Evaluation of NBC defence capability.

ANNEX A - SCOPE AND LIMITATIONS

A101 Scope

In revising AEP-38 the team of experts had many challenges, some of which were:

a. to reinforce common, minimum standards of IPE protection for NATO interoperability,

b. to account for recent global threats such as terrorism in an uncertain operational environment and how that may contribute to different systems of IPE as the situation dictates regarding dermal protection,

c. to incorporate revised chemical challenge levels from the 2001 CSG report, and to provide a brief explanation how the CSG determines challenge levels for personal protection,

d. to identify typical user groups and the selection of equipment for specific user groups,

e. to outline the selection of requirements, test methodologies, different material technologies and the life cycle of equipment,

f. to use international and NATO standards and test methods such as ISO standards wherever possible,

g. to modernize general test methodology and procedures so that descriptions are clear and unequivocal for all users so as not to give rise to interlaboratory differences, and to ensure comparable system performance understanding no matter which methods are used.

h. to re-introduce a nerve agent vapour-vapour test (with soman) due to changing material technologies,

i. to incorporate, where applicable, toxic effect levels for CWA as defined in AEP-52, and preliminary data for TICs and biological agents, and

j. to update requirements and test methods for clothing properties other than CBRN protection.

A102 Classification

For ease of use Volume I is NATO/PfP UNCLASSIFIED and Volume II, containing the pages detailing specific challenge levels for CBRN agents, is NATO CONFIDENTIAL.

A103 Major structural changes compared to the AEP-38 1998 edition

There were major changes from the 1998 edition to this one. The most significant changes were:

a. Wherever applicable using the acronym CBRN instead of NBC.

b. User groups have been included.

c. All forms of skin (dermal) protective clothing and all applications of the clothing are discussed in one table instead of in separate annexes.

d. The new triptych reflects that new material technologies have emerged, as well as new concepts of use for IPE.

e. Explanatory information is given with respect to the various clothing items and applications, and to the selection of test methods and requirements.

f. Additional background information for equipment and tests selection is presented.

g. While still maintaining protection against the most extreme threat, the document is performance-based, not threat-based. For instance, it is recognised that for some tasks or operations the required level of protection could be lower than the defined worst-case situation.

h. For liquid- and vapour-vapour challenges a nerve agent (soman, GD) was introduced.

i. For the first time asymmetric threats and TIM challenges have been taken into account.

j. More emphasis is placed on protection against aerosol challenges (specifically biological agents).

k. Requirements and test methodologies for non-CBRN protective properties have been updated.

A104 Limitations

Several limitations were identified by the ToE in revising this document. Due to time constraints and the availability of (scientific) information, several subjects could not be fully explored.

a. The PPSG instructed the ToE to restrict itself to skin protection. The integration of and compatibility with other systems like the respirator, helmet, body armour and load carriage systems was not fully studied.

b. Other methods of dermal protection, such as barrier creams or preventive measures such as vaccination or decontamination were not taken into account when detailing the requirements and test method descriptions.

c. The general assumption is that the ensemble can be worn for an extended period when uncontaminated. Single day wear items have not been discussed.

d. The document is not intended as a clothing design manual or a commander's guide.

e. The "user component" of the IPE, like maintenance, training, size and fitting, is not described in this document.

f. To effectively revise AEP-38 and accommodate the necessary trade-offs of protection versus comfort, information was needed concerning threat levels and operational conditions. Neither operational analyses for different user groups nor threat analysis regarding the likelihood of the various scenarios the CSG used to define appropriate challenge levels were available. Therefore, no dedicated test regimes could be designed that in many cases could have resulted in decreased need for protection and thus allowing for increased comfort. As a result, at times the ToE made their own determinations regarding appropriate test conditions and whenever this occurs it was clearly noted.

g. The document does not cover specific tasks that require protection against long term exposures to low levels of CBRN agents, like those experienced in a dismantling facility.

h. The discussion of TIMs is limited to TICs in vapour form. Other forms of TIM challenges were not studied. Also, the list of TICs certainly does not represent the bulk produced/transported chemicals most toxic to skin.

i. The skin-toxicity of biologicals, aerosols and TIC challenges is largely unknown, so – although tests could be performed- no breakthrough criteria are available and results cannot be expressed as “pass” or “fail”.

j. Only a limited number of criteria could be given for non-CBRN properties.

k. No tolerances could be assigned to many critical test parameters.

l. Testing of human factors, swatch testing of seams, zippers, seals and so on and Whole system tests with droplets and the different (liquid or solid) aerosols are only described briefly. Swatch testing of materials worn close to the skin (like undergarments) is not described.

m. Further investigation is needed into the occurrence of pressure points on the body, the magnitude of the pressure and the translation into test methods, investigation is also needed into the proper method to apply non-CBRN contaminants.

n. Prevention of skin contact with rain and pollution (under item “liquid resistance”) needs investigation and better description.

o. The protection offered by the suit (as determined in the whole system test) is only to a limited extent resembled by swatch test results: it is unclear what the translation between these results is.

p. No efforts were made to convert all units to the International System of Units (SI). Units currently in common use were applied throughout the document.

q. The test methods in this document need to be validated by round robin testing.

ANNEX B - USER GROUP AND TASK ANALYSIS

B101 Introduction

This Annex offers guidance to the selection of requirements for specific user groups.

B102 User Groups

1. Generalized representative major user groups have been identified:
   a. combat soldier, dismounted,
   b. combat soldier, mounted (vehicle),
   c. special operations,
   d. fast jet pilot and other closed cockpit personnel,
   e. helicopter pilot and other open cockpit personnel,
   f. aircraft rear crew,
   g. air force ground crew,
   h. amphibious / maritime personnel,
   i. CBRN operational specialist personnel (e.g. decontamination),
   j. logistics personnel,
   k. medical personnel,
   l. command/staff roles, and
   m. EOD and related tasks.

2. It should be noted that this list does not encompass all the roles that are undertaken within NATO. Certain specialist small user groups (e.g. fire-fighters amongst others) will have requirements not covered specifically in this document. However the guidelines in this document will prove useful in the selection of clothing for specialists, and other documents exist that can provide guidance for requirements, selection and use. In addition, casualty protection has been identified as an additional requirement/user group that lies outside the scope of this AEP.

B103 Challenges

1. When determining the requirements for IPE for each user group, the challenges that are likely to be encountered by the user group have to be established. Each user group has different challenges that affect the performance of their IPE during the performance of their tasks. Challenges related to climate are generally common for all user groups but other challenges that may vary include exposure to
   a. CWA vapour,
   b. CBRN aerosol,

c. CWA neat liquid agent,

d. CWA thickened liquid agent,

e. TIMs,

f. flame/fire,

g. water,

h. high wind speeds (from transport or rotor), and

i. battlefield contaminants.

2. The likelihood of encountering these challenges depends on specific roles and tasks undertaken by each user group. The toxic hazards from attacks that involve CBRN use relate to the location and duration of operations after an attack, and the specific tasks performed. The CBRN hazards include: high concentrations of liquids, aerosols, vapours, and contaminated surfaces in the vicinity of an attack; airborne hazards downwind including the primary release and secondary off-gassing or re-aerosolisation; and immediate hazards like heat, flash and blast from nuclear explosion. The conventional battlefield use of CWAs, B and R generally defines the requirements against these agents, while asymmetric use of TIMs is also possible – the limitations of respiratory protection usually mandate the use of safe distances for such releases limiting the dermal hazard.

3. Other information that can be used to define the severity of the hazard to a user depends on tasks. A few examples are described here. Users performing an equipment decontamination role require a degree of waterproofness, while individuals performing tasks that could involve significant surface contact in a highly contaminated area require more protection against penetration by liquids/surface contaminants. The presence of high winds (usually resulting from proximity to some form of mobile vehicle/craft, i.e. travel in an open vehicle or operations near helicopters) needs to be taken into account, as this will affect penetration of airborne agents.

4. The following is a more detailed discussion of the forms of CBRN hazard that require some degree of protection, and the circumstances under which they are encountered. In designing protective equipment and setting requirements, these hazards should be managed/reduced by: changes in procedures, including methods to mitigate the hazard by avoidance; changing duration of operations or operational procedures; decontamination, prophylaxis or treatment; or if by no other means, by design of CBRN protective systems. The burden of protection should only be placed on the individual as a last resort.

5. The intent of the information that follows is to relate the operational conditions under which various hazards would be encountered to the conditions in which equipment should be evaluated.

Table B-1 – Operational conditions under which various hazards would be encountered

Toxic Material	C Vapour incl TIC	C, B, R Aerosol	C Liquid Neat	C Liquid Thickened	N heat, radiation
Initial Hazard From Release	Downwind hazard – far from release point, hundreds of m to km	Downwind hazard - close to release point	Falling, spray or explosive - close to release point	Falling, explosive - close to release point	Fire, intense heat and extreme radiation exposure up to km from release point
Subsequent Hazard	Off gassing from contaminated soil or other contaminated items	Biological, radiological or dry chemical aerosol: re-aerosolisation from contamination (ground or items)	Uptake of contamination (liquid or gas) from ground or items	Uptake of contamination (liquid or gas) from ground or items	Radiation

6. The following environmental hazards can significantly degrade protection. They should be managed by (in order of preference): changes in procedures; ancillary protective items used when needed; or lastly by design of CBRN protective systems.

Table B-2 – Cross check what environmental conditions could have degradation effects on protection (and when)

When	Very High Wind*	Water	Battlefield Contaminant
Simultaneous with Exposure to Toxic Materials	Open, moving vehicles (helicopter, transport, tank, recon, naval vessel) or rotor wash	Seawater, sweat	e.g. petroleum/oil/ lubricants; cleaners; smoke; dirt
If Prior to Exposure to Toxic Materials	None	Immersion (sea or fresh water), rain, pickup of rain from wet equipment, sweat	See above
If Subsequent to Exposure to Toxic Materials	Open, moving vehicles (helicopter, transport, tank, recon, naval vessel) or rotor wash	Spray/soaking during cleaning or decontamination or heavy rain/high sea	Decontamination solutions/ cleaners, particularly applied with high pressure

Note In excess of normal most hazardous wind conditions during challenge release, see AEP-38 Volume II Sections V and VI.

7. The duration of the hazard and therefore the protection required may be shorter than the expected duration of a single use of a particular protective item/system. Many material properties must remain unchanged over several single use cycles. Some properties, particularly those involved in CBRN protection, may only need to provide a period of protection corresponding to the duration of the hazard. Some special user groups may have a single use period and/or expected exposure to the toxic hazard much shorter than the norm for a ground soldier. This will provide options for design alteration to

improve the balance of system performance. The requirements officer should communicate closely with design and/or procurement officer and with the operational community to ensure that planned durations of single use are well understood. The intended number of repeated uses in the absence of contamination is based on logistical considerations of the individual nation as well as technical limitations of equipment durability. Reuse after contamination is a separate issue; the decontaminability requirement may be set by requirements for safe doffing/minimisation of contamination spread, or by intent to re-use after decontamination. Therefore, reuse after contamination is an individual nation's decision based upon logistical considerations.

Table B-3 – Examples of duration of hazard vs. duration of operation for different tasks

	Exposure Duration to Toxic Hazard	**Duration of Operations (Single Use Duration)**
First responder / explosive ordnance disposal (mitigation/rescue role)	0.5-1 hr for each entry to hazard zone (low)	1-8 hr; limited by burden imposed by IPE (low)
Dismounted ground soldier	May continue as long as hazard to wearer has not been removed by personal decon/doffing or in some cases by leaving contaminated environment (high)	Up to 24 hr (high)

8. These other hazards may require management by the overall protective system, and protection may be incorporated into the CBRN ensemble or into an additional item of protective equipment worn over/under the ensemble. Encountering the hazard may have a detrimental effect on protection, or, incorporating protection against the hazard may have a positive or negative effect on protection.

Table B-4 – Cross effects of non-CBRN threats on CBRN protection

	Flame/Fire	**Static Charge**	**IR Detectability**	**Ballistic/Blast**
If Hazard is Encountered without mitigation	May degrade subsequent CBRN protection due to material damage	No impact on CBRN protection	No impact on CBRN protection	Will degrade subsequent CBRN protection when loss of system integrity
If Protection is Provided	Anti flame/fire treatment of material, may be incompatible with other treatments and degrade comfort	No impact on CBRN protection, however many flame/fire protective solutions themselves require the inclusion of ESD mitigation controls	Anti-IR detectability treatment of material, may be incompatible with other treatments and degrade comfort	Normally in additional equipment; may improve CBRN protection by addition of layers, may degrade CBRN protection due to system integration issues, decrease comfort and cause decontamination problems

9. Hazards have been further assessed according to the user groups described in B0102, by estimating the level of risk to various CBRN hazards for each group. This breakdown –presented in Table B-5- is intended as initial guidance: national policies, threat assessments, and operational requirements will determine its application and final form.

10. The challenges in Table 1-4 in AEP-38 Volume II apply to the general-purpose CBRN protective ensemble worn by dismounted ground forces, while Table 1-5 in AEP-38 Volume II describes challenges relevant to the asymmetric threat environment. Table B-5 indicates how other user groups may have different requirements in the various categories noted above.

B104 Suggestions for further study

Several (civilian) standards can offer assistance in the user group/hazard analysis.

a. STANAG 2909 Ed. 2 Commanders guidance on defensive measures against Toxic Industrial Chemicals (TIC).

b. "Selection and use of personal protective equipment for the Canadian first responder to a CBRN terrorism event: Interim Guidance Document", RMC Report CPT-0505a, August 2005 (revised 2006). http://www.rmc.ca/academic/chem/research/crti/reports/cpt0505/Selection_and_use_of_PPE_for_Can_FR_to_CBRN_terr_event_Aug_2006.pdf; US NIJ/DHS standard for bomb suits" (under development)

c. responder knowledge base https://www.rkb.mipt.org/contentdetail.cfm?content_id=65903;

d. US standards:

(1) 42 CFR 84 NIOSH CBRN PAPR Statement of Standard;

(2) 42 CFR 84 NIOSH CBRN APR Statement of Standard;

(3) 42 CFR 84 NIOSH CBRN SCBA Statement of Standard;

(4) 42 CFR 84 NIOSH CBRN APER and SCER Statement of Standard;

(5) NFPA 1994: Standard on Protective Ensembles for First Responders to CBRN Terrorism Incidents, 2007 Edition;

(6) NFPA 1971: Standard on Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting, 2007 Edition;

(7) NFPA 1951, Standard on Protective Ensembles for Technical Rescue Incidents, 2007 Edition;

(8) NFPA 1981, Standard on Open-Circuit Self-Contained Breathing Apparatus, 2002 Edition;

(9) NFPA 1991 Standard on Vapour-Protective Ensembles for Hazardous Materials Emergencies, 2005 Edition;

(10) North American Emergency Response Guide, 2007 edition.

Table B-5 – Example of functions, user groups, challenges and hazards

	Vapour incl TIC			Aerosol			Liquid Neat			Liquid Thickened			Flame or Fire			Water			Very High Wind			Battle field Contamination			Duration of Ops			Duration of Protn			Electrostatic Discharge			IR
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	
Combat soldier dismounted			x			x			x			x		x			x	x		x			x			x			x			x			yes
Combat soldier mounted (vehicle)		x			x		x			x					x		x			x	x			x			x			x			x		yes
Special operations			x			x			x			x		x				x			x			x			x			x			x		yes
Fast jet pilot and other closed cockpit roles	x			x			X			x					x	x				x			x			x			x					x	desirable
Helicopter pilot and other open cockpit roles			x			x		x			x				x			x			x			x			x			x					x	yes
Aircraft rear crew			x			x			x			x			x			x			x			x			x			x					x	yes
Air force ground crew			x			x			x			x			x			x			x			x			x			x			x		yes
Amphibious or maritime personnel	x			x			x			x					x			x			x			x			x			x					no
CBRN specialist personnel (e.g. decon)			x			x			x			x	x		x			x			x			x			x			x			x		no
Logistics personnel	x			x			x			x			x			x			x			x					x			x			x		desirable

	Vapour incl TIC			Aerosol			Liquid Neat			Liquid Thick ened			Flame or Fire			Water			Very High Wind			Battle field Contam ination			Duration of Ops			Duration of Protn			Electro static Dis charge			IR
	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	
Medical personnel	x	x		x	x		x	x		x	x		x	x		x	x		x	x		x			x			x			x			yes
Command or Staff roles			x			x			x			x	x	x			x			x		x			x			x			x			yes
EOD and related tasks		x			x				x			x			x			x			x		x			x			x				x	desirable

Legend:

High – There is a need for protection to the highest prescribed NATO levels.

Medium – Either a lower risk of contamination to high challenge levels, or the levels of contamination to be encountered will probably be over a shorter time period.

Low – There is a very low risk of contamination and/or a lower or shorter duration. NATO Challenge levels are relevant

Notes:

1. *This table is not definitive and is only intended to illustrate the performance assessment processes that should be undertaken whilst setting requirements, developing, specifying and procuring a protective system that gives the operational levels of protection required under certain operational conditions.*

2. *The use of the high/medium/low designations in the table is intended to be a composite indication of risk; the likelihood of encounter of the hazard combined with the magnitude of the hazard if encountered. These entries are intended as guidelines only, based on the ToE's expert opinion. The operational community may provide a different assessment.*

ANNEX C - SPARE

ANNEX D - TOXICOLOGICAL CRITERIA

D101 Introduction

1. Protection against CBRN agents is required due to their high toxicity. However, even highly toxic agents will not cause harmful effects unless they have entered the body in sufficient quantity. Next to the respiratory system the skin is one of the major entry routes of CBRN agents into the body. The level of skin exposure is determined by the combination of the level and duration of the outside challenge and the degree of protection offered by IPE. IPE aims to prevent agents reaching the skin or at least to reduce the penetration into the clothing to non lethal or incapacitating levels. It also should aim to reduce the skin decontamination burden where possible.

2. Unless otherwise stated the values in this Annex can be used as pass / fail criteria for testing at system level. They can not be translated into pass / fail criteria for tests at swatch level, but could -with caution- be used as a benchmark.

D102 Chemical warfare agents - liquids

No criterion can be given for liquid exposure / contamination of the skin unless full system tests are applied. Due to the high human and skin variability a mg/man criterion can not be applied for material testing with non-systemic acting toxic agents like mustard agent.

D103 Chemical warfare agents - vapours

1. For CWA vapours, the relevant values from AEP-52 pertain to protection against sulphur mustard (HD), a locally acting vesicant agent, and soman (GD) and VX, systemically acting nerve agents. In each case, it is the vapour toxicity that is relevant, as systems are designed to let through no liquid agent under the chosen challenge conditions, but could permit a finite dosage of vapour to pass through that is below a specific effects threshold. The ToE recommends the "negligible military impact" values for use. Data are presented in Table D-1. Additional information for each agent is presented below.

Table D-1 – "Negligible military impact" values for CWAs

Agent	Permissible dosage ($mg.min/m^3$)
HD	50
GD	350
VX	30

2. Sulphur mustard. The primary effects caused by sulphur mustard occur at the point of contact – reddening, blistering, ulceration. Systemic effects can occur at high dosages. AEP-52 quotes "no military significant effects" at a dosage of **50 $mg.min/m^3$** received over minutes to hours (representing a range of 10-100 $mg.min/m^3$), specifically excluding the head region from the analysis due to sparse data.

There is no information on the length of time permissible between repeat exposures at the maximum allowable dosage, but it is expected to be days-months due to the long-term nature of observed effects.

3. Although using a single value to represent the dosage allowable to the entire body is reasonable for making a simple initial approximation, it is preferable to take into account body region variability, because the single value is insufficiently conservative for a few regions and may mean overprotection for others. Further, although AEP-52 states the given value is for militarily insignificant effects such as skin irritation, this conclusion may not apply when data obtained under cool conditions (inappropriate for exposure within IPE) are excluded from the original data set. The following table [1] contains the recommended values that have been calculated for each of the body regions, and are based only on hot/humid exposure data given in AEP-52.

Table D-2 – Alternative way of expressing sulphur mustard toxicity at the negligible effect level

Body region	Permissible dosage (mg.min/m^3)
Head/neck, torso (excluding crotch), leg/foot	100
Arm/hand	50
Crotch	25

4. Soman. The primary effects caused by soman are those of nerve agent poisoning, which for dermal absorption at low exposures include flushing and sweating, then moving through more incapacitating toxic symptoms such as nausea and vomiting to death. The given value of **350 mg.min/m^3** implies significant cholinesterase inhibition but few if any other adverse effects. However, only a single exposure to this dosage is permissible until cholinesterase inhibition is reversed.

5. VX. The effects caused by and considerations for VX are similar to those of soman. The recommended value is **30 mg.min/m^3**.

D104 Chemical warfare agents- liquid aerosols

Liquid aerosols –when deposited on the skin- can absorb directly into the skin or cause a challenge by evaporation or after dissolving in sweat. Due to the small size of the aerosol droplets, evaporation will be relatively fast for most agents, and for toxicological interpretation could be looked upon as a vapour challenge.

D105 Chemical warfare agents - solid aerosols

Solid aerosols (agent on carrier) will also show a vapour hazard from the agent evaporating out of the carrier. Agent on carrier deposited on skin might also be dissolved in sweat and thus transport into the skin. The hazard to skin cannot currently be properly assessed in the absence of appropriate data on the nature and magnitude of the challenge to skin.

[1] Estimates of percutaneous toxicity of sulphur mustard vapour suitable for use in protective equipment standards, E.F. Gudgin Dickson, J. Toxicol. Env. Health A, 71:20, 1382-1391, 2008.

D106 TICs

1. Acute toxicities for TICs have generally been based on the inhalation route. Very little percutaneous toxicity data exists. That which does exist is based on animal studies. While the animal data cannot necessarily be extrapolated to humans, it is the best available approach at this time for estimating percutaneous effects. Data are presented in Table D-3.

2. The possibility exists that certain (hazardous liquids and their associated) vapours, such as strong acids or alkalis, contact the skin causing localised burns. While unlikely, any such burns which should occur could be debilitating. A degree of percutaneous penetration may also be possible with a few of the other TICS.

3. Only a limited number of dermal toxicity values are known for the TICs mentioned in the CSG list. Therefore the toxicity has been estimated based on respiratory toxicity. The method used is described in the frame, the resulting values in Table D-3. It should be noted that other skin effects of TICs, like etching, have not been taken into account.

4. Various guidelines can be used to determine maximum respiratory exposure levels for TICs. Civil services all over the world tend to use the Emergency Response Planning Guidelines (ERPG) which are based on animal respiratory toxicology research. If no such value exists the Temporary Emergency Exposure Limits (TEEL) are applied instead, which are based on statistical assumptions.

5. ERPG-2 is the maximum concentration in air below which it is believed nearly all individuals could be exposed for up to one hour without experiencing other than mild transient adverse health effects or symptoms that could impair their abilities to take protective action. If no ERPG-2 exists for a chemical substance, the comparable TEEL-2 values should be used (see also: http://orise.orau.gov/emi/scapa/teel-ref.htm).

6. ERPG-2 and TEEL-2 values assume body intake via the respiratory route.

Table D-3 – Animal toxicity data for oral or inhalation exposure and calculated threshold dermal exposure concentration for those TICs whose action is primarily systemic

Agent	Median lethal dosage (oral or inhalation)		Input values for model		Mild toxic (non-corrosive) effects to the skin, estimated value	
	Oral LD_{50} for liquid or solid (mg/kg), LC_{50} for gas (mg/m^3)	Species	Log coefficient (Octanol/ Water)	ERPG-2 based on inhalation	Threshold gaseous concentration	Threshold dosage, rounded value
			[-]	[mg/m^3]	[mg/m^3]	[$mg.min/m^3$]
Acrolein	LD_{50} 18	Rat	0.9	0.2		
Ammonia (100%)	LC_{50} 1420	Rat	0	100		
Benzene	LC_{50} 32000	Rat	2.1	470	313 000	9500000
Carbon monoxide	LC_{50} 7470	Rat	1.8	430	19839000	600000000
Chlorine	LC_{50} 852	Rat	1	6		
Hydrogen chloride (100%)	LC_{50} 7290	Rat	0.3	33		
Hydrogen cyanide	LC_{50} 222	Human	-0.25	10	136	4000
Hydrogen fluoride	LC_{50} 1030	Rat	0	20		
Nitric acid	LC_{50} 126 (NO_2)	Rat	0 – 1 [1]	10		
Phosgene	LC_{LO} 360	Human	0 – 1 [1, 2]	1		
Phosphoric acid	LD_{50} > 850	Rat	0	5		
Phosphorus trichloride	LD_{50} 18	Rat	0 – 1 [1, 2]	10		
Phosphoryl trichloride	LC_{50} 201	Rat	0 – 1 [1, 2]	3		
Potassium cyanide	LD_{50} 5	Rat	0	5	(solid) [3]	(solid) [3]
Sodium cyanide	LD_{50} 6.44	Rat	0.4	5	(solid) [3]	(solid) [3]

Agent	Median lethal dosage (oral or inhalation)		Input values for model		Mild toxic (non-corrosive) effects to the skin, estimated value	
	Oral LD_{50} for liquid or solid (mg/kg), LC_{50} for gas (mg/m^3)	Species	Log coefficient (Octanol/ Water)	ERPG-2 based on inhalation	Threshold gaseous concentration	Threshold dosage, rounded value
			[-]	[mg/m^3]	[mg/m^3]	[$mg.min/m^3$]
Sodium hydroxide	LD_{50} 4090	Rat	0	5	(solid) [3]	(solid) [3]
Sulphuric acid	LD_{50} 2140	Rat	0 [2]	10		

Legend:
(1) The approach is based on solubility in water.
(2) If a gaseous substance reacts with liquid water, a value of 2000 was used in the Skinperx-calculations;
(3) A dermal uptake can only be calculated from a water solution of the substance.

Notes:

1. The following notes help to explain the last two columns in table D-3. ERPG-2 and TEEL-2 can be used to estimate the maximum allowable body intake for the TICs in the CSG list.

Critical uptake = ERPG-2 x breathing rate x time *[1]*

2. To perform the calculations as critically as possible, a rather low value for breathing rate is used (a resting person: about 17 litres/minute). The time corresponds with the maximum time for the ERPG-2 value which is 60 minutes resulting in Formula 2 and because of the coincidental fit of the factors 0.017 and 60 results in a factor 1
:
Critical uptake = ERPG-2 x 0,017 x 60 [mg/m^3 x m^3/min x min = mg]. *[2]*

3. If no ERPG-2 value was known the TEEL-2 value has been used. However, If the maximum allowable body uptake for a chemical is known, and it is assumed that the skin is the only entry route of the chemical into the body, the skin uptake rate can be used to calculate the maximum allowable concentration of the TIC outside the body (maximum allowable concentration = maximum allowable body intake / skin uptake rate). Since hardly any dermal uptake rates are known for TICs on the CSG list these had to be calculated as well.

4. The dermal uptake of a gaseous chemical has been calculated by the Skinperx-model[2], using the solubility in water and partition between water and octanol. If for the TIC no log(octanol/water)-coefficient is known, this is approached using the Industox formula [3]. A value of 1 presents the lowest critical concentration, a value of 0 results in the highest critical concentration in the table.

[2] The latest version of this model of professor W. ten Berge can be downloaded from: http://home.wxs.nl/~wtberge/

5. This formula [3] below should only be applied when the solubility in water is less than 10000 mg/l. For a larger solubility Log PoW is assumed to be zero:

Log PoW = 4.5 – 0.75 x Log WO with,
PoW = octanol/water partition coefficient, and
WO = water solubility in mg/l (mark the dimension!!)

6. The critical exposure concentration ahs been calculated from these skin uptake rates:

(a) The exposed skin surface is assumed to be 2 m2 (adult 1.80m length, weight 80kg), and
(b) The exposure time (vapour TIC only, so no liquid particles) has been set at 30 minute.

7. These values in table D-3 are only given as a benchmark and should be replaced by experimental skin toxicity data as soon as these are available. Those agents that act locally (corrosives/oxidisers/other) have not been given an estimated dermal threshold dosage value because the method is not applicable; they pose an unknown dermal hazard.

D107 Biological agents - skin exposure

1. The general view is that biological agents can not penetrate intact human skin, except for some toxins[3]. Penetration through broken skin, caused by wounds, rashes and so on is however likely. Assuming that all agents deposited onto the damaged part of the skin enter the subdermal area under the skin, values for subdermal exposure might serve as a reference. They can, however, **not** be used as a toxicological criterion, because

a. assumptions have to be made about the size of the wound,

b. it has to be assumed that every organism that is deposited can cause infection via the subdermal route, and

c. no translation can be made between penetration through the clothing and deposition onto the skin.[4]

2. The subdermal infectious dose of anthrax (**LD_{50}**) depends on the strain and varies **between 6 and 10^9** viable organisms for monkeys[5].

D108 Biological agents - re-aerosolisation

Since re-aerosolisation from both clothing and skin is assumed to be a respiratory problem, the requirements for respiratory protection apply. The respirator triptych, D/103, can be used as reference. When wearing respiratory protection aerosol dosages resulting from re-aerosolisation should not exceed the challenges used in respirator testing. For those situations in which no respiratory protection is worn,

[3] LTSS SAS-024 on the Defensive Aspects of Chemical and Biological Warfare; NATO-document; RTO-TAR-57; AC/323(SAS)TP/30; (2002) NATO CONFIDENTIAL.
[4] Measuring the deposition is therefore strongly preferred over measuring the penetration, although this AEP only gives a method for the latter.
[5] Microbiological Diagnostics of Anthrax, Staritsyn, N.A.; Pomerantsev, A.P.; Aleshin, V.A., and Afanasyev, S.S.; VUNMTs, Russian Ministry of Public Health, Moscow (1999).

toxicological criteria for respiratory exposure apply. A similar approach can be used for exposure through ingestion.

D109 Radiological and nuclear warfare agents.

One reason for having protective clothing in a radiological or nuclear environment is that it prevents the body from getting contaminated itself; this would imply difficult decontamination procedures and the probability of spreading the contamination. The clothing also distances beta- and gamma-emitters from the skin reducing the received dose. Toxicological criteria can be derived from STANAG 2473 (2)[6] that states that decontamination of the skin can be stopped when the residual activity has become smaller than **10 Bq/cm^2.**

[6] Commanders Guide to Radiation Exposures in non-Article 5 Crisis Response Operations, the chapter "Contamination Limits for 7-Day and 3-Month Operations", subparagraph 2, Skin Decontamination.

ANNEX E - TEST SELECTION AS DETERMINED BY LIFE CYCLE PHASE

E101 Life cycle phases

Five major phases have been distinguished: Research and Development (R&D), selection/qualification (evaluating performance while new, during use; wear & tear, decontamination, etc.), pre-production (validation of selection and manufacturability), production control, and storage (assessment of shelf-life).

E102 R&D

1. In the R&D phase, major efforts will aim at determining the most critical properties of the material and (in a later stage) the clothing system. To do so requires a reproducible and severe test, which does not need to be completely realistic. For air permeable materials, this could be a high challenge vapour procedure to test the filter/carbon layer(s), an aerosol procedure to test the total combination of layers, and a large droplet liquid test to test the outer layer combined with the carbon layer. Pressure on the liquid agent, or contamination with sweat or battlefield contaminants could increase penetration and should also be examined during R&D.

2. For non air-permeable materials, a large droplet liquid test - again possibly combined with pressure on the liquid agent, or contamination with sweat or battlefield contaminants - and testing of seams and closures would be adequate material tests.

3. Due to experience, certain parameters are expected to be critical for a system (e.g. tearing strength, melting or flammability, ability to withstand wear and tear), and it is wise to give these critical points evaluation during R&D.

4. In addition, both the ability of a material to be effectively incorporated/manufactured into a protective system and the implementation of any appropriate system design elements (particularly closures) should be evaluated, especially if a new material has physical properties that are significantly different from materials currently in use,. Whole system testing using a standard high vapour challenge should be used (at a minimum) to evaluate prototype designs.

5. R&D may also incorporate alternate test formats that examine a particular feature of a protective material/system that is under consideration.

E103 Selection/qualification

In this stage, the design of the item/whole system must be evaluated with human testing for fit and comfort as well as with whole system vapour testing to determine leakage and the overall protection offered to the user. The item will have to show its capability to deal with all of the relevant requirements laid down in this document. Protection against realistic but severe combinations of physical (stored, worn, washed, polluted) and CBRN (liquid, vapour, aerosol agents) conditions should be evaluated on the total system, although for many evaluations swatch testing will offer much cheaper and faster answers on material level. Human trials combined with a follow-on laboratory whole system evaluation of the worn IPE will present the most valuable information on comfort, protection and durability.

Selection/qualification should be performed with prototype systems as a final development activity or on systems that have not yet entered mass-production, depending on national procurement methods. Only following completion of this phase should procurement specifications be prepared/finalised.

E104 Pre-production

This phase is required to verify that the equipment performs as required prior to it being mass produced. A significant selection of critical material and system level evaluations, as well as examination of manufacturing integrity, must be performed to confirm the manufacturing capability and consistency, and may need to be repeated several times before specifications are fully met.

E105 Production control

In the production control phase it may not be required to repeat all tests performed during the acquisition, pre-production phase. Again a challenging but reproducible material (and sometimes seam) test, not necessarily realistic, is needed to monitor the most critical parameters. This could, for instance, be adsorption rate or capacity plus liquid resistance for adsorbing/reactive systems and liquid-vapour permeation for non air-permeable systems. At least one type of system level test such as vapour test is also desirable but is not essential. Such testing tends to find a number of production control problems that are difficult to capture by inspection alone. Lastly, an over-all quality check of the system (adherence to sizing, sewing/seaming, packaging requirements etc.) should be performed.

E106 Storage

After manufacture, items must be stored in accordance with national requirements and the manufacturer's guidance. Although a shelf-life may be estimated based on accelerated aging studies, performance will still need to be validated by sampling of stored items, preferably from several storage depots, at designated intervals. The tests that must be performed are dependent on the types of materials and items in question. Ageing of polymers and natural fibres may cause both loss of structural integrity and reduced resistance to permeation and loss in tear strength, whereas storage conditions might affect the adsorption capacity of carbon or the reactivity of reactive materials. Material tests are adequate for these functions. The fit to the wearer or integration with other equipment items may be affected by aging (stiffening, shrinking), which might not be obvious during visual inspection or material testing. Suspect items should be further evaluated at the subsystem or system level.

E107 Required versus desired tests

1. Table E-1 provides guidance to the selection of test methods from Section 8.3 of the Triptych. Information is further broken down to indicate what type of testing should be done at each phase of the life cycle.

2. Non-marked cells indicate tests that are desired as well, but –at that stage- are felt to be not that informative to the degree of the tests mentioned in the table.

Table E-1 – Mandatory (M) and desired (d) tests for determining properties of clothing

				Life cycle phase				
Type of material	**Hazard or property**	**Test level ***	**Test type**	**R&D**	**Selection/ Qualification**	**Pre-prodn**	**Prodn control**	**Storage**
Air permeable	Vapour	material	vapour incident wind	d	d	M	d	
	Aerosol	material	aerosol incident wind	d	d	d	d	
	liquid neat	material	liquid neat incident wind with/without pressure (new and used clothing)	d	M	M	M	M
All	liquid thickened	material	liquid thickened falling drop diffusive	d	M			
	nuclear heat	material	heat flash		d			
	Durability	material	durability/laundering	d	M	M	M	M
	flame/heat	material	flame/heat		M			
	Comfort	material	Comfort	d	M			
	Vapour	whole system	chamber trial	d	M	M	d	d
	Aerosol	whole system	chamber trial	d	d			
	liquid neat	whole system	chamber trial	d	d			
	Comfort	whole system	user trial	d	M			
	compatibility	whole system	field trial	d	M			
	weight/volume	whole system	weight/volume	d	M			
	Camouflage	whole system	field trial	d	M			
	Durability	whole system	field trial		M			
Air impermeable	Vapour	material	vapour diffusive	d	M	M	d	

				Life cycle phase				
Type of material	**Hazard or property**	**Test level ***	**Test type**	**R&D**	**Selection/ Qualification**	**Pre-prodn**	**Prodn control**	**Storage**
	liquid neat	material	liquid neat diffusive with/without pressure (new and used clothing)	d	M	M	M	M

Notes:

1. *The distribution of the testing over the life cycle –as presented in this table- is not a requirement but a suggestion, based on the expert opinion of the ToE.*

2. *Any test performed on system level does not need to be replicated on material level.*

ANNEX F - TEST METHODS CBRN PROTECTION

SECTION F.1 PREPARATION

F101 Introduction

Before tests can be started, several preparatory actions are needed. This section describes those actions.

F102 Representative sampling

F102.1 Sampling location

1. Test samples shall be taken in such a way that they are representative for the entire quantity of material or quantity of clothing items they are meant to represent. If possible, tests should be carried out on systems or materials from the same lot, batch or blend. Each different part of a clothing system might need to be investigated, dependent on the test method and the aim of the test. If the protective material to be tested consists of more than one layer, the material "system" should be layered as they would be worn and the swatch cut from the layered system.

2. Swatches of material for the test cell may be cut from a larger piece/roll of material. Care should be taken to avoid cutting the swatch too near the edge, as well as to avoid obvious areas of imperfection related to the fabrication/manufacture of the material. Swatches of material should be cut to a size such that when test cells are assembled, a tight seal between cell parts is formed and no leakages along edges can occur.

3. Recommended methods for cutting the swatch include sharp tailor's scissors or a die-punch with a sharp cutting edge.

F102.2 Replicates

1. Different phases in the life cycle of the clothing item, and the variability shown by different test methods, can require different:

   a. sampling frequencies,

   b. numbers of samples per sampling location, and

   c. number of sampling locations.

2. Especially in the production control phase, sampling frequencies might be decreased or increased based on the variability and absolute value (relative to criterion) of results.

3. In order to obtain sufficient information for a statistical evaluation of a particular protective material, replicate tests are necessary. Data (or appropriately treated data, e.g. logarithm of data) should be treated with an appropriate statistical test to determine if it is normally distributed about the mean. If the data fails the normal distribution test, additional tests on the material should be undertaken to determine the true nature of the statistical distribution. For normally distributed data, sample variation

may be expressed either in terms of the standard deviation or standard error about the mean. Non-normally distributed data should be described by the median, 25th and 75th percentiles.

4. As a default value for swatch testing **three** samples per sampling location are considered essential, but eight are desired for the purposes of a formal comparison between different protective materials. If the data is determined to be non-normally distributed as many as 8 to 16 additional tests may be necessary to confirm its statistical nature.

5. For Whole system tests with volunteers **eight** suits are to be evaluated as minimum qualification requirement (25 desired). For whole system tests with a mannequin **three** replicates as a minimum shall be applied, since a mannequin only represents one part of the entire user population size distribution.

F103 Air permeability and air flow resistance

1. Air flow resistance / air permeability measurements must be done on the actual test sample. When this is not possible measurements must be performed on a similar sample cut just next to the tested sample.

2. The air flow resistance is determined by drawing air through the sample assembled in a cell with a fixed linear velocity (e.g. 1 cm/s) and measuring the resulting pressure difference with a manometer. From this result, the air resistance R_{mat} is calculated in [mm water/(cm/s)].

3. Alternatively, the air permeability is determined by applying a fixed pressure difference over the sample and measuring the resulting flow. From this result, the air permeability is calculated in [$cm^3/(cm^2.s)$] or [$l/(m^2.s)$].

4. It has been shown that for a normal air permeable material (air permeability between 2-90 $l/(m^2.s)$) the value determined for the velocity can be correctly extrapolated from a measurement at 1 cm/s. Vice versa, it has also been demonstrated that the velocity calculated indeed will result in the expected pressure difference over the sample[7].

5. The air flow resistance R in [mm water/(cm/s)] and the air permeability in [$cm^3/(cm^2.s)$] are correlated via the formula F.1.1:

$$R = \frac{12.70}{air\ permeability} \qquad \text{(F.1.1)}$$

F104 Preconditioning

1. Preconditioning is meant to get material or systems into a reproducible state, to get most reproducible results. Also, the preconditioning is meant to get a realistic state, which is assumed to be a skin-like temperature and relative humidity on the side most close to the sweaty skin. Samples shall be preconditioned at the same test conditions as the actual test, described in AEP-38 Volume II, Section VI (using the inside humidity).

[7] Theoretical and Experimental Study of Airflow Through Clothing around Body Parts. P. Brasser: *AIChE J.*, 52(11), 3688 – 3695 (2006).

2. Preconditioning for at least 12 hours is assumed to be adequate to obtain steady state condition. Care shall be taken that the test sample is in full equilibrium at the required conditions and that any actions needed between preconditioning and the actual test do not influence the conditioning state of the test sample.

F105 Pre-treatments

F105.1 Overview “ageing” of materials

1. Most tests are performed on "new" (unused and untreated) material. In addition to performing tests on "new" material, degradation of the material as a result of its storage and use, and the effects on the protective properties, should be tested as well. Use of the suit changes the material characteristics because the material suffers abrasion, and the surfaces are roughened and contaminated with sweat or dirt or forms of “field contaminants” like petrol, oil and lubricants (POL). Washing powder and surfactants also change the characteristics of the suit during laundering.

2. To evaluate these effects, protective characteristics are determined on pieces of material (when relevant including seams) after "use" of the material as simulated by laundering, and/or field trials and/or other wear and tear tests. Field trials offer the most realistic approach but are labour and cost intensive. Additionally, the results are not controllable or reproducible. Laundering combined with controlled wear conditions is a much more reproducible method to obtain worn material with or without sweat contamination.

3. The preparation of swatches of material with controlled fouling with field contaminants is also described in this method. The swatches thus obtained should be further evaluated with applicable test methods for protection.

F105.2 Required/prerequisite for the method

1. To age the material one needs:
   a. clothing item,
   b. a volunteer or mannequin, and
   c. laundering instructions/cleaning systems.

2. To treat the material with pollutant one needs:
   a. The material (supplied as a piece of material),
   b. The pollutant concerned, in correct concentration,
   c. Equipment like Petri dishes, weights, pipette, test cells; and
   d. Instructions on amount of pollutant per surface area, contact time, way of removal of pollutant.

F105.3 Sensitivity / reproducibility

For the tests where the material is polluted with chemicals like sweat or POL, reproducibility can be highly influenced by pollutant passing around test cell sealing mechanisms. Care should be taken to prevent the pollutant flowing along the edges to reach the side of the material normally not directly into contact with the pollutant.

F105.4 Test set-up

F105.4.1 Ageing

F105.4.1.1 Laundering

1. The clothing item should be laundered according to its laundering instructions. Laundering temperature, washing chemicals (and hardness of water), loading of the washing machine, washing program and even the kind of washing machine can affect the final result. The way the material is dried afterwards (tumble dried or open drying) and ironing also can make a difference.

2. A well known standard is ISO 6330, but within this standard still several conditions (temperature, washing duration, etc) are open for choice and should be decided on.

F105.4.1.2 Mechanical load and sweat

Several options can be used to expose a suit to mechanical load and sweat in a controlled environment, without "interference" of field contaminants.

a. Bicycle test. A volunteer completes a bicycle tour on a home trainer in a conditioned room (e.g. a 250 km bicycle tour with a 75 W workload, at 70 revolutions/minute and an average velocity of 25 km/hour, completed in 5 series of 2 hours). During this ageing, sweat will be released and evaporated, which contaminates the suit. The aged suit is allowed to dry before conditioning and exposure to the chemical agent tests.

b. Obstacle course. A volunteer completes a defined movement cycle (e.g. as described in Section F.2) in a conditioned room. Several series might be needed to achieve proper ageing. During this ageing sweat will be released and evaporated, which contaminates the suit. The aged suit is allowed to dry before conditioning and exposure to the chemical agent tests.

c. Mannequin. A mannequin completes a defined movement cycle (e.g. as described in Section F.2) in a conditioned room. Several series might be needed to achieve proper ageing. Since no sweat will be released, simulated sweat (EN 1811) will have to be applied separately, preferably before the movement series. The suit needs to be soaked with the sweat solution. The aged suit is allowed to dry before conditioning and exposure to the chemical agent tests.

F105.4.2 *Polluting with Non-CBRN contaminants*

F105.4.2.1 Background polluting with non-CBRN contaminants

The scenario for realistic pollution of suits is not defined. The worst case is dipping in (liquid) contaminants, which results in a very heavy pollution and the maximum effect. For larger areas to be "polluted" by sweat and sea water and for small areas -especially for gloves and boots- one could still expect this to be more or less realistic.

F105.4.4.2 Important parameters for pollution testing

1. Important parameters are:
   a. Chemicals, see below for a list of known field contaminants;
   b. Application method:
      (1) Side of material to be exposed,
      (2) Amount of chemical to be applied per surface area,
      (3) Application method (dipping, submersing, pouring, spraying, application of separate droplets)
      (4) Duration of exposure,
      (5) Removal of contamination (decantering, tamponing/blotting, wiping with tissue, evaporation), and
   c. Time and conditions until further testing.

2. For each treatment, the hazards involved with the pollutant (toxicity, flammability) should be mitigated.

F105.4.2.3 Examples of non-CBRN contaminants

Examples of non-CBRN contaminants (Exact components will vary per nation).

a. Petrol;
b. Oils;
c. Lubricants;
d. Solvents;
e. Decontaminants;
f. Field decontaminants,
g. Detergents,
h. Insect repellents;
i. Sweat;
j. Urine;
k. Feces;

l. Blood; and

m. Sea water.

F105.4.2.4 Application method for polluting with Non-CBRN contaminants

1. Several methods for polluting with non-CBRN contaminants are available, with the differences that in field situation both sides of the material will be polluted or only one side will be polluted. Two-sided pollution is performed by dipping, and one-sided exposure by applying the liquid to only the outside or inside of the material.

2. The application methods aiming at polluting just one side should prevent the pollutant reaching the other side (via wicking around the edges of the swatch material) unless penetration occurs. Effects of seams, local pressure of rings on the material, etc. all can influence the severity of pollution. This creeping of pollutant along edges is often difficult to observe and may highly influence further results. One way to prevent malicious pollution of the swatch is by assembling the swatch material on a round-bottomed pole which is dipped into the pollutant. Care should be taken that the edges do not get near the liquid surface. Also, after the polluting, care should be taken to prevent the surplus of pollutant from reaching the rear of the material when the pole is turned, the material is disassembled, and the testing swatch is cut out of it.

3. Other means of performing this pollution are with a cell where the edge of the material is elevated compared to the exposure area. The material combination is fixed by a ring which should seal onto the material and thereby prevent the liquid to go around the edge. This seal is also necessary during the end phase of the pollution when the surplus of material is removed.

4. Usually surplus of pollutant is removed from the surface before assembling the material in the testing cell for evaluation with CWA. The method of removal should be specified.

5. For sea water, sweat, urine and faeces, TOP 8-2-501[8] prescribes formulation for simulated pollutants and their application. ISO 16603[9] gives a formulation for synthetic blood. For sea water dipping of the swatch material during one hour could be chosen. The material is kept submerged by means of small weights onto the material. For body fluids/faeces, the specified amount (0.2 ml/cm^2) is applied on the inside of the material.

5. For other field pollutants, only pollution of the outside of the material combination should be applied. The amount applied can range from dipping to application of a few g/m^2 in small droplets. This can make a significant difference on the subsequent results.

6. For the time in between the application of the pollution and further tests, it makes a difference whether the polluted material is contaminated with warfare agent while still wet or after the polluting chemical has been removed or otherwise been allowed to evaporate.

[8] Permeation and Penetration Testing of Air Permeable, Semipermeable, and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing) TOP 8-2-501 (2004).

[9] ISO 16603:2004 Clothing for protection against contact with blood and body fluids -- Determination of the resistance of protective clothing materials to penetration by blood and body fluids -- Test method using synthetic blood.

7. For decontamination solutions –which should be applied as soon as possible after "detection" of the toxic challenge- the order of application on the sample is to start with application of the toxic agent followed (with some time delay) by decontamination, directly followed by determination of the protection/penetration.

F106 Agents

1. The purity and content of the agents used should be known, to ensure reproducible data.

2. Thickened chemical agents, because they are a mixture of distilled agent in a polymer carrier vehicle, are never pure. They are applied by mass as a drop or a "smear". Historically, distilled agents have been thickened with a standard batch polymer such that the viscosity was said to be 6.0 poise at 20ºC, but this value largely depends on the analysis method applied and should at room temperature be about 6 poise, extrapolated to "zero shear".

3. Some useful parameters of the warfare agents mentioned in this Annex are described in Table F-1.

Table F-1 – Some physical parameters of chemical warfare agents

Parameter	Units	Tabun	Sarin	Soman	VX	Mustard	Lewisite
Mass	g/mol	162	140	182	180	159	207
Density	g/cm^3	1.08	1.10	1.03	1.13	1.27	1.89
Boiling point	°C	247	158	198	298	217	195
Vapour pressure	Pa	4.83	282	36.4	0.044	9.14	29.3
Surface tension	N/m	0.033	0.0255	0.0251	0.032	0.0432	0.0418
	10^3 N/m^3	-	26.4	25.2	30.1	42.2	-
Viscosity	g/ms	2.56	1.54	3.64	12.4	4.47	2.26

Note. When tests are performed with a simulant only, the simulant/agent correlation shall be validated.

F107 Safety measures

1. The highly toxic nature of the agents used in the test methods means that handling these agents poses a high risk to human health. A thorough risk assessment is needed before setting up a test. The sources of the risk depend on the nature of the tests. Some of the potential sources of risks are human errors, unsafe application of personal safety equipment, vapour and aerosol releases, thread formation with thickened agents, adsorption of the agents to surfaces, insufficient decontamination of cells and other surfaces, and generation of toxic fumes and flame/fire.

2. Risks can be minimised by applying proper safety protocols and by continuous safety awareness amongst staff. Some elements of these measures are training of staff, both in handling the agents and handling the equipment, raising and maintaining safety awareness, continuous attention and common sense, proper air ventilation and filtration, working in containments, frequent checking and proper maintenance of test set-ups and air filtration, proper labelling of material and equipment, working in a

clean and well-organised workspace, setting up and maintaining emergency plans, presence of decontamination measures and equipment, suitable waste management, presence of medical countermeasures, and use of IPE for critical activities. It should be realised that wearing IPE can lead to diminished dexterity which in itself is risk enhancing.

SECTION F.2 WHOLE SYSTEM TEST - VAPOUR

F201 Overview of the method

1. This method is used to evaluate the design of the clothing system regarding leakages and the skin protective performance of an entire protective ensemble worn by people against a vapour challenge. For qualification, the test involves human wearers and a simulant vapour (e.g. methyl salicylate).

2. It should be stressed that by using a mannequin instead of volunteers during the qualification process, the information on fit and protection (size, effectiveness of closures, human factors like sweating) for the entire user population will be lost.

3. For experiments where fit to the entire human population is of less importance, a mannequin test platform can be applied.

4. The penetration of the challenge chemical through the materials and closures is measured using passive dosimeters that are designed to not interfere with air flow or system performance. The dosimeters are located at the important body parts to obtain representative data that reflect performance of the system at regions of different agent sensitivity and protective performance. The dosage measured at each location within the ensemble is compared with the test challenge dosage in order to obtain the protection factor at each location. These values, when combined with challenge and toxicological criteria for selected persistent chemical warfare agents, are used to obtain pass/fail criteria for the ensemble.

5. Use of other equipment like webbing or belt in system testing usually decreases penetration due to closer wear to the skin. If additional equipment is always worn, it should also be applied in this test procedure.

F202 General applicability

1. Applicability in the life cycle phases:

Table F-2: Applicable Life Cycle Phases

Phase of system qualification	Use and applicability
Research and development	May be used to determine effect of: • IPE design parameters e.g. materials, closures, overall garment design including fit • integration with other equipment • other variables e.g. wind speed and activity level of the wearer based on ranking, comparing or acceptability against criteria.
Acceptance/qualification for acquisition	Shall be used to accept/reject based on toxicological and challenge criteria.
Pre-production	Shall be used to evaluate manufacturing quality.

Phase of system qualification	Use and applicability
Production quality control	May be used. Can be replaced if desired by material tests and visual inspection.
Post-production shelf life and storage QC	May be desirable in addition to material tests if visual inspection indicates possible degradation of material/closure properties that could have an impact on system integrity.

2. While the methodology does assess the performance of peripheral items, such as gloves and boots and their integration with clothing, its primary usefulness is assessing the performance of clothing items, and their integration with other items.

> *Note: Using ancillary items or peripheral items other than the ancillary items or peripheral items of the intended use might seriously affect the result of the test and its interpretation.*

3. Subsystem tests (for example, glove or boot using nonhuman platforms) can be designed using similar principles specifically to evaluate peripheral items.

F203 Required/prerequisite for the method

1. Test specimens: Complete IPE per test includes respirator, protective garment, gloves, boots etc., which might be re-used for a next test.

   a. To be worn with appropriate ancillary items such as underclothes and other operational equipment (if desired) when equipment integration is to be investigated.

   b. For qualification, minimum eight replicates (at least 25 highly desired) must be tested with volunteers. 50 % of these shall be tested after use in field trials. Both new and used suit sizes must cover the 5^{th} to the 95^{th} percentile of the user population (both females and males) to the highest degree and as evenly distributed as reasonably possible, i.e. the anthropomorphic mean and variance of the human test subjects should be as close as possible to those for the military user group and must be reported (see F.1).
   For mannequin test a minimum of three replicates is required (see F.1).

   c. The anthropomorphic characteristics of each human test subject for a qualification trial must be determined and the IPE chosen to fit the test subjects (or the mannequin) according to the clothing sizing system.

   d. It may be possible to clean/decontaminate and re-use some test specimens that have been used in prior testing but new ensembles should be used unless the effect of reuse is well understood.

   e. Equipment worn outside the chemical protective layer in previous vapour system tests can usually be re-used provided it is not donned until after the entire vapour protective layer of the basic ensemble is in the closed state.

   f. Additional tests may be performed on ensembles preconditioned if desired e.g. laundering, previous wear.

2. Donning/doffing instructions for IPE.

3. Storage/care/laundering/decontamination instructions for ensemble if applicable.

4. Chemical protective materials used in the IPE having been qualified against the test vapour for the same test dosage/duration/environmental conditions in a material level test format.

5. Should a user group require a specific activity routine to be used because the standard routine of the method is deemed not sufficiently representative of activity type or level, an appropriate activity routine will be developed between the user group and the test specialist.

F204 Test method

ASTM F2588-07 "Standard Test Method for Man-In-Simulant Test (MIST) for Protective Ensembles" describes the test method as it is used for first responder style equipment when testing with humans[10]. Battensby et al[11] (live agent testing) and TNO[12] (simulant testing) describe a similar method for mannequin testing. Alterations on the ASTM method that shall be used for other types of more typical military equipment and with mannequin test platforms are outlined below.

F205 Sensitivity of the method

The method as described in this section can be expected to measure penetration values down to 10 mg.min/m^3 with some confidence and up to at least 20000 mg.min/m^3 under certain conditions. Future improvements to the method may permit better sensitivity. The desorption from the contaminated IPE and subsequent adsorption on the samplers during undressing may be an important contributor to the measured dosage for some material.

F206 Reproducibility of the method

There is a high variability in test results that arises from real variation of protection in use, e.g. due to fit to the wearer, closure performance and activity level. The value in increasing the number of test replicates is to obtain more confidence in the magnitude of this variation in actual use, not to reduce the variability of the measurement. This real performance variability will typically greatly exceed any variation that could result from undue variation in test conditions, provided reasonable and normal care is taken in test execution to avoid artefacts in measurement.

[10] Further details and discussion of the general methods are given in "A New Whole-Body Vapour Exposure Chamber for Protection Performance Research on Chemical Protective Ensembles", E.J. Scott Duncan and Eva F. Gudgin Dickson, 2003, American Industrial Hygiene Association Journal, 64 (2) 212-221
Whole system testing of NBC protective clothing, effect of leakage and comparison of different types of suits. H.F.G. Oudmaijer, R.J. van Eenennaam, 9th CBW Protection Symposium, Gothenburg Sweden 2007.

[11] A whole system test for assessing the protection afforded by NBC protective clothing after a liquid or vapour chemical agent challenge. J. Battensby, A.E. Hayhurst and A.L. Webb, CB Systems,CBD, Porton Down, Salisbury, UK. 6th CBW Protection Symposium, Stockholm, Sweden. 1998.

[12] Test methods of TNO-PML for air permeable and air-impermeable NBC protective materials, H.F.G. Oudmaijer, R.J. van. Eenennaam, TNO report PML 2004-PU-2, April 2004.

F207 Important parameters

F207.1 Environmental and challenge conditions

1. Wind speed is the single most important environmental variable for all styles of protective systems. Increased wind will cause increased penetration through air permeable materials and through closures in any material.

   a. Turbulent flow is preferred as laminar flow is not a realistic test condition.

   b. Homogeneous wind speeds in the wind tunnel are more important for a mannequin platform than for humans, as present-day mannequins do not relocate within the test chamber. Humans will receive an averaged wind effect as they relocate and reorient themselves.

   c. Wind speeds in the range defined in AEP-38 Vol II should be achievable within the test chamber.

2. Temperature and humidity conditions are described in AEP-38 Volume II, Section VI. For human use considerations (reducing the thermophysiological burden during the test) lower temperatures and/or humidities might be used, provided it has been shown that these changes do not affect the test result. Temperature and/or relative humidity may cause differences in performance when important material properties are affected: for example, lowered temperature may cause increased stiffness resulting in different closure leakage, while changes in temperature/relative humidity may affect moisture vapour permeable membrane structure. Note that since mannequins do not typically sweat, high environmental humidity may (partially) compensate for this in mannequin testing. These effects have not yet intensely been investigated, and for instance, it is unknown whether the heat from the working volunteer body does not more than compensate for any change in room temperature.

3. Except when over-saturation of the system could occur, the challenge concentration of test agent typically does not affect test outcomes when results are expressed as protection factors. In most cases, protective performance (when expressed as protection factor) is independent of challenge dosage but application of a realistic dosage is preferable.

4. Test challenge agent shall be sulphur mustard (mannequin only) or methyl salicylate as a generally validated simulant for sulphur mustard[13] . When using a simulant it should always be verified that its properties appropriately mimic those of the agent of interest (*see non-applicability*). The validation for methyl salicylate shall be reconfirmed for types of protective equipment/materials that have not been previously qualified.

5. Standard wind and test chemical challenge dosages for use in general-purpose ensemble qualification shall be derived from AEP-38 Volume II, Section VI, as outlined for HD.

F207.2 Test platform (human/mannequin)

1. A human test platform is usually preferred when the effect of garment design parameters is being investigated, particularly in the later stages of design, where variation in the human anthropometry is a

[13] Riviere, J. E., Smith, C. E., Budsaba, K., Brooks, J. D., Olajos, E. J., Salem, H., and Monteiro-Riviere, N. A. Use of methyl salicylate as a simulant to predict the percutaneous absorption of sulphur mustard. J. Appl. Toxicol. (2001), 21:91-99.

critical factor in performance of closures and in equipment integration. In addition, sweating can affect material and closure performance. Additional benefit is also derived from human feedback on other aspects of design performance such as comfort, fit, thermal burden, and ease of donning/doffing.

a. An approved human use protocol must be used when testing with humans.

b. Human use considerations include the use of methyl salicylate as challenge vapour, heat exhaustion/dehydration, psychological effects, and ability to safely wear IPE while performing activities.

2. A mannequin platform is useful when a highly controlled/repeatable or rugged test platform is required (in particular, tests to determine single individual variance, repeated tests with a change in a single environmental parameter, early R&D, quality control tests) or where there could be ethical concerns with human subjects (e.g. long duration tests > 2 hours, chemical warfare agent challenge, extreme temperatures).

a. The mannequin platform shall attempt to replicate representative human anthropometry and motion to the extent possible, including appropriately tissue-like sealing surfaces near closures.

b. For ease of decontamination, the mannequin typically will have mostly chemically hardened surfaces. These however will not behave like skin in terms of their vapour sorptive properties and this may be an issue when investigating protective systems that themselves have no sorption (e.g. polymeric materials vice active carbon systems); protection may be underestimated relative to the human. Alternately a highly sorptive mannequin surface could result in overestimation of protection.

c. It is desirable that the mannequin be able to rotate with respect to the direction of the incident wind so that the IPE is challenged with incident wind in all possible directions over the course of the test.

d. The fixing point of the mannequin shall be such that it does not interfere with the (moving) IPE clothing system and does not allow for leakages.

3. Application of either mannequin or human each has advantages and disadvantages[14].

[14] See also T. van Houwelingen, E.F. Gudgin Dickson and J. Tremblay-Lutter. Human-mannequin comparisons in testing NBC protective clothing. 6th CBW Protection Symposium, Gothenburg, Sweden. 2004.

Table F-3 – Mannequin or Human Advantages and Disadvantages

Mannequin		Human	
Advantage	**Disadvantage**	**Advantage**	**Disadvantage**
Size and movement are reproducible. Movement can be prolonged for long time.	The muscle and skin texture and softness is not represented adequately which may lead to non-representative closure performance.	All aspects of suit design and performance including interaction with human anthropometrics and physiology are investigated.	Medical-ethical aspects are involved; test will not be allowed at stressing environments like high temperature or with long duration. Variation in anthropometry is difficult to control in different test series; availability of appropriate IPE sizes for available volunteers is required
Adsorption tubes can be applied (into the body).	Mounting points for mannequin might require modification of IPE items; donning can be difficult due to limited range of motion	Dressing is usually simpler; no modifications to equipment required	Arranging tests depends on availability of volunteers
Live agent can be used as challenge agent	Most mannequins do not sweat and the skin will adsorb differently compared to real skin.	Movements and sweating are very realistic.	Only Simulant challenges can be used, which makes this test inappropriate for detoxifying systems.
	Uniformity of chamber exposure conditions within the mannequin exposure area is critical.	Uniformity of chamber exposure conditions is not as critical as individuals relocate within the chamber.	
	Thorough decontamination of the mannequin surface can be time-consuming for some construction materials; vapours may adsorb into materials with long off-gassing periods, and construction materials may not be resistant to all decontaminants. Immediate re-testing may not always be possible, slowing accrual of data.	Data accrual can be relatively rapid. Thorough decontamination is not an issue when new volunteers are available. People self-decontaminate of some types of challenges relatively quickly through hygiene	

F207.3 Activity routine

1. Activity level is important to performance, as motion will stress the protective system in a variety of ways. The activity level shall not exceed the expected level of intended use, nor should it fail to reflect realistic stresses to the system.

2. A standard human activity routine is provided below, and a routine as similar as possible shall be used unless the intended user group has greatly different operational requirements (e.g. first responder groups may use the activity routine given in the ASTM standard).

3. Standard human activity routine:

   a. Move weights. Two 2.5 kg weights are repeatedly lifted from a shelf (at waist level) and placed on the floor. A standing position is then assumed. The weights are retrieved and returned to the shelf. The right side of the participant faces the wind.

   b. Sit (facing wind).

   c. Jumping jacks. One jumping jack is performed about every 2 seconds, and every few seconds, the participant rotates position so that a different aspect is facing the wind.

   d. Sit (back to wind).

   e. Walk on treadmill. The participant walks at a rate of 1.3-1.8 m/s facing the wind.

   f. Sit (facing wind).

   g. Climb ladder. The test participant repeatedly climbs 2-3 steps of a stepladder and touches the ceiling of the vapour test chamber (alternating hands), then returns to the floor and squats to touch the floor with both hands. The back of the test participant faces the wind.

   h. Sit (back to wind). The participant looks side-to-side then at ceiling and floor every 15 seconds.

4. Use of the protocol:

   a. This protocol reflects a moderate activity level.

   b. The order of the activities is not critical to protective performance; in a 2-person chamber, alternation of the active and resting activities permits one person to rest while the other is active.

   c. The duration of each activity is identical (e.g. 5 minutes each, repeated a total of 3 times for a 2 hour test duration; 3.75 minutes each, repeated twice, for a 1 hour test duration).

   d. The routine is designed to provide movement of the participant over the full useful area of the test chamber and varied orientation with respect to the wind direction. The wind orientations above are suggestions and other varied orientations balanced over the test duration are permitted.

   e. If multiple persons are tested simultaneously, care should be taken that all participants receive reasonable exposure to the wind with minimal shielding of each other.

5. Mannequin activity routine:

   a. The standard mannequin activity routine should mimic as closely as possible the level and type of activities provided above. Ideally mannequins should be able to replicate the full range of human movement including bending at the waist and head movement.

F207.4 Test duration

1. In most cases the test duration will have little effect on the test outcome (see non-applicability). The preferred test duration for a standard evaluation exceeds 1 hour.

2. Longer test durations can evaluate degradation in protective performance over time e.g. closure failure, and resolve higher protection factors.

3. Shorter test durations may be necessary when respirator performance is limiting (e.g. self-contained air with human test subjects); however no test shall be less than 30 minutes in duration (to improve equilibration of measurement systems and ensure protective performance).

F207.5 Contamination issues

1. It is important that dosimeters not be unduly contaminated by the test challenge vapour, or any other interfering material, at any point during their handling.

2. An appropriately clean environment must be provided at all stages where the dosimeters are exposed. Only during doffing will the dosimeters necessarily be exposed to background contamination; the doffing area should be as clean as possible. Background test chemical dosages shall be measured during dosimeter recovery.

3. All test materials that are re-used after potential contamination (e.g. sample containers, protective equipment) shall be treated in a manner that will ensure no significant contamination of the dosimeters.

F207.6 Dosimetry

1. Dosimeters must not themselves affect the outcome of the test. Important characteristics thus include:

   a. Passive sampling.

   b. Low profile/sampling surface flush with surface of test platform.

   c. Sampling (vapour uptake) rate comparable to that of skin. Skin adsorption rates for these chemicals are on the order of 0.1 – 10 cm/min.

   d. Reasonably linear, calibrated response in the range of (at least) 1 - 2000 mg.min/m^3.

2. Acceptable current examples of dosimeters consist of a package or tube with the following components:

   a. A membrane (e.g. silicon or high density polyethylene film) with a calibrated uptake rate for the test challenge chemical on the order of 2 - 4 cm/min that limits the diffusion of test agent into the dosimeter.

   b. An adsorbent that can take up the entire received vapour dosage. The test chemical can be quantitatively removed from the adsorbent by thermal desorption (typically GC analysis) or solvent washing (typically HPLC analysis).

3. PADs (passive adsorbent dosimeters) are small flat adhesive packets that can be stuck to skin or other surfaces. Taping of the PAD to the skin will minimise loss during testing and adsorption of the test challenge chemical to the adhesive on the back of the PAD. PADs cannot be reused. The uptake rate of the dosimeter (by lot of polyethylene film/PAD) must be determined regularly.

4. Dosimeter tubes intended for thermal desorption GC analysis are also used with mannequins. Tubes can be reused if cleaned appropriately.

5. PADs or dosimeter tubes shall be located at a minimum at all positions specified in the ASTM method for human testing, and as closely as possible for mannequin testing.

6. Extra positions may be used to assess additional desired performance features (specific closures, etc.). Addition of extra samplers must not lead to bias towards well protected areas, but in stead lead to better identification of the true protective performance of the clothing, especially at its weak areas. Placement should not interfere with the efficacy of any closures/seals to the skin. Each extra sampler shall be assigned to a body region as described in ASTM F2588. An example is presented in Figure F.1.

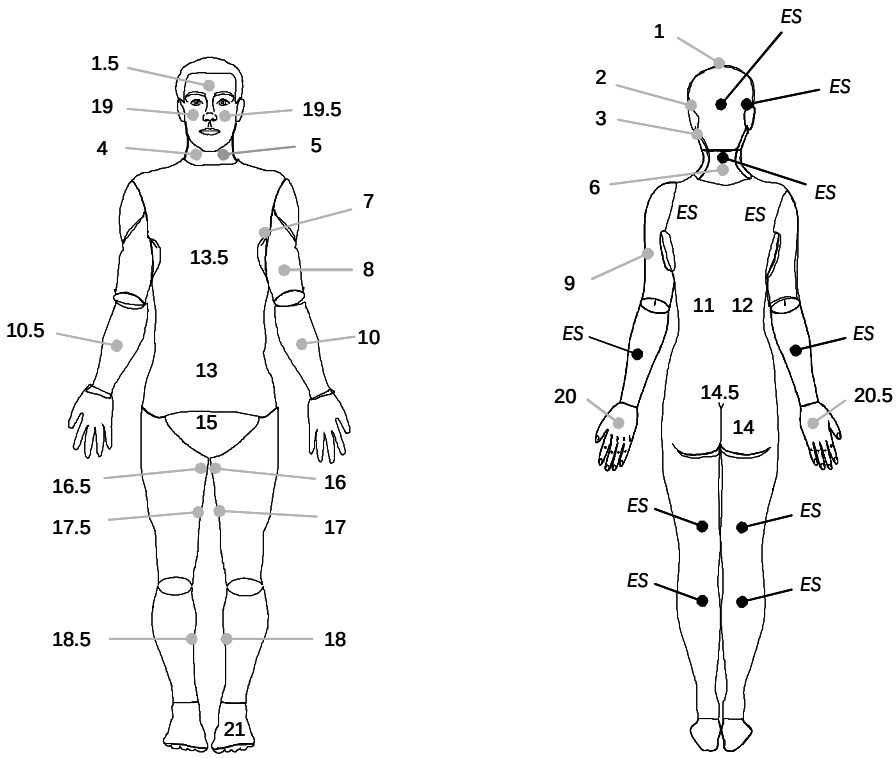

Figure F-1 - Example of sampler positions*

Note: The numbers are samplers according to ASTM F2588, with extra sampler positions (ES) added to achieve full coverage of the suit system's characteristics, in this case at the body regions at the back of the person.

F207.7 Dressing/undressing

1. Skilled dressers trained in the wear of the items are required; these may be either the wearer or test personnel. At a minimum, one skilled dresser should be available to supervise the process.

2. Undressing must be performed correctly, in order to minimise undue dosimeter contamination. This involves appropriate, speedy doffing procedures that minimise contact transfer of contamination from hands or IPE surfaces.

F208 Data analysis

1. Before analysis samplers shall be analyzed for physical damage. Damaged samplers shall not be analyzed and shall be considered as lost. No more than 5% of the dosimeters shall be lost in any given test or the test shall be invalid for qualification purposes. Losing samplers shall not lead to the absence of data on any body region as defined in ASTM F2588.

2. For its first purpose (estimation of leakage points, determination of over-all protection factor) the test data can be –for instance- presented as a graph showing penetrations per body area.

3. Although the test might be performed with a simulant, the penetration values shall be toxicologically analysed for HD. The penetration values for HD shall be toxicologically analysed at every body location (each of the dosimeter locations for each test) using the test data for each individual test. Data must be normalised to the aimed for challenge conditions given in AEP-38 Volume II, Section VI, and compared with the acceptable effects dosages given in Annex D.

$$normalized\ \ penetrated\ dosage = \frac{aimed\ \ for\ challenge\ dosage}{actual\ challenge\ dosage} \times actual\ \ penetrated\ dosage \qquad (F.2.1)$$

4. This calculation can only be done for systems that show linear behaviour of penetration with external challenge dosage in the range of the actual and aimed for challenge dosage.

5. The toxicological analysis for GD can be performed using the methodology of the ASTM method using the test data for each individual test, aimed for challenge conditions given in AEP-38 Volume II, Section VI, and the acceptable effects dosages given in Annex D.

Note: The formula given in the 2007 edition of ASTM F2588 has been found out to contain an error in it for calculation of the systemic PPDF (compared with the equation that is in the NFPA 1994-2007 standard that is correct). The ASTM will be correcting that equation as a result[15].

[15] Another possible future amendment involves the vales in the table "ED50 values by PAD and body location". It has been suggested that some values might be switched for a couple of the regions: ED(50) upper arm lateral and forearm extensor should both possibly be 2.8 and upper arm medial and forearm flexor should both possibly be 6.57. Users of the standards are recommended to follow the development of new editions closely and to cross reference with other sources.

$$normalised\ systemic\ dosage = \frac{aimed\ \ for\ challenge\ dosage}{PPDF_{sys}} \qquad (F.2.2)$$

F209 Pass/fail criteria

1. Not more than at one body region in any test shall samplers be permitted to fail the requirement for HD. None of the samplers at that body region shall fail by more than a factor of 2. If the sampler is, however, the single representative of that body region, comparison with the same body region results from other tests of the same suit system is allowed, to determine whether this sampler was an outlier.

2. No individual system tested should fail the requirement for GD.

F210 Non-applicability

1. The application of simulants should be used with even more care whenever the contribution of penetration/permeation through the material is more significant. In that case the question whether the simulant indeed represents the behaviour of the agent becomes more important. This performance should always first be assessed in material level vapour testing, with the chosen test agent (simulant or CWA) both under the test conditions and under the intended conditions of actual use. Some materials may give non-linear performance as a function of time or concentration.

2. This method will not yield data on protective performance against toxic vapours that do not behave like persistent chemical warfare agents (or the chosen simulant methyl salicylate if used) in terms of their interactions with materials (sorption, reaction, permeation).

3. This method -in general- is currently not sensitive enough to measure required respiratory / eye protection performance against vapours; it will measure skin protection within the respirator. Some information on respiratory/eye protection performance and its possible degradation by integration with the system may be inferred if measurable dosages are observed on the dosimeters within the respirator.

F211 Reporting

See ASTM F2588 for a general reporting format. Next to the normalised penetration results and their interpretation, additional information should be provided about fit of the clothing system to the test subject(s) (e.g. sizes of subjects and clothing), agent selection, test conditions and methods, and the analysis method used.

SECTION F.3 WHOLE SYSTEM TEST - LIQUID AND AEROSOL

F301 Overview

1. No widely established methods are available for the determination of the protective performance of entire clothing systems against liquid and aerosol challenges. Still, there will be useful information (additional to just material testing) upon determination of the combined effects of moving and intermittent pressure onto the liquid, movement of the material and airflows underneath the clothing. In this section some remarks are made about the methods, based on experiences with the whole system vapour test, described in Section F.2, and the experiences by laboratories that are already performing the tests.

2. The basic method for system exposure to liquid and aerosol sampling is identical to that of vapour testing, with some exceptions, amongst which the application of liquid and positioning of samplers, and the generation of aerosols, detection methods and toxicological interpretation of results (see also Section F.9) are most noticeable.

F302 Required/prerequisite for the method

See F0203.

F303 Applicability/non-applicability

1. When simulants are used, a limitation is formed for both forms of challenges by the degree the simulant is able to represent the real agent. This involves both the penetration behaviour and the possibility to extrapolate penetration/deposition data from the simulant to the agent it is meant to represent.

2. Next to the factors determining the applicability of the whole system vapour test, the applicability of the CWA liquid test is determined by the representativeness of the liquid application and by the degree of representative sampling.

3. Next to the factors determining the applicability of the whole system vapour test, the applicability of the aerosol test is determined by the degree of representative sampling of the deposition onto the skin (and the vapour exposure to the skin, for volatile agents) and for non-human test platforms the difference in deposition velocity of the surface compared with human skin. A non-volatile simulant cannot be used to predict the effects of a volatile agent.

F304 Sensitivity / reproducibility

1. Similar general information as presented in F.2 can be given about the sensitivity or reproducibility of the methods, but no data can be given yet about the range of dosages/protection factors that can be detected.

2. The sensitivity of the liquid challenge test is dependent of the relative location of the drops and the samplers. The samplers must be positioned so that the maximum challenge to the skin caused by the drop is detected.

3. For aerosol challenges, some remarks are made in Section F904.

F305 Test set-up

F305.1 Liquid challenges

F305.1.1 Agent selection

Tests can be performed with CWAs or with simulants. It should be noted that chemicals which are good simulants for CWAs in vapour form need not be so for agents in liquid form. Particularly liquid-outer layer interactions can be different (contact angle, chemical interactions). Even when using simulants for safety reasons the use of a mannequin platform might be preferred over participation of human volunteers.

F305.1.2 Hardware

See F.2. Instead of a vapour generation device, a method is needed to apply drops in a representative way, see also Section F.5. Identical sampling methods as used with the vapour test can be applied.

F305.1.3 Test specimen and replicates

See F.2.

F305.1.4 Agent application

Challenge levels may be delivered as per AEP-38 Volume II as liquid, thickened liquid, laid drop, falling drop or with the application of pressure (identical pressure as in the swatch test). See also Section F.5.

F305.1.5 Analysis

See F.2.

F305.2 Aerosol challenges

F305.2.1 Agent selection

Currently, only simulants are used for aerosol protection measurements. An aerosol of the appropriate size should be used, as defined in AEP-38 Volume II, section VI. Simulants may be either organic solids or liquids (non volatiles) such as sodium fluorescein, sodium chloride, syloid, DEHS and Emery Oil or biological particles such as *Bacillus Atrophaeus* (formerly *Bacillus Subtilis Var Niger*) (BG). A solid radiological aerosol with a short decay rate can be used as simulant for radiological challenges. Even when using simulants for safety reasons the use of a mannequin platform might be preferred over participation of human volunteers.

F305.2.2 Hardware

See F.2. Instead of a vapour generation device, an aerosol generation device is needed (some remarks are made in F0905). Depending on the nature of the agent, other sampling devices can be needed.

F305.2.3 Test specimen and replicates

See F.2.

F305.2.4 Agent application

Challenge levels may be delivered as per AEP-38 Volume II, Section VI. A reproducible dissemination method should be used such that the aerosol concentration delivered to the exposure room is homogeneous and steady. The mass median diameter and range of the challenge must be described.

F305.2.5 Analysis

1. For solid and non-volatile aerosols deposition measurements are needed[16], for volatile aerosols both concentration and deposition measurements. Different methods of detection will be required to measure dermal deposition of aerosol dependent on the aerosol used. Methods include fluorimetric detection and/or biological culture for chemical and biological aerosols and direct activity reading for radiological aerosols.

2. Care must be given to the placement of passive dosimeters to ensure that any penetrating agent vapour is detected.

F306 Test parameters

1. The duration of the test should be as defined in AEP-38 Volume II, Section VI. If possible intermediate points are needed at 2 and 6 hours (unless the time stated for the test is shorter).

2. In addition to the parameters described in F.2 the result of the liquid system test is dependent on:

   a. Drop application,

   b. Drop size, and

   c. Positioning of samplers.

3. In addition to the parameters already described in F.2 and F.9 the result of the aerosol system test is dependent on

   a. Aerosol mass distribution / particle size distribution. Heavier/larger particles tend to settle faster on surfaces and will be filtered out faster by air permeable clothing.

   b. Aerosol volatility. The volatility of the aerosol will determine whether particle size distribution is varying due to evaporation and whether a significant vapour challenge is present.

   c. Doffing procedures. Particular care should be taken during undress to avoid transfer of aerosols from the outside of the clothing to the skin and samplers.

   d. Sampling procedure. The degree to which the sampling procedure reflects human skin behaviour determines the degree to which the results can be used to assess the protective performance of the clothing. The sampling procedure may determine only the total mass of

[16] Alternately, a penetration test can be used following the calculations of F907.3.

the deposited material, or the total number of particles of deposited material. In both cases the other cannot always be inferred. The sampling procedure may determine only deposited aerosol or aerosol concentration within the protective ensemble. These differences may be important depending on the mechanism of toxicity of the aerosol.

F307 Interpretation of test results

1. Liquid agent penetration results might be interpreted in a similar way as vapour penetration results with regard to skin toxicity. Data can be compared with the data presented in Annex D. Protection factor calculations are different, since no simple linear correlation can be made with an outside dosage.

2. The interpretation of skin exposure data after aerosol challenges is complicated, especially for (solid particles impregnated with) volatile agents, since skin exposure is then a combination of particle and vapour exposure. If the test is not performed using humans, the difference in deposition velocity on the mannequin surface compared with skin must be taken into consideration. Since no criterion exists for skin exposure to aerosols, except for radiological agents (Annex D) a comparison with toxicological data cannot lead to a decision whether the protective performance of the suit is sufficient. Chemical aerosol dosages can, however, to some degree be compared to vapour dosages, see Annex D.

3. If the test with a radiological aerosol is not performed using humans, the difference in deposition velocity of the surface compared with skin must be taken into consideration. Reduction of skin dose to the required level will be achieved by a combination of protection and subsequent decontamination. The required protection can be calculated using a combination of the challenge, the decontamination efficiency and the allowable dose to be left on skin for beta-emitting radiological agents (10 Bq/cm^2, Annex D).

F308 Reporting

See ASTM F2588 for a general reporting format. Next to the normalised penetration/deposition results and their interpretation, additional information should be provided about agent selection, test conditions and methods, and the analysis method used.

SECTION F.4 CWA AND TIC VAPOUR SWATCH TEST

F401 Overview of method

The method involves exposure of material combination to a vapour challenge. The penetrated amount of vapour in a specified time is determined.

F402 Required/prerequisite for the method

The required prerequisites for the method are:

a. Material,

b. Air flow resistance of material (see F01013 determination),

c. Test fixture and cells,

d. Information on size of body part and distance between skin and clothing to be simulated, and

e. Simulant versus agent correlation (if a simulant is applied).

F403 Applicability

1. The test is explicitly suitable to rank materials during R&D and for first qualification before more expensive (complicated) qualification by means of a system test is performed.

2. The described vapour test is mostly applicable to air permeable materials, but with an adjusted ("flushing") cell design it can also be applied to air impermeable materials, and brief information on adjusting the method for air impermeable materials is presented at the end of the description. For air impermeable materials this test should only be performed when liquid tests (see Annex F.7) show penetration.

F404 Sensitivity / reproducibility

The minimum sensitivity of the analytical system should be such that over the prescribed period a minimum of $1/10^{th}$ of the criterion as defined in Annex D can be detected. To calculate the absolute sensitivity needed, flow, number of samplings, accumulation time per interval and the criterion should be taken into account.

F405 Test set-up

F405.1 Agent selection

1. The method can be used directly for any chemical agent that can be delivered in the vapour phase. The vapour test gives rise to a homogeneous vapour contamination of the material combination to be evaluated.

2. A validated simulant can be applied instead, but the correlation should be validated on the actual kind of material to be evaluated. This makes simulant application only routinely suitable for Quality Control testing. The important parameters of the agent/simulant depend on the technique for protection applied in the material combination.

a. When adsorptive layers (carbon or other adsorbing filters) are applied the boiling point and the affinity of the agent/simulant for the carbon are most important while size of the molecule usually is less important. When a simulant has to be chosen those aspects should be correlated.

b. For a technique based on molecular filtering (microporous membranes) the size, form, solvability and polarity of the agent/simulant molecules are probably more important.

c. For a technique involving reactivity, the interaction of reactant and chemical is important.

F405.2 Hardware

1. The hardware of the test set-up consists of a generation system to create the required amount of humidified air contaminated with the prescribed toxic agent concentration. The generation system is connected to a conditioned confined space (vessel or room) where –during the exposure part of the test- the cells with the outside of the samples exposed to the agent in the vessel have been introduced.

2. Each sample is fixed with the edges secured leak tight in a cell which has an opening at the back to a suction system to draw air through the sample. For a cell a minimum diameter of 4 cm is felt most appropriate to be large enough to be able to identify inhomogeneity of material in the replicates of the test and not to see too much influence of wall effects. Regarding the cell design, it is felt most important that the flows through, over, and under the clothing are homogeneous and in direct contact with the clothing.

3. During the actual test, the samples in the cells are thus exposed to a regulated and controlled agent vapour concentration, temperature, relative humidity during a specified time (see AEP-38 Volume II for sets of agent/concentration/humidity/wind speed/time). The exposure should mimic a wind blowing perpendicular to the fabric. The concentration above the sample combination should be monitored and the amount of challenge "used" by the samples should be re-supplied, which needs a dynamic generation of challenge. For air permeable materials in a cell this can be simulated by drawing air through the material with calibrated flow regulators (e.g. mass flow controllers) at a linear flow calculated with the formula[17]:

$$F_{mat} = \frac{0.058952}{1 + 0.006429 \times r_{cyl}^2 / \left(d^3 \times R_{mat}\right)} \times \frac{V_w^2}{R_{mat}} \qquad \text{(F.4.1)}$$

With:

F_{mat} = linear flow through material [cm/s]

r_{cyl} = radius of the body part to be simulated [cm]

[17] The formula is both theoretically derived and practically validated to simulate the maximum flow (at the point of perpendicular flow) through an air permeable material folded at a fixed distance along a cylindrical object. Theoretical and Experimental Study of Airflow Through Clothing around Body Parts. P. Brasser: *AIChE J.*, 52(11), 3688 – 3695 (2006).

d = distance between clothing material and skin [mm]

R_{mat} = Air flow resistance of material [mm H_2O/(cm/s)]

For the suggested standard settings using rcyl (10 cm) and d (2-5 mm) the formula changes back into the well known:

$$F_{mat} = 0.057 \times \frac{V_w^2}{R_{mat}} \qquad \text{(F.4.2)}$$

4. The volumetric flow rate (cm^3/min) is obtained by multiplying the calculated linear velocity (cm/s) with the cell surface area (cm^2) and a factor 60.

5. For the air permeable material the air drawn or blown through the material can be scrubbed in an organic solvent or collected onto an adsorbing medium like Tenax, which can be analyzed at the end of the test to reveal the amount of agent penetrated through the fabric. This amount can be recalculated with the flow into an average exposure dosage by means of formula:

$$Dosage = \frac{penetrated\ amount}{total\ volume\ of\ air} \times time \qquad \text{(F.4.3)}$$

Note: When blowing air towards clothing the flow through the material depends on the material resistance and the resistance of the equipment behind the material.

6. Alternative methods for contamination and detection. Another appropriate way to analyse the protection offered by the material is to have a passive dosimeter or an on-line detector at a small distance underneath the material combination with the flow of air through (and subsequently) underneath the clothing flowing over the dosimeter. At the end of the test the dosimeters are removed and analysed, recalculating the exposure dosage by means of the calibration curve.

Note: The calibration curve is prepared at comparable conditions of flow, concentration and exposure time.

7. An example of such equipment is the "cylinder" test, where the agent vapour is applied as the flow of contaminated air at and along the object. The advantage of this configuration is that fewer modelling assumptions are made, while the disadvantages are that it requires a larger test fixture and involves a method that is quite in its developmental state.

F405.3 Test specimen

1. The air resistance of the conditioned test specimen is determined and the required amount of swatches is cut to fit the cell. Measuring the air resistance of each individual swatch is advisable (see F.1). Each swatch is examined to note obvious flaws; if flawed it should be discarded and another swatch should be prepared.

2. The swatches are assembled in the cells and stored for conditioning for at least 12 hours.

F405.4 Agent application and test duration

1. Analysis systems are attached to (or assembled in) the cell, and the cell is connected to the vessel containing the dynamically generated vapour concentration. The material is exposed for the required test time under the calculated flow through the cell to the challenge concentration as presented in AEP-38 Volume II.

2. The duration of the test should be as defined in AEP-38 Volume II, Section VI. An intermediate point is needed at 2 hours (unless the time stated for the test is shorter).

F405.5 Analysis

The amount of agent or simulant penetrated through the material can either be accumulated in a liquid or in a solid adsorbent. It could also be monitored on-line.

a. Liquid adsorbent:

   (1) Here the agent or simulant is adsorbed in a known aliquot of liquid by flowing the penetrated vapour through. The liquid is usually contained in an impinger. The agent vapour is extracted from the air flow as it bubbles through the solvent. The collection efficiency of the impinger for the selected solvent and chemical agent must be determined at the collection air flow rate, RH and temperature that will be used in the test. The advantage of using impinger samplers is that there is usually sufficient sample left to perform a repeat analysis. The disadvantage however is that sensitivity maybe limited and the increased volumes of hazardous waste. The volume of the air flow drawn through the lower chamber and into the gas bubbler impingers has an impact on the trapping efficiency of the solvent used in the impingers. If the air flow and/or the vapour pressure of the agent are too high the trapping efficiency is reduced. The total amount of agent/simulant collected during the test should remain well below the adsorption capacity of the liquid.

   (2) At the end of the test the amount of penetrated chemical in the liquid is determined by -for instance- Gas Chromatographic analysis and a calibration curve.

   (3) The chemical agents of interest must be highly soluble in the solvent in order to maximise the extraction of agent from the air stream passing through the impinger. Solvent loss from the impinger must be kept to a minimum to avoid artificially concentrating the agent in the solvent. Two recommended solvents are diethyl succinate for sulphur mustard (HD) and for soman (GD), for which dibutyl phthalate can be applied as well. Chemical agent collection efficiency must be $\geq$95% for a test of any duration. Solvent loss must be small and known, preferably $\leq$5% over the duration of a 24 h test, which can be achieved by cooling.

b. Solid adsorbent:

   (1) The agent or simulant adsorbed in a solid adsorbent – a piece of material or an adsorption tube for instance- can be eluted with a known amount of liquid or by thermodesorption. For both methods the extraction efficiency should be known and the resulting liquid sample (or vapour sample for the thermodesorption) shall be analysed with -for instance- Gas Chromatographical analysis and a calibration curve.

c. On-line monitoring:

(1) The advantage of an on-line monitoring system is the additional information about the breakthrough process by means of the obtained breakthrough curve (instead of a cumulative breakthrough amount). Disadvantages of the automated sampling and analysis systems are that no reserve sample is available to check results and unexpected high penetration may saturate the instrument and result in lost data.

(2) The on-line monitoring system should be calibrated for the agent/simulant. Because this system has a smaller accumulation time compared to the aforementioned detection methods, the on-line system should be highly sensitive. Sensitivity to differences in other environmental properties (pressure, relative humidity, temperature) or interferences (chemicals desorbing from the sample) should be validated.

(3) When a flow has to be drawn into the detector system care should be taken that no additional airflow through the sample combination is introduced.

F405.6 Replicates

The number of replicates is described in F102.2.

F405.7 Critical parameters

1. The prescribed environmental and challenge parameters for the vapour test are presented in AEP-38 Volume II, Section VI.

2. Parameters that should be regulated, controlled and reported for this test are:

Table F-4: CWA and TIC Vapour Swatch Test Critical Parameters

Flow through material	Flow will have an impact on the penetrated dosage.
Concentration	Challenge dosage and concentration increase concomitantly.
Time	Challenge dosage and time increase concomitantly.
Equipment materials	Used behind the test sample should be non-adsorptive for the toxic agent applied.
Pre-conditioning	Temperature and relative humidity can influence some materials.
Temperature	Has a limited effect of about 1%/°C.
Relative humidity	Can affect penetrations (e.g. high RH may reduce adsorption capacity) and can have a large impact on certain membrane like materials.
Size of cell	Shows no relation with dosage above minimum size.
Ventilation rate below material (for air-impermeable systems)	An increase will linearly decrease measured penetrated concentration; since toxicological interpretation depends on concentration/dosage only ranking is possible unless ventilation rate is known to be meaningful.

F406 Interpretation of test results

1. The important parameter is penetrated dosage as function of time. These results do not necessarily relate directly to whole system test data, but describe material performance against vapour under a select set of controlled conditions.

2. The criteria for a whole system test –if available for the agent evaluated- are presented in Annex D. These can be applied as a benchmark for the material test as well.

F407 Adjustments of hardware (F405.2) to air impermeable material

1. Each sample combination is fixed with the edges secured leak tight in a cell which has two openings at the back, one of which is to be connected to a suction system to draw air along the bottom side of the sample with at least 100 ml/min to the detecting device. The detection system should be sampling this air drawn along the bottom of the polymer film which should be underneath the sample. To allow for calculation of a (static) penetrated dosage a calibrated polymer film dosimeter may be placed under the material (see F.7). If no polymer film is used only a penetrated mass or mass per area can be reported.
The contaminated air is introduced through the second opening in the cell and should be flushed over or at the sample, as no air will be drawn through the sample.

2. The cylinder test described in F0405.2 “Alternative methods for contamination and detection” for air permeable material is also suitable to be applied to air impermeable material.

F408 Adjustments of test method for TICs testing

If necessary, adjustments needed for TICs testing include:

a. Adjustment of the vapour generation device, e.g. by using a compressed gas cylinder;

b. Adjustment of the test cell materials and other materials in the test equipment to account for corrosive TICs; and

c. Adjustment for the analysis method.

F409 Reporting

The report should show:

a. Identification of the tested material.

b. Pre-treatment(s) of the material before testing.

c. Description of the test method and test conditions, including;

(1) actual challenge agent,
(2) concentration,
(3) temperature and relative humidity,
(4) linear flow of air applied through the clothing, and
(5) duration of the test.

d. Observations like visible changes in the material.

e. Dosages at the successive time intervals.

SECTION F.5 DROP APPLICATION METHODS

F501 Volume/Mass of Liquid Drops to Contaminate Material Swatches

1. The liquid drop contamination density is the total mass of chemical agent in droplet form present on the surface of the swatch per unit area. To determine the contamination density it is necessary to know the density of the chemical agent (see F.1), the total volume to be applied, and the gross area of the swatch exposed to agent (typically the inside diameter of the test cell).

2. After the material swatch is positioned in the test cell, the chemical agent is applied to the surface as a liquid droplet. Any drop volume/mass may be considered for the applicable methods depending on the hazard under consideration. However, investigators should be aware that there is a direct dependence between drop volume/mass and the amount of agent vapour that will penetrate a material system. Different penetration results will be obtained for the same protective material depending on whether it was contaminated with one 1 µl drop or one 10 µl drop.

3. The liquid should preferably be applied when the test cell is already positioned in the test equipment. If that is not possible the liquid should be applied in a fume hood, then the test cell is quickly transported to the equipment (see F.7 and F.8) where it is attached to start the determination of the penetration. A possible method to prevent release of toxic vapour during transport of the contaminated cells is to place them in a carbon containing box which is closed tightly during transport.

4. Care should be taken that drops (especially on repellent materials) do not change position during transport.

F502 Liquid Drop Pattern on Material Swatch

The specific pattern of drop placement on the swatch should be such that there is proportionally equivalent contamination density to the entire swatch. Drops should be placed the same distance from the exposed edge of the swatch as from each other to minimise edge effects related to the test cell size that may affect vapour penetration through the material. Achieving such a pattern with fallen droplets is not possible with all devices, and if not achievable, then only one droplet can be applied per cell. Droplets can be applied manually by the touch-off method or by using a robotic dispenser. A calibrated dispenser is required for either approach.

F503 Laid (touch off) droplet

1. For neat agents, the dispenser should have a flattened needle to prevent injection of the liquid into the sample. Droplets of agent are gently touched off (laid) onto a material combination. Care should be taken not to smear the droplet from the needle onto the surface (thus enlarging the droplet's surface) or to jet the droplet from the syringe (adding kinetic energy and creating safety hazards).

2. For thickened agent, the droplet is applied with a calibrated pipette. Formation of threads of the thickened agent should be prevented.

3. Robotic handling of the neat or thickened toxic agent is allowed as well.

4. After application of the droplet(s), a pressure **can** be applied during a short time (F505).

F504 Fallen droplet

F504.1 Neat agent fallen droplet

1. Drops are created in falling drop towers which are ventilated through filters, securing sufficient inward flow of air to maintain safety in the laboratory at all time. The flow might be reduced when openings of the tower are closed to optimise the reproducible targeting of the drop.

2. The test sample in the cell is challenged with a droplet of agent, free falling from a height of at least 2 meters. A 1 µl droplet will thus reach about 90 percent of its free fall velocity. A statically charged agent-loaded hollow micro needle is one way to obtain this free falling droplet.

3. Another means to obtain this velocity is a vertical rail with a weight equipped with needles on which the droplets are hung. The weight is dropped from a sufficient height and stopped right above the test cell which allows the droplets hit the material surface with almost final velocity.

4. When the drop does not land completely on the CBRN material, a new swatch in a new cell should be tested.

5. More than one droplet can be applied to obtain the required contamination density, but care should be taken that droplets are not in contact with each other. The test can also be performed with just one drop provided small cells are applied (about 1.25 cm^2 for a 1 µl drop, to simulate correct contamination density) and the result is corrected for the applied contamination density.

F504.2 Thickened agent fallen droplet

Needles, as discussed in F0504.1, cannot be used to apply a thickened agent fallen drop. One way to create the required thickened agent droplet is by means of a motor driven syringe and a moving, heated metal wire ring to detach the formed droplet from the syringe. Upon moving the ring down from the syringe while heating the wire (by running a small current through it), the droplet detaches and starts to fall. The bigger droplets need a greater height to reach their final velocity: for example, a height of 7.5 meters suffices for a 30 µl droplet to reach about 90 percent of its free fall velocity. The impact of the bigger droplets (their accumulated kinetic energy) is much higher than for the smaller drops.

F505 Pressure

The fabric swatch shall be placed upon a rigid steel surface. The liquid challenge agent is applied to the fabric according to the required method (touch off or fallen) as described in F0502. A PTFE block of at least the same size as the swatch of fabric shall then be placed on the drop(s). A weight shall then be gently applied on top of the PTFE block to apply a pressure of either 20 or 200 kPa to simulate either sitting or kneeling/leopard crawl on the contamination. After a period of 5 minutes, the PTFE block and the weight shall be removed and the contaminated fabric swatch placed in the evaluation systems described in F.7 and F.8.

F506 Critical parameters

Table F-5: Drop Application Critical Parameters

Agent	Influence on adsorption, solution, evaporation
Viscosity	Difficult relation with penetration and pressure
Temperature	Influences viscosity, diffusion, evaporation
Size of droplets	Larger drops show increased penetration results
Means and procedure of application	Increased energy (dropping), local pressure (tip needle), short time between application and start test, all increase penetration
Flow under and over exposed surface	Influences evaporation
For the pressure test: Surface structure under and on top of the contaminated material	Rough surfaces result in locally increased pressures
Speed or dynamic pressure at which the weight is placed	Energy on the droplet can increase penetration
	Pressure tests should only be applied to materials (combinations) that are actually applied at pressure points in the suit.

SECTION F.6 CWA LIQUID SWATCH TEST - QUALITATIVE METHODS

F601 Overview

This section describes qualitative quality assurance tests to determine the penetration of liquid chemical warfare agents through clothing materials. The agent penetrates either in liquid or in vapour form. The penetration is detected by colour change of detection paper, placed at the inside of the material. Challenge agent contamination densities are larger than described in AEP-38 Volume II.

F602 Required/prerequisite for the method

The prerequisites for this method are:

a. Material.

b. Liquid agent: HD, GD or VX.

c. Detection paper, with enough sensitivity for the chemical warfare agent.

d. Test fixture and cells.

F603 Applicability/non-applicability

1. The tests described in this section are useful in identifying weak spots in seams, zippers et cetera, especially in semi-permeable and air impermeable materials. Test specimens such as seams are of special importance in this test, but it can also be applied to determine penetration through materials without seams/closures.

2. The large area contaminated enhances the chance of detecting a weak spot. The tests are applicable to the three agents defined in AEP-38 Volume II, but also to other nerve agents and lewisite.

3. The tests are not intended to reflect an actual threat. They are designed for quality control purposes, and they can be used in R&D to identify weak spots in prototypes.

4. The tests could be used for selection purposes, provided that the correlation between the results of these tests and the results of the tests executed according to the challenge conditions described in AEP-38 Volume II, is known. However, nations are encouraged to develop and use more quantitative tests such as those described in Sections F.7 and F.8.

5. For quality control and R&D purposes, higher contamination densities can be used than described in AEP-38 Volume II or in the test method description.

F604 Sensitivity / reproducibility

1. The required minimum sensitivity depends on the aim of the method (detecting any liquid breakthrough or detecting a relevant vapour breakthrough). It should be mentioned that the detection paper and solutions might decrease in sensitivity once made and that different production batches might have different sensitivities.

2. The reproducibility of the method is determined by the reproducibility of the detection paper and the procedure of detection (mainly the quality of contact).

F605 Test set-up

F605.1 Agent selection

Tests are performed with liquid HD (so-called Spotted Disk or SD-test), GD or VX in neat form, as well as with tabun, sarin and lewisite.

F605.2 Hardware

1. Test cells should be large enough to ensure that a representative part of the material is exposed to the liquid, including seams, et cetera. For safety reasons and to prevent leakage around the edges of the material, it is advisable to use a method that ensures that the liquid cannot reach the edges of the cell and remains within the exposed area of the sample. Possible methods are applying the drop on a small filter paper in the centre of the exposed area or fixing (waxing) a ring in the centre of the cell.

2. The test cell design shall allow the vapour detection paper to be in close contact with the inner side of the test sample and allow for the easy on-site detection of colour changes and/or easy removal of the detection paper for replacement / further analysis.

3. The test cell construction shall be such that uneven materials like seams and zippers can be fixed into the cell without allowing leakage of the agent along the edges of the material.

4. To prevent evaporation of the agent, the top side of the cell (outside clothing material) must be sealed off after agent application (an inverted petri dish sealed with wax on top of the cell is one possibility).

5. The vapour detection papers are described in Section F605.5.

6. For liquid agent penetration, the Mandrel test[18] can be employed, which is used to test air-permeable, semi-permeable, and impermeable materials. A droplet of liquid or thickened agent (with no pressure on the droplet) is applied to a swatch of material under tension. The test simulates how the material in a garment would be stressed by pressure from knees, elbows, etc. The test is qualitative (pass/fail), based on a color change in M8 sampling paper placed under each test swatch. The equipment used for this test includes a Mandrel (41 mm i.d. glass tubing), 234-g weights, and M8 chemical agent detector paper. The weights on the ends of the clothing stress the contaminated clothing hanging over the detector paper which is placed on the glass rod.

7. An environmental control chamber (cupboard) (ECC) is needed to maintain and monitor a constant exposure temperature.

[18] Permeation and Penetration Testing of Air Permeable, Semipermeable, and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing) TOP 8-2-501 (2004).

F605.3 Test specimen

Representative sampling and preconditioning of the samples is described in Section F.1. The sample is pre-treated during 24 hours in an oven of 50 °C to remove possible interferents. The disadvantage of causing (small) changes in the material composition is thought to be of minor importance compared to the chance that interferents will poison the detection paper.

F605.4 Agent application

Using a dispenser, a quantity of 50 µL of the agent is applied on filter paper to the center of the cell. Care should be taken that the liquid remains within the edges of the cell. The contaminated side is sealed gastight to prevent evaporation of the agent. The cell is placed in a 37 °C ECC. For this type of test, an evaluation temperature is applied deviating from the standard temperature (20 °C) because these tests are mostly applied to gloves and boots. Both items will not show much ventilation inside and often show high insulation, so temperature will rise to core rather than to skin temperature.

F605.5 Analysis

F605.5.1 General

1. After contamination, the test specimen is monitored/checked for the occurrence of agent penetration. The monitoring interval is short in the beginning and increases with time. A suggested minimum schedule for monitoring penetration is to examine specimens at 0, 2, 6 and 24 hours after contamination.

2. Liquid detection papers are supposed to respond only to liquid penetration, whereas vapour detection papers will respond to both liquid and vapour penetration, where in general any liquid penetration will give rise to sharper-edged spots than those created by vapour penetration.

F605.5.2 HD detection

1. Mustard agent penetration is usually determined using a detection paper made out of pH neutral Congo Red paper covered with many tiny drops of a chlorimide solution.

   a. Congo red impregnation. In 10 minutes of stirring, 500 mg Congo red is dissolved in 1 litre distilled water brought to pH 3.3 with 0.1 N H_2SO_4. When the solid is totally dissolved, the pH is then brought to 5.0-5.2 with 0.1 N H_2SO_4 if it is still too basic, or 0.1 N NaOH if it is too acidic. Whatmann 1 paper is dipped in this solution and dried for 24 hours at 30 °C.

   b. Chlorimide solution. The chlorimide solution (500 mg 2,4 dichlorophenyl benzoyl chlorimide /10 ml carbon tetrachloride) should be made fresh every 24 hours, stored in the dark and at $3 < T < 10$ °C. It is applied onto the Congo Red paper in tiny dots (to increase visibility of colour change), which can be performed by first dipping a holder equipped with all tiny blotted needles into the chlorimide solution and next onto the Congo Red paper.

2. Mustard agent penetration is visible by the appearance of blue dots, which indicates that the sulphur mustard has reacted with the impregnated Congo paper, producing hydrochloric acid. The

hydrochloric acid causes a change of the Congo paper from red to blue. The time elapsed between contamination and first observation of blue dots is taken as the breakthrough time.

3. When no breakthrough is observed within 24 hours, the detection paper should be replaced with a fresh detection paper and the test should be continued for another 0.5 hour (proving absence of "false negative"). If a positive detection is observed, the former detection paper must be assumed to be poisoned, and the test should be repeated with a change of the detection paper after each hour. When a full coloring of the detection paper occurs, the detection paper should be replaced, and breakthrough should occur again in the next five minutes (this is done to make sure no "false positive" occurs).

4. The detection limit of this method should be at least 0.5 µg/cm^2.

F605.5.3 Nerve agent (GA/GB/GD/VX) detection

1. Nerve agent penetration is usually determined using impregnated silica adsorption paper, Schleicher and Schull biochemical paper nr. 601 (or an equivalent).

2. To check the penetration of agent, the adsorption paper is removed, an amount of ButyrylCholinesterase (BuChE) enzyme solution is sprayed on the paper, and after about 10 seconds an amount of the substrate solution is sprayed on the paper.

a. Enzyme solution. 600 mg trishydroxymethylaminomethane dissolved in 50 ml demineralised water and brought to pH 8 with concentrated hydrochloric acid, 130 mg BuChE added and dissolved. The solution should be stored at 5-25 °C and be prepared fresh every few weeks (change as soon as the "blank" test does not form enough colour anymore).

b. Substrate solution. 10 mg 1-naphtylacetate dissolved in 5 ml acetone, added 50 mg Fast Blue B-salt and 95 ml of water. The solution should be stored in the dark at 5-25 °C and be prepared fresh every day.

3. To check the performance of the enzyme- and substrate solution, a blank is performed using a fresh adsorption paper and the same detection procedure. The color of the paper changes from blank/slightly yellow to purple/blue when no nerve agent (GA, GB, GD or VX) is present. The time elapsed between initial contamination and the moment that decreased formation of the purple colour is observed upon treatment with enzyme and substrate, is taken as the breakthrough time.

4. The detection limit of this method should be at least 0.1 µg/cm^2.

F605.5.4 Lewisite detection

1. Lewisite penetration is usually determined with silica gel detection paper impregnated with molybdate and zinc.

a. Molybdate and zinc impregnation. Silica gel paper is submerged for 30 seconds in a demineralised water solution of 0.5 percent (5 g/l) ammonium molybdate (NH4)6Mo7O24.4H2O) and 0.25 percent (2.5 g/l) zinc sulphate (ZnSO4.7H2O).

2. Lewisite penetration is visible by a colour change from slightly greenish to blue caused by the reaction between the ammonium-molybdate and the arsenic of the lewisite. The colour is intensified by adding a drop of 0.1 N sodium hydroxide. The time elapsed between contamination and first observation of colour formation is taken as the breakthrough time.

3. The detection limit of this method should be at least 0.5 µg/cm^2.

F606 Critical parameters

Table F-6: CWA Liquid Swatch Test Critical Parameters

Temperature.	The diffusion coefficient of the agents is temperature dependent.
Contamination.	The contaminated surface area should be large enough (>1 cm^2)
Flow over the sample.	Normally this test is performed without flow, so evaporative loss of challenge agent is absent or minimal.
Contact between sample and detection paper.	The paper should be in good contact with the test sample, otherwise only vapour penetration or no penetration can be identified.
Ability to detect colour change.	Inter- and intra-person differences might lead to different identifications of penetration.
pH of mustard detection paper.	Basic detection papers take longer to form a colour.
Time between application of enzyme and substrate for nerve agents.	The sensitivity of the method increases when the time for the reaction between nerve agent and enzyme is prolonged.

F607 Reporting

The report should show:

a. Identification of the tested material.

b. Pre-treatment(s) of the material before testing.

c. Description of the test method and test conditions, including actual challenge agent with temperature and relative humidity, duration of the test.

d. Results at the successive time intervals.

SECTION F.7 CWA LIQUID SWATCH TEST - DIFFUSIVE FLOW

F701 General Overview

1. The purpose of this test method is to provide a standardised procedure to quantitatively assess the penetration of toxic vapour through samples of a protective material contaminated with liquid chemical agent. Evaporative or non-evaporative conditions may be simulated. The method encompasses hardware, test parameters, operating procedures, analytical procedures and interpretation of results. The method draws upon some aspects of the methodology developed in QSTAG 991[19], referenced in the previous version of NATO AEP-38.

2. In this method a sample (swatch) of material on top of a polymer film is placed in a test cell, drops of liquid chemical agent are applied on the material, the required air flows over and under the swatch are introduced, and vapour that penetrates through the material is measured.

3. The polymer film acts as a calibrated dosimeter and could be used to determine the dosage just underneath the material resulting from the contamination. The polymer film also prevents airflow between the upper and lower chambers of the test cell.

F702 Required/prerequisite for the method

The following are prerequisites for this method:

a. Test material.
b. Polymer film, permeable for the test agent
c. Conditioned test fixture and cells, exposition equipment in adequate safety cabinet
d. Decision on contamination method
e. Equipment and fume hood for application of contamination
f. Test agent.
g. Controlled air supply (air flow, temperature, humidity)
h. Analytical means to measure penetration.
i. Decontamination reagents and procedure for contamination equipment / cells
j. Optional: box for transport of contaminated cells

F703 Applicability/non-applicability

1. This test method is applicable to air permeable and air impermeable materials.

2. The method is suitable for research and development investigations, more general ranking of material tests and for QA/QC applications.

[19] ABCA Armies Standardisation Program, A Standard Test for Measuring the Penetration of CW Agents Through Protective Clothing

F704 Sensitivity / reproducibility

The minimum sensitivity of the analytical system should be such that over the prescribed period, a minimum of 1/10th of the criterion (as defined in Annex D) can be detected. To calculate the absolute sensitivity needed, flow, number of samplings, accumulation time per interval, and the criterion should be taken into account.

F705 Test Set-up

F705.1 Agent selection

1. In this test, the swatches of material are contaminated with liquid drops of chemical agent, HD and GD, because the liquid drops are considered to represent a greater hazard and challenge to the protective material than a vapour challenge, especially when drops are applied under pressure. VX can specifically be applied to evaluate seams.

2. The purity of the chemical agent used for the liquid drop contamination test should be known to ensure reproducible data.

F705.2 Hardware

F705.2.1 Test cell

1. A schematic representation of a single permeation test cell consisting of an upper and lower chamber is shown in Figure F.2. Both the lower chamber and upper chamber should have at least one air inlet port and one air outlet port to allow air to flow through each respective chamber. The permeation cell shall have a mechanism to clamp the swatch and cell compartments together securely. There should be an effective seal between the test material and the two chambers to prevent the test chemical from leaking from one chamber to the other or from the test cell itself. The upper and lower chambers of the test cell, including the air inlet and outlet ports, must be made of a non-sorbing, easily de-contaminable material such as stainless steel or anodised aluminium to prevent the test chemical agent from adsorbing into the cell material, which may result in residual carry over contamination and affect the reproducibility of the test. The internal depth of the lower and upper chambers must be such that the air flowing through each chamber is in direct contact with the lower and upper surface of the test material and the droplet(s). The minimum inside diameter of the test cell shall be no less than 4.0 cm, which is equivalent to an exposed sample area of 12.6 cm^2.

2. A controlled flow of temperature and humidity conditioned air is passed through the upper chamber of the test cell to influence or promote the evaporation of the chemical that was placed on the surface of the swatch. A separate air flow is passed through the lower chamber of the test cell to quickly sweep chemical vapour that has penetrated through the protective material into an analytical device to measure the agent vapour. Ambient air may be used for the lower chamber air supply, but for humidity sensitive materials, regulation of temperature and humidity might be required. Precautions must be taken to ensure that the lower chamber air supply is not contaminated with the test agent or other compounds that may be present in the laboratory, causing interference with the analysis.

3. Air flows might be generated either by pulling or pushing air through the cell chambers. Commonly used ways to generate and/or regulate the air flow beyond the laboratory air supply are a vacuum pump or mass flow controller.

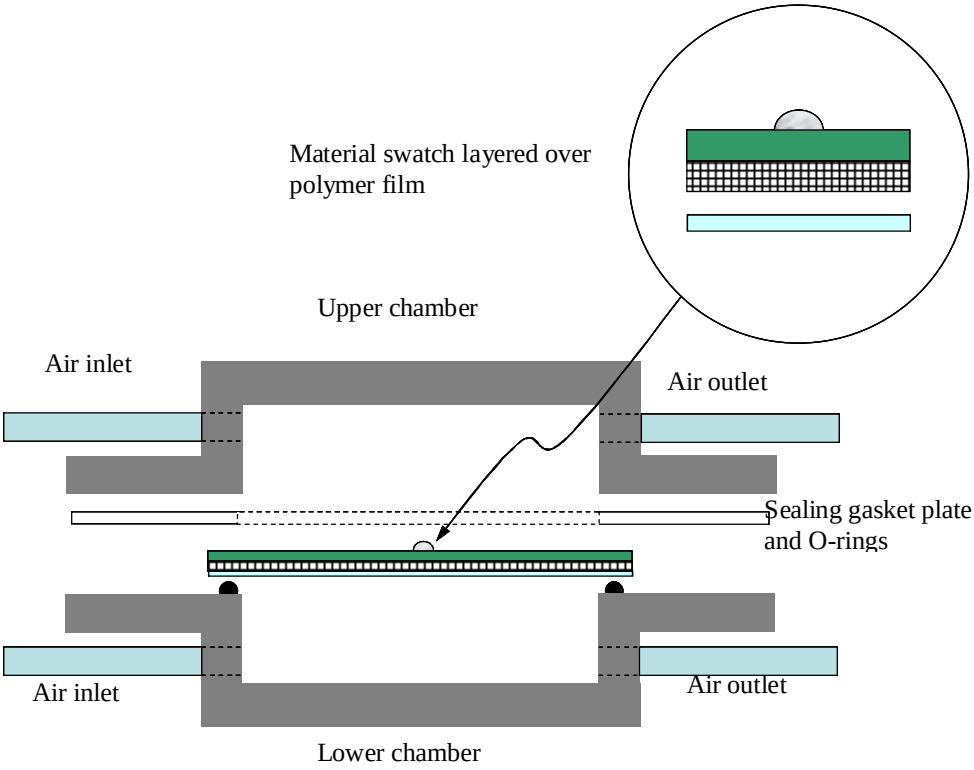

Figure F-2 - Generalized illustration of a test cell.

4. A cell leak test may be conducted after the polymer film and material swatch is correctly positioned in the cell and the upper and lower chambers are clamped tightly shut. This can be done by blocking the air inlet to the lower chamber (and air outlet to the upper chamber) and checking whether or not air escapes from the air outlet of the lower chamber (e.g. visible by a stream of bubbles through an impinger).

F705.2.2 Environmental Chamber

To improve the temperature control for the permeation test cell, it may be placed in an environmental chamber installed in a fume hood or other device to protect against toxic vapour.

F705.3 Test specimen

F705.3.1 Material

Sampling methods for the test material are described in Section F.1.

F705.3.2 Polymer Film

1. The purpose of the polymer film employed in this test is to serve as an airflow-preventing barrier. It is also used as a calibrated dosimeter, thus enabling the calculation of the concentration-time dosage (*Ct*) just beneath the protective material, i.e. in the air gap between the protective material and the polymer film. The permeability of the film must be in the same order of magnitude as the permeability of human skin for the agent, to allow for this calculation to be valid (F707.1).

2. The thickness and permeability of the polymer film is of importance for the determination of the *Ct*, therefore it is necessary to achieve a steady-state flux through the film as quickly as possible including a very quick reaction to concentration changes. A suggested film thickness is 10-25 micrometres (µm).

3. For the calibration of the polymer film permeability, the film can be evaluated as described in the vapour test for impermeable materials (Section F.4). The concentration of the vapour can be increased to increase accuracy. Sampling intervals should be frequent during the first 30 min in order to establish when steady state diffusion begins. Sample collection may be with gas bubbler impingers or an air sampling GC. Given that the polymer film ideally should have a high permeability to the test chemical, large amounts of chemical are expected to penetrate through the film and the GC should be calibrated accordingly.

4. The permeability P of the polymer film is calculated with formula F.7.1:

$$P = \frac{m_{pen}}{C \times t \times A} \qquad \text{(F.7.1)}$$

where m_{pen} is the cumulative mass of chemical agent that penetrated through the polymer film during steady-state diffusion, *C* is the concentration of chemical agent, *A* is the area of the swatch exposed to the vapour and *t* is the duration of time for steady-state diffusion which resulted in m_{pen}.

5. The test should be continued until the determined permeability reaches a steady value.

F705.4 Agent application

Drops can be applied as laid drops, fallen droplets and as laid droplets with applied pressure. Details of the drop application methods are given in Section F.5. AEP-38 Volume II, Section VI, describes the contamination densities and drop sizes.

F705.5 Analysis

Several types of vapour sampling/collection methods may be considered to measure vapour that penetrates through the material. The two most common include gas bubbler impingers (solvent traps, cumulative sampling) and automated air sampling GCs (on-line sampling). Details of the analysis are described in Section F.4, Vapour test.

F706 Test Conditions and Parameters

Test conditions are described in AEP-38 Volume II, Section VI. A detailed discussion of the test conditions and parameters is given below.

F706.1 Airflow and cell geometry

1. The air flow (velocity) through the upper chamber of the test cell for the standard test method is 0.5 ±0.02 m/s at the location of all droplets, also those close to the edge of the cell. The actual volume of air per unit time that must be delivered to the upper chamber to achieve this wind speed will depend on the individual test cell geometry.

2. The air flow through the lower chamber of the permeation cell must be high enough that the lower chamber is cleared quickly but not so high that a negative pressure is created pulling the polymer film down into the lower chamber. Precautions must be taken to ensure that the lower chamber air supply does not affect the analysis (trapping efficiency impingers, hydrolysis reactions). Recommended air flows through the lower chamber of a 12.6 cm^2 cell are 100 mil/min for sulphur mustard (HD) and 50 ml/min for soman (GD). Trapping efficiencies of 95% must be achieved for this method.

F706.2 Test Duration

The duration of the test should be as defined in AEP-38 Volume II, Section VI. Intermediate points are needed at 2 and 6 hours (unless the time stated for the test is shorter), to achieve more detailed information such as the time required for the agent to breakthrough the material and to take into consideration the threat scenario, where materials being considered for the asymmetric threat state may be tested for shorter periods of time.

F706.3 Temperature and Relative Humidity

1. The purpose of controlling the temperature and relative humidity of the air flows through the upper chamber of the permeation cell is to simulate the effect of different climatic conditions on the evaporation of chemical agent from the surface of the test material. The penetration behaviour of the material might also be dependent on these conditions.

2. Care should be taken that the temperature and RH conditions do not influence either the liquid or the analysis in an unrealistic way (e.g. by causing hydrolytic degradation of the test agent).

F706.4 Replicates

The number of replicates is described in Section F.1.

F707 Interpretation of Results

F707.1 Background and limitations

1. This test method provides the investigator with a value for the cumulative mass m_{pen} (typically expressed in micrograms (µg)), that has penetrated through a protective material for some pre-defined period of time resulting from a certain contamination density to the material. It may be convenient to normalise this quantity by the area of the swatch contaminated with liquid drops. No confirmatory work has been done, however, to verify that the area normalised mass penetrated is fully independent of test cell geometry. Care should be taken when comparing this value with results obtained at other laboratories.

2. The use of the polymer film in this test method as a calibrated dosimeter allows the investigator to calculate the concentration-time dosage in the air gap between the base of the protective material and the top of the polymer film. Only if the permeability of the polymer film is similar to the permeability of human skin will the calculated *Ct* be representative of a localised dosage that might be expected beneath protective material worn in close contact to the skin, caused by a localised point source of contamination on the outside of the material. There is no air flow in the gap between the swatch and the polymer film in this test method, as would usually be the case for material in a protective system worn over skin, thus it reflects only what could be considered a static exposure condition. Relating the calculated dosage to critical toxicological endpoints, such as those discussed in AEP-52, is only strictly valid for exposure conditions that closely match those of the laboratory test set-up and test conditions.

3. It must be stressed that results derived from this test method cannot be used to interpret the performance of a protective suit system when worn by an individual in a contaminated environment. The ingress of chemical through closures and interfaces with other equipment, the direct penetration of vapour through air permeable materials due to impinging wind, as well as air movement under the suit caused by the bellows effect (pumping action of the suit on the body when movement occurs), all effect the protective performance of a suit system to various degrees and are factors that are not accounted for in this test method.

F707.2 Interpretation of results for locally working agents

1. For locally working agents the dosage at the location of the drop has to be determined. The dosage Ct in mg.min/m3 can be calculated with

$$Ct_{\text{local}} = 1000 \times \frac{m_{pen}}{P \times A} \qquad \text{(F.7.2)}$$

where m_{pen} is the cumulative mass of chemical agent that penetrated through the polymer film (µg), P is the permeability of the polymer film (cm/min), and A is the area (cm^2).

A problem is found in defining what the area A is. For neat agents it can be assumed that the contamination was homogeneously distributed over the cell surface area. Therefore for neat agents $A=A_{cell}$.

No such assumption can be made for thickened agents. For these agents the actual size of the drop(s) has to be used if one assumes no air mixing at all under the clothing. The actual surface area of the drops is however, usually unknown. Another factor is that contrary to neat agents the drop size chosen is not at the very end of the drop size distribution. An alternative approach is to use the formula for the systemic acting agents.

F707.3 Interpretation of results for systemic working agents

1. Both for neat and thickened systemic working agents the penetrated dosage per test cell needs to be recalculated to the total penetrated dosage that a person would be exposed to. In this four assumptions have to be made

   a. Only 1 m^2 of the body is exposed to the liquid.

   b. The dosages in Annex D are derived from exposure of about 1 m^2 body surface and can therefore be used as a benchmark.

   c. The penetration of the agent through the material is linearly dependent on the drop mass.

   d. The permeability of the film is same order of magnitude the permeability of human skin.

2. The dosage Ct in mg.min/m^3 can then be calculated with formula F.7.3.

$$Ct_{\text{systemic}} = 100 \times m_{pen} \times \frac{\text{aimed for contamination density}}{\text{applied mass on the cell}} \times \frac{1}{P} \qquad \text{(F.7.3)}$$

where m_{pen} is the cumulative mass of chemical agent that penetrated through the polymer film (μg) and P is the permeability of the polymer film (cm/min). The aimed for contamination density (AEP-38 Volume II) is expressed in g/m^2 and the applied mass in mg.

F708 Special conditions

1. There are two special conditions for this method. The first is referred to as a static, non-evaporative test condition. This involves no air flow over the swatch (by means of closing the cell) which results in a saturated vapour state developing above the swatch in addition to the liquid contamination on its surface. It is recommended that if investigators plan on testing polymers, they use static no flow conditions, as this is the most severe challenge and simulates occluded agent in cracks.

2. The second involves the test being carried out without the polymer film in place. In this configuration, for air permeable materials in particular, the air flow through the upper and lower chambers should be identical to ensure that there is no pressure drop across the swatch material.

F709 Reporting

The test report should include the following information:

   a. Identification of the tested material.

   b. Pre-treatment(s) of the material before testing.

c. Description of the test method and test conditions, including

   (1) evaporative or non-evaporative test

   (2) actual challenge agent

   (3) contamination density applied

   (4) volume, temperature and relative humidity of air flow through the upper and lower chambers of the test cell

   (5) duration of the test

   (6) amount of agent applied to the sample

d. Observations like visible changes in the material.

e. Cumulative mass of agent measured as a function of time.

f. Permeability of the polymer film for the test agent and the resulting calculated dosages.

SECTION F.8 CWA LIQUID SWATCH TEST - INCIDENT WIND

F801 Overview

1. This test method is meant to simulate and quantitatively assess the penetration of CBRN material contaminated with a liquid toxic agent, under incident wind conditions. This wind will result in airflow around the droplets and through the material towards the skin and along the body. The intensity of the flow depends on the air resistance of the material, the distance to the skin (very close to the skin the total resistance to flow will increase), and the angle with and the force of the wind (as described in Section F.4; the vapour incident wind test).

2. The air flow results in higher evaporative loss of the agent from the droplets and therefore a more severe challenge to the material than will occur in a diffusive flow situation.

F802 Required/prerequisite for the method

The prerequisites for this method are:

a. Test material,

b. Air flow resistance of material,

c. Conditioned test fixture and cells, exposition equipment in adequate safety cabinet,

d. Decision on contamination method,

e. Equipment and fume hood for application of contamination,

f. Test agent,

g. Controlled air supply (air flow, temperature, humidity),

h. Analytical means to measure penetration,

i. Decontamination reagents and procedure for contamination equipment / cells, and

j. Optional: box for transport of contaminated cells.

F803 Applicability/non-applicability

1. This method can be applied to any material but has most impact on air permeable ones, because these will allow some air to pass through. For non-air permeable materials an adjusted (flushing) cell design will be necessary.

2. The method is required for qualification (if no whole system test is performed), and is also suitable for research and development investigations, more general ranking of materials, and for QA/QC applications.

3. The nature of drop application, as described in Section F.4, (touch-off in contaminated terrain/ fallen during on target attack), the nature of the chemical agent (thickened or neat) and the behaviour of the protective material before and after becoming contaminated, as described in Section F.1 (spill of field

contaminants already on the clothing, pressure on the liquid because sitting/kneeling on or even leopard crawl), all can be chosen in combination with this method.

F804 Sensitivity / reproducibility

This method is known to have a high standard deviation, mostly determined by the material properties. The total analytical system (either on-line or by cumulative dosimeter) should be sensitive enough to detect less than 10% of the threshold value (mentioned in Annex D).

F805 Test set-up

F805.1 Hardware

See F0405.2 but without the vapour generation part. All hardware should be calibrated and periodically checked.

F805.2 Test specimen

See F0405.3.

F805.3 Agent selection and application

The agent shall be selected and droplets shall be applied according to the method described in Section F.5, onto clothing assembled in a cell as described in Section F.4.

F805.4 Analysis

Analysis can be performed according to F405.5.

F806 Test parameters

F806.1 Flow

The flow is calculated by means of Formula (F.4.1) or Formula (F.4.2) in F.405.2. As in this test, the flow is regulated by calibrated flow controllers.

F806.2 Time and dosage

1. The duration of the test should be as defined in AEP-38 Volume II Section VI. Intermediate points are needed at 2 and 6 hours (unless the time stated for the test is shorter).

2. Penetration can be measured either on-line in mg/m^3, where this concentration has to be integrated over time to obtain the acquired dosage, or it can be measured cumulatively.

3. For QA application this is not necessary and a cumulative figure over the required protection time (see AEP-38 Volume II) is enough.

F806.3 Temperature and humidity

Standard temperature and humidity conditions are applicable (see AEP-38 Volume II).

F806.4 Replicates

A standard triplicate is required. Especially in the production control phase, sampling frequencies might be decreased or increased based on the variability and absolute value (relative to criterion) of results.

F807 Interpretation of test results

F807.1 Background

1. The important parameter is penetrated dosage as function of time. These results do not necessarily relate directly to whole system liquid test data, but describe material performance against vapour under a select set of controlled conditions. The criteria for a whole system test –if available for the toxic agent evaluated- are presented in Annex D. These can be applied as a benchmark for the material test as well.

2. It must be stressed that results derived from this test method cannot be used to interpret the performance of a protective suit system when worn by an individual in a contaminated environment. The ingress of chemical through closures and interfaces with other equipment, direct penetration of vapour through air permeable materials due to impinging wind, as well as air movement under the suit caused by the bellows effect (pumping action of the suit on the body when movement occurs), all effect the protective performance of a suit system to various degrees and are factors that are not accounted for in this test method.

F807.2 Interpretation of results for locally working agents

1. For neat agents it can be assumed that the contamination was homogeneously distributed over the cell surface area. Since the drop size chosen is at the high end of the drop size distribution the penetrated dosage observed in the test can be directly compared with the benchmark criterion defined in Annex D.

2. For thickened agents the same discussion regarding the area A and the drop size can be held as described in F707.2. Contrary to neat agents the chosen drop size is not at the very end of the drop size distribution. The discussion could not be finalised whether some correction factor needs to be applied to the measured dosage to take into account the fact that in reality many drops of different sizes will cover the surface.

F807.3 Interpretation of results for systemic working agents

1. Both for neat and thickened agents the penetrated dosage per test cell needs to be recalculated to the penetrated dosage that a person would be exposed to. In this three assumptions have to be made:

   a. Only 1 m^2 of the body is exposed to the liquid.

   b. The dosages in Annex D are derived from exposure of about 1 m^2 body surface and can therefore be used as a benchmark.

   c. The penetration of the agent through the material is linearly dependent on the drop mass.

2. The dosage Ct in mg.min/m^3 can than be calculated with formula F.8.1.

$$Ct_{\text{systemic}} = 0.1 \times Ct_{pen} \times \frac{\text{aimed for contaminat ion density}}{\text{applied contaminat ion density}} \qquad \text{(F.8.1)}$$

where Ct_{pen} is the dosage of the chemical agent measured in the test (mg.min/m^3). The aimed for contamination density is expressed in g/m^2 and the applied contamination density is expressed in mg/cm^2.

F808 Critical parameters

The critical parameters are as follows:

a. Liquid switch test incident wind;

b. Design of cell: good sealing of swatch, homogeneous flow through sample, flow directly over swatch surface,

c. Contamination: qualified application of droplets without “smearing” over surface,

d. Temperature: because of diffusion coefficient, evaporation rate, change surface tension,

e. Flow over the sample (increases evaporation), and

f. Flow through sample (independent measurement or on-line measurement).

F809 Reporting

The report should show

a. Identification of the tested material.

b. Pre-treatment(s) of the material before testing.

c. Description of the test method and test conditions, including;

   (1) actual challenge agent,
   (2) contamination density applied ,
   (3) linear flow of air applied through the clothing,
   (4) temperature and relative humidity, and
   (5) duration of the test.

d. Observations like visible changes in the material.

e. Dosages at the successive time intervals.

SECTION F.9 AEROSOL SWATCH TEST

F901 Overview

1. This test method determines the protective properties of air permeable materials against penetration of aerosols under incident wind conditions.

2. A piece of clothing material is placed in a test cell and challenged under controlled conditions by an aerosol containing air flow in a test chamber. During a known time, the challenge concentration and particle size distribution are measured, and the amount of aerosol penetrated through the clothing is also determined. By comparing the penetrated amount with the challenge concentration, the protective properties of the material are determined.

F902 Required/prerequisite for the method

The prerequisites for this method are:

a. Test material,

b. Air flow resistance of material,

c. Conditioned test fixture and cells, exposition equipment in adequate safety cabinet,

d. Equipment for application of contamination,

e. Test agent in correct aerosol particle size distribution,

f. Controlled air supply (air flow, temperature, humidity),

g. Analytical means to measure penetration and

h. Decontamination reagents and procedure for contamination equipment / cells.

F903 Applicability/non-applicability

1. The method is applicable to all air permeable materials. It is intended to cover all aerosol challenges identified in AEP-38 Volume II, Section VI. The absence of pass/fail criteria, Annex D, does not exclude the possibility to describe a test. Penetration does not necessarily have a direct relation to deposition, and thus offers no prediction to the amount contacting the skin.

2. Although [skin] deposition measurement is therefore preferred for aerosol challenges, the current state of scientific development does not allow for the full description of a swatch test method which measures deposition **and** dosage build-up (when applicable). Therefore the method described here concentrates on penetration measurement. It should therefore only be used for ranking purposes, research and development, and production control. This restriction holds especially for the test described here, because material penetration can be significantly higher than the actual deposition onto the skin, and there is not necessarily a linear relation between clothing penetration and deposition on the skin.

F904 Sensitivity / reproducibility

1. The air *flow* through the test sample influences the various processes that result in capture versus penetration of the agent through the clothing. These include residence time in the clothing layer, impaction, diffusion, and others. Because these processes work on different time scales, flow dependency can be high. Flow through the material must therefore be strictly controlled and be homogeneous.

2. Penetration is more or less linear with *concentration*. There are, however, limits to this linearity. With high aerosol challenges the captured agent may begin to clog the material, increasing the filtration efficiency of the material. If, for detection limit or other reasons, concentrations other than those stated in the table have to be used, care should be taken that this clogging does not occur. If clogging is part of the material behaviour at a concentration/dosage as stated in AEP-38 Volume II, Section VI, it is part of the (protective) performance of the clothing.

3. The penetration is highly dependent on *particle size*. Larger particles are usually better filtered out of the challenge flow. Particle size control in the challenge concentration is therefore of large importance. High amounts of particles with diameters outside the intended range should be avoided, especially with larger particles, but in some cases (evaporative behaviour) also with smaller.
The particle size dependency of the penetration will often also result in a different particle size distribution in the penetrated aerosol. This difference must be measured and reported, because in the end the deposited *mass* forms the actual toxicological threat.

4. The *temperature* dependence of aerosol penetration is limited to those materials which themselves show temperature dependent behaviour, e.g. swelling of fibres or biocidal activity, or to aerosols that show temperature dependent behaviour, like liquid chemical aerosols and aerosols generated by evaporation of suspensions. By validation it should be determined to which degree certain materials and aerosols show temperature dependent behaviour. This environmental condition should then be controlled accordingly.

5. The *humidity* dependence of aerosol penetration is limited to those materials which themselves show humidity dependent behaviour, e.g. swelling of fibres or biocidal activity, or to aerosols that show humidity dependent behaviour, like aerosols generated by evaporation of watery suspensions. By validation it should be determined to which degree certain materials and aerosols show humidity dependent behaviour. This environmental condition should then be controlled accordingly.

F905 Test set-up

F905.1 Hardware

F905.1.1 Test rig

1. Tests can be performed in a wide variety of test set-ups, provided that they answer to the requirements/restrictions given below.

2. The test set-up shall as a minimum consist of closed test apparatus, containing an aerosol generation device, a flow generation device, a test cell containing the test sample, and a measurement system.

3. The length of tubing should be restricted to a minimum, as well as changes in flow direction. Tubes, angles, connection points and other surfaces in the test apparatus should be such that aerosol deposition is restricted to a minimum and has no influence on the test result, for example due to re-aerosolisation of the deposited particles. This might, for instance, occur when the aerosol size and/or the agent is changed.

F905.1.2 Aerosol generation device

1. Many different aerosol generators are commercially available. Care should be taken during operation that small deviations in the settings (operating pressure, liquid level suspension, homogeneity suspension, age suspension, temperature, mixing flow, rotating speed and so on) do not cause a major change in the concentration and particle size distribution challenging the test cell[20].

2. The introduction method of the aerosol in the test chamber (diameter, length and angles of tubing, entry point) and the mixing in the test chamber should be such that both the concentration and the particle size distribution in the actual challenge to the test cell is homogeneous and stable; there should be at least 100 particles in every class of sizes being considered for evaluation.

Note: Addition of extra air to the test chamber, aimed at dilution, could have an influence on the stability of the concentration and particle size distribution.

3. The generation process should not lead to

   a. aggregate formation, unless it is part of the process to generate specific particle sizes;

   b. large changes in the viability of the agent (applies if viability is one of the test parameters; and

   c. undue charging of the aerosol (in that case neutralisation should be applied).

4. Care should be taken to empty/clean the test chamber in between tests. The presence of particles with other particle sizes should be minimised (see geometric standard deviation of particle size). Before starting the generator, the test rig should be monitored for the absence of aerosols, and channels are to be calibrated from time to time with test dust (e.g. latex) of known particle size.

5. Deposition on surfaces in the test apparatus is allowed, provided that it does not influence the result of the present or of future tests by generation of particles of the same or other sizes or by vapour generation (maximum acceptable suggested value 5 percent).

F905.1.3 Flow generation device

1. The flow generation device shall be constructed such that only the intended flow will occur through the clothing sampling. Ventilators and flow inlets close to the cell can cause extra, unintended flows through parts of the test sample. The maximum acceptable suggested value for the extra flow generated by the device is 1 percent.

[20] ISO 16900-3: 2006 'Respiratory protective devices - Methods of test and test equipment Part 3: Determination of particle filter penetration', draft for formal vote, 1 May 2006, prescribes a maximum acceptable geometric standard deviation between 1.4 and 1.8.

2. Flow can be generated either by suction or by impinging wind speed. When using suction, the amount of sucked air should represent the flow that would result from the wind speed mentioned in AEP-38 Volume II, Section VI, flowing freely perpendicularly at the clothing. For this the reader is referred to the discussion and calculations in Section F.4, CWA vapour testing. When using impinging wind speed, care should be taken that no obstruction exists for the wind flow. When the test cell design and/or the measurement system diminish the airflow, some form of compensation should be utilised. The direction of the flow must be perpendicular to the surface of the clothing sample.

3. The generation of flow and the flow needed for the measurement of the challenge conditions can cause pressure drops in the test apparatus, which could lead to undue flows through the sample and/or concentration changes. Care should be taken that this does not occur. The sampling flow should have no undue influence on the penetration process, e.g. by increasing the flow through the sample above the desired value.

F905.1.4 Test cell

1. The test cell shall be constructed such that no leaking can occur along the edges of the test sample. The construction of the cell and its position in the test apparatus shall be such that the flow through the entire test sample is homogeneous, with maximal 5 percent as suggested variation across the test sample. The surface area of the exposed part of the test sample shall be large enough to allow for representative studies of the penetration process, also for zippers and seams. A minimum of 30 cm^2 is recommended.

2. Testing multiple cells simultaneously is possible, provided that the measurement of both challenge and penetration in one cell is not influenced by the measurement of both challenge and penetration in one of the other cells (maximum acceptable suggested value 1 percent)

F905.1.5 Measurement system

1. The measurements system needs to measure both the actual challenge conditions in the test apparatus and the actual penetration through the material with the same method and with the same accuracy. The challenge concentration and particle size distribution shall be measured as close to the outside of the test sample as possible, without influencing penetration processes. The penetrated concentration and particle size distribution shall be measured as close as possible to the inside of the sample, again without influencing penetration processes, and ensuring that the penetration through the entire cell surface is measured. Analogously the measurement of flow, humidity and temperature should be such that the actual environmental exposure conditions are known for the test cell.

2. The measurement system should be selective and specific for the challenge agent. Both real-time and cumulative sampling is possible, as long as the penetration is known at the time mentioned in AEP-38 Volume II, Section VI, and the intermediate points at (0,) 2 and 6 hours (unless the time stated for the test is shorter). The system must be able to detect one particle per cm^3 when sampling real-time and be lower than 10 percent of the penetration criterion when sampling cumulatively.

Note: For practical reasons another combination of time and concentration than that mentioned in AEP-38 Volume II, Section VI might be needed to achieve the required challenge dosage.

3. The sampling time used during real-time sampling should be long enough to ensure that no start-up or other effects exist that would influence the test results (e.g. it would make no difference whether the sampling period is 30 seconds or 60 seconds). When measuring real time and using one device to measure both the penetration and the challenge, these measurements should be intermixed, e.g. challenge-penetration-challenge-penetraton-challenge-penetration-challenge.

4. The measurement system should be able to measure the viability of the agents when testing materials which are aimed at influencing the viability of the agent, like biocidal materials. In other tests using biological agents, viability testing is optional. The viability testing method for both challenge and penetration should be identical.

5. If dilution is needed for proper measurement, the use of equipment such as calibrated diluters should ensure that the dilution process does not influence the test result.

6. The small drop sizes of liquid aerosol allow for evaporation of even low volatility agents. If liquid agents are used, the measurement system shall therefore include separate vapour measurement for both challenge and penetration (see Section F.4 in this Annex). Care should be taken that aerosol and vapour measurements do not interfere.

7. The measurement system must also measure the actual challenge time with less than 5 percent variability.

F905.1.6 Test samples and number of replicates

Sampling procedures, determination of air flow resistance, preconditioning, and other treatments are described in Section F.1.

F907.2 Agent selection

1. Although testing with live agents is preferred, testing with simulants is possible. These simulants should be validated against the live agent to ensure that the penetration behaviour is the same or close to the live agent for the type of material studied. Examples of parameters that might be of influence are volatility, particle shape, particle diameter, viability, electrostatic properties and other interactions with materials.

2. It should be noted that the test results can vary depending on the type of material combined with the choice of simulant.

F906 Analysis

The data-analysis should include the challenge and penetration concentrations/dosages, the particle sizes of both challenge and penetration, and the environmental conditions, including the wind speed through the material. If any of these has fluctuated outside the allowed limits, retesting should be ordered.

F907 Interpretation of test results

F907.1 Chemical agents

1. For chemical agents, the total dosage of particles with particle sizes between 1 and 3 micrometers should be calculated for both the challenge and penetrated dosage. Other particle sizes should not be taken into account, but their penetration might be reported separately.

2. The penetrated dosage shall then be recalculated to a normalized penetrated dosage, using Formula F.9.1. This formula applies if a linear relation exists between concentration and penetration (which is to be expected until clogging occurs).

$$normalised\ \ penetrated\ dosage = measured\ \ penetrated\ dosage \times \frac{aimed\ \ for\ challenge\ dosage}{measured\ \ challenge\ dosage} \qquad \text{(F.9.1)}$$

3. A combined calculation can be done for agents that penetrate in vaporous form, summing both the vapour and aerosol dosage in both challenge and penetration. The exact nature of this summation has not been determined yet, but for reasons of comparison it is assumed that a linear combination can be used.

4. The toxicological criteria and the restrictions given in Annex D can be used as a benchmark with which to compare results.

F907.2 Biological agents

1. A calculation similar to the one for chemical aerosols (Formula F.9.1) can be used for biological agents. Dosages are now expressed as CFU*min/m^3. If viability is a test parameter, dosages should be corrected accordingly, Formula F.9.2.

$$viable\ dosage = measured\ \ dosage \times \frac{viability\ (\%)}{100} \qquad \text{(F.9.2)}$$

where the viability is expressed as the percent of the total number of particles in the chosen size range.

2. A translation of the dosage into a number of deposited particles cannot be given. This translation is only possible if the deposition velocity of the agent is known. For reasons of comparison, it is however possible to assume that all penetrated particles will deposit on the surface. The number of penetrated particles can be calculated from Formula F.9.3 and then be compared with the data given in Annex D, but under the limitations given in that Annex.

$$number\ of\ \ CFU's = measured\ \ dose \times \frac{penetrated\ \ volume}{total\ \ time} = measured\ \ dose \times flow_{through\ material} \qquad \text{(F.9.3)}$$

F907.3 Radiological and nuclear agents

F907.3.1 Calculation of penetration

1. The calculation of the penetrated dosage is similar to the calculation for chemical agents, F907.1.

2. The toxicological criterion given in Annex D cannot be used as a benchmark with which to compare results since it is a deposition value[21]. This value can be used, however, to estimate the order of magnitude of the required protection factor.

F907.3.2 Example Protection Factor calculation

1. In this example the required protection factor is derived using an assumed deposition velocity.

2. The allowable dose to be left on skin after decontamination for beta-emitting radiological agents (e.g. ^{90}Sr) is 10 Bq/cm^2 (Annex D). Reduction of dose to this level will be achieved by a combination of decontamination and protection.

2. According to Andersson et al.[22], a likely deposition velocity onto skin for particles of 3 μm aerodynamic diameter is 0.03 m/s. Using this deposition velocity, an allowable dose above the skin of 5×10^4 Bq.min/m^3 will give rise to the allowable skin dose of 10 Bq/cm^2.

3. **Example of required protection factor.** For an outdoor challenge value of 1.1×10^{10} Bq.min/m^3, to achieve the allowable dose above skin would require a PF of 2×10^5. A swatch test will be relatively ineffective in determining protection factors at this level since system level leakage will be important. Therefore the swatch test will be used as guidance in determining the general capabilities of the material in the system only, and the system test described in Section F.3 is to be preferred.

4. Evaluation of the effectiveness of relevant skin decontamination procedures should be performed in addition as this will determine the supplementary factor by which skin dose can be reduced. A high decontamination efficiency can reduce the protection factor required from the clothing system.

F908 Reporting

The report should show:

a. Identification of the tested material.

[21] If a study on deposition behaviour of penetrated radioactive particles will deliver calculable ratios between penetrated and deposited particles, this could be transformed into a PF to simplify testing doing penetration measurements.

[22] See Table 4.1 and p. 63 in Andersson, K.G., Roed J., Byrne M.A., Hession H., Clark P., Elahi E., Byskov A., Hou S.L., Prip H., Olsen, S.K. Roed T. (2004). Airborne contamination in the indoor environment and its implications for dose. Risø-R Report-1462(EN), Risø National Laboratory, Roskilde Denmark April 2004. Conditions are indoor, moving persons, moist skin, similar to conditions within protective clothing. This value reduces for smaller particles and dry skin. The value given is the interpolated value for deposition of 3 micrometer particles on a non-moving person with dry skin, as derived from Table 4.1 in this report, multiplied by 4 to allow for the effects of both moving and having a wet skin on the deposition velocity, as described in this report.

b. Pre-treatment(s) of the material before testing.

c. Description of the test method and test conditions, including;

(1) actual challenge agent,
(2) concentration,
(3) particle size distribution,
(4) temperature and relative humidity,
(5) linear flow of air applied through the clothing, and
(6) duration of the test.

d. Observations like visible changes in the material.

e. (Normalized) dosages at the successive time intervals.

SECTION F.10 RE-AEROSOLISATION

F1001 Overview

1. At this time there is no ratified small-scale test for re-aerosolisation of particles and droplets from CBRN protective clothing. If this area is considered of interest the following testing could be adopted.

2. Volunteers dressed in the IPE of interest should be exposed to a suitable simulant challenge as described in Sections F.3 and F.9 above, to the levels prescribed in AEP-38 Volume II, Section VI, whilst undertaking simulated military duties. These subjects should then be taken through standard doffing protocols in a representative environment like a confined non-ventilated space simulating the entrance of a ColPro. The concentrations of the "simulant aerosol" airborne at each stage in the undressing depends on the volume of the space and should be measured as should any remaining dermal contamination. Airborne concentrations should be compared with respiratory exposure guidelines, like those outlined in D/103, and with ingestion criteria. A risk assessment can then be made as to the adequacy of the dermal IPE for the intended task.

SECTION F.11 NUCLEAR HEAT FLASH TEST

F1102 Overview

In the nuclear heat flash test a clothing swatch is exposed to a short heat flash, aimed at simulating the thermal radiation corresponding to a standard fission 30 KT nuclear explosion in air at a distance of 2.2 km (required) or 1.6 km (desired) in clear weather conditions. The effect of the heat flash on the clothing and the 'skin' is determined. System level tests are under development and can be used after validation, see section 8.3 item 1.4.3.

F1103 Required/prerequisite for the method

The prerequisites required for this method are:

a. Material,

b. Light/heat source,

c. Environmental control system,

d. Detection system, and

e. Safety measures, for eye protection, and for fire and toxic gas formation.

F1104 Applicability/non-applicability

1. The test is applicable to all clothing materials. Some materials might react to the heat flash by melting and/or the formation of fire and/or toxic fumes. Proper safety measures shall be taken.

2. The heat flash should be delivered according to the normalized pulse defined in AEP-4 for the 30 kT weapon. For practical reasons a square pulse is used.

3. The test only assesses the damage on the location of the heat flash. No extrapolation to total body results can be made without additional system tests.

F1105 Sensitivity / reproducibility

Three samples, taken from the same material, in general show identical results.

F1106 Test set-up

F1105.1 Hardware

1. The hardware consists of a heat source able at generating 60 (essential) or 120 (desired) J/cm^2 to the material.

2. One method to generate this energy is to use a 2.5 kW Xenon bulb pulsed during 0.95 ± 0.03 second at 5 times its nominal power. This results in a heat source of 6000 K with a light spectrum like the

sun. The beam in the target area has a diameter of at least 20 mm with homogeneity better than ± 5 percent. The energy flux is set at 30, 60 or 120 W/cm^2.

3. Proper eye protection is needed when applying the heat flash, since permanent damage to the eyes can occur due to the intensity of the light flash.

4. Other hardware consists of a cell to fix the sample, and a method to measure and analyse the energy, which penetrates through the clothing and would reach the skin.

5. A possible device to measure the heat flux is a copper disk calorimeter.

F1105.2 Test specimen and replicates

1. The clothing material is tested with any additional layers worn under operational conditions, like underwear. Sampling, preconditioning methods and replicates are described in Section F.1, as well as ageing and other pre-treatments. Preconditioning of the material combination is important: the water content of the material can strongly influence the results. Realistic humidity preconditioning is required.

2. The material is mounted in the test cell, in close contact to the 'skin'.

F1105.3 Agent application

The heat flash is applied for one second.

F1105.4 Analysis

1. The nature of the damage to the clothing layer is determined. In addition, the presence of flames and glow after irradiation are noted, including the times till extinction.

2. The energy flux delivered to the 'skin' is measured. The time to reach the Stoll/Chianta[23] curves (resembling the doses necessary to develop pain or blisters) as well as the maximum dose and corresponding time are recorded[24].

F1107 Test parameters

The test parameters are as follows:

a. Contact between clothing and 'skin'.

b. Intensity heat source.

c. Form of heat pulse.

d. Size of irradiated surface.

[23] A.M. Stoll, M.A. Chianta, "Method and Rating System for Evaluation of Thermal Protection", Aerospace Medicine, Vol.40, No.11, Nov 1969.
[24] Other methods based on temperature evolution (Henriques, Weaver, Wu, etc.), on total fluence (Jaymes correlation), on the thermal dose concept (Hymes, Rew, etc.) are also usable.

e. Humidity of clothing.

f. Detection method.

g. Temperature environment.

F1108 Interpretation of test results

1. The heat dose should not exceed the blister dose. A high pain dose could also be reason for rejection (level to be decided per country).

2. Per item, or per layer in case the item is an assembly of layers, a rating for the damage to each individual layer is given ranging from 0 (undamaged) to 5 (completely lost) corresponding with the evaluation criteria that are shown in the table below. It is also noted when the front side and the backside show different effects.

3. A rating 3 or higher will render the clothing ineffective for further use.

Table F-7 – Damage rating in Heat flash test

Rating	Damage to the layer
0	undamaged
1	slight colour change
2	colour change and/or slight carbonisation
3	strong carbonisation and/or loss of material
4	strong carbonisation and small holes
5	large holes, material burned away

4. Example: when the damage of a three layer assembly shows the rating 5;2/3-1;1 this would mean:

a. outer layer : large hole

b. middle layer in colour : slight up to strong carbonisation, back side only slightly changed

c. bottom layer : slight colour change

F1109 Reporting

The report shall include:

a. the damage to the clothing layers,

b. the time to exceed pain or blister levels according to the Stoll/Chianta curves,

c. the maximum dosage and the time when that is reached, and

d. the presence of flames and glow after irradiation.

ANNEX G - TEST METHODS NON-CBRN CLOTHING PROPERTIES

SECTION I - GENERAL

G101 Contents of this Annex

Section G102 of this Annex describes the test methods for non-CBRN tests as used in Section 8.3, the Triptych and gives suggestions for additional tests nations might consider necessary. Section G103 gives suggestions for test schemes, which allow non-CBRN properties to be determined simultaneously.

G102 Test methods

1. Table G-1 gives suggestions for test methods for many clothing properties related to the requirements presented in the Triptych, Section 8.3. Many other civilian standards are available as well. Nations can use national standards, except for the standards specifically mentioned in the Triptych.

2. When the number of replicates needed is not explicitly mentioned in this Annex or the standards that are applied, Annex F.1 gives guidance towards the selection of samples.

Table G-1 – Test methods for non-CBRN-properties

Triptych section	Mandatory or Desired	Test Method Description	Comments	Recommendation
2.1 Packaged state				
2.1.1 Weight and 2.1.3 Packaging weight	M	Woven fabrics: Determination of mass per unit length and mass per unit area	Woven fabrics	**ISO 3801**
		Textiles - fabrics: Determination of mass per unit area using small samples		EN 12127
		Textiles-Test methods for nonwovens-Part 1: Determination of mass per unit area	Non-woven fabrics	ISO 9073-1
2.1.2 Packaged Volume	M			This Triptych
2.2 Donning and doffing				
2.2.1 Donning/Doffing uncontaminated clothing	M			This Triptych
2.2.2 Open and closed state	M			This Triptych
2.2.3 Doffing contaminated clothing	M			This Triptych
2.2.4 Contamination Control Area (CCA) Procedures	M			This Triptych
2.3 Comfort				

Triptych section	Mandatory or Desired	Test Method Description	Comments	Recommendation
2.3.1 Fit	M			This Triptych
2.3.2 Comfort	M			This Triptych
2.3.2 Comfort - thickness	M	Textiles - Determination of thickness of textiles and textile products		ISO 5084
		Textiles-Test methods for nonwovens-Part 2: Determination of thickness		ISO 9073-2
2.3.2 Comfort - stiffness	M	stiffness	Kawabata assessment protocol consists of several tests which may be used in any combination	Kawabata, bending (B mean) for stiffness
		Rubber-or plastics-coated fabrics-Low temperature bend test		ISO 4675
		flexing, crumpling	air impermeable materials	ISO 7854, ASTM F392
2.3.3 Skin Irritation and Toxicity	M	skin sensation/toxicity		
2.3.4 Odour	M	odour		SNV 195651 (Swiss standard)
2.3.5 Noise	M	hearing/sound generation		
2.4 Performance				
2.4.1 Performance reduction				
2.4.2 Heat stress	M	air permeability		

Triptych section	Mandatory or Desired	Test Method Description	Comments	Recommendation
		Determination of the permeability of fabrics to air		ISO 9237
		Textiles-Physiological effects-Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)		EN 31092 (ISO 11092)
	M	moisture vapour transmission		ISO 11092
	M	thermal resistance		ISO 11092
	D	solar loading		-
2.4.3 Vision	M			D/103
2.4.4 Hearing	D	hearing/sound generation		D/103
2.4.5 Touch	M	hand/touch		ASTM F2010
	D	touch (ability to feel touch)		
2.4.6 Identification	M			STANAG 2420
2.4.7 Respiratory Detection	M			This Triptych
2.4.8 Urination or Defecation	D			This Triptych
2.5 Equipment compatibility				
2.5.1 Compatibility				This Triptych
2.5.2 Static electricity	D	electrostatic properties	product dependent as to method selection	CCC-T-191:5930, 5931 are most commonly used
2.5.3 Magnetic properties	D	magnetic		
2.6 Protection against non-CBRN contaminants and fire				

Triptych section	Mandatory or Desired	Test Method Description	Comments	Recommendation
2.6.1 Liquid resistance - water		Determination of water resistance of fabrics by the Bundesmann rain-shower test		ISO 9865 (EN 29865)
	D	Determination of resistance to surface wetting (spray-test)	non-woven fabrics	ISO 4920
2.6.1 Liquid resistance - water and POL	M	Textile fabrics-Determination of resistance to water penetration-Hydrostatic Pressure Test	applicable only to non air-permeable materials; hydrostatic pressure at seam/seam junction, assuming seams are taped, sealed, or welded	ISO 811
2.6.1 Liquid resistance - POL	D	Resistance to decontamination chemicals	national choice, contaminants of interest, product dependent, methods used and chemicals selected	This Triptych
	M	Resistance to battlefield contaminants / POL	national choice, contaminants of interest, product dependent, methods used and chemicals selected	This Triptych (AATCC 118)
2.6.2 Flame and fire	D	Flame and fire		
		Textile fabrics-burning behaviour-Determination of ease of ignition of vertically orientated specimens		ISO 6940
		Textile fabrics-burning behaviour-Measurement of flame spread properties of vertically orientated specimens		ISO 6941
		Protective clothing-protection against heat and fire		ISO 6942
		Protective clothing-protections against heat and flame		DIN 54336 (ISO 15025)
		Protective Clothing-Protection against heat and flames-Test method : Determination of the heat transmission on exposure to flame		EN 367
		Fire resistance for whole clothing ensemble		ISO 13506.2
2.7 Counter surveillance				

Triptych section	Mandatory or Desired	Test Method Description	Comments	Recommendation
2.7.1 Camouflage	M	Camouflage - visual	national requirement	national selection
	M	Camouflage - NIR	national requirement	national selection
	D	Camouflage - other IR/radar/microwave	national requirement	national selection
2.7.2 Silhouette	D			This Triptych
2.7.3 Noise	M			This Triptych
2.8 Training	D			This Triptych
3.1 Durability				
3.1.1 Durability - abrasion	M	Determination of the abrasion resistance of fabrics by the Martindale method - Parts 1-4	product dependent	ISO 12947-1, -2, -3, and -4
		Determination of fabric propensity to surface fuzzing and to pilling - Parts 1-2		ISO 12945-1 and -2
		Standard test method for snagging resistance of fabrics (mace)		ASTM D3939
3.1.1 Durability - adhesion	-	Adhesion/delamination	air impermeable materials	ASTM D751
3.1.1 Durability - bursting		Textiles-Bursting properties of fabrics-Part 1	non-woven materials	ISO 13938-1
3.1.1 Durability - colour fastness	M	Colour fastness to light, rubbing, perspiration, accelerated ageing, wet scrubbing, organic solvents, water, seawater, chlorinated water, perspiration, spotting (acid, alkali, water), hot water, milling, dry heat, etcetera.		ISO 105, various sub-parts
3.1.1 Durability - cracking	-	Cracking/crazing/blooming	air impermeable materials	after ISO 7854 or ASTM F392
3.1.1 Durability - flexing		Rubber-or plastics-coated fabrics - Determination of resistance to damage by flexing		ISO 7854-A
		Rubber-or plastics-coated fabrics - Determination of blocking resistance		ISO 5978

Triptych section	Mandatory or Desired	Test Method Description	Comments	Recommendation
3.1.1 Durability - folding		Determination of the recovery from creasing of a horizontally folded specimen by measuring the angle of recovery	crease recovery	ISO 2313
		Textiles-Evaluation of the wrinkle recovery of fabrics-Appearance method		ISO 9867
3.1.1 Durability - fungus	D	Resistance to micro-organisms/anti-fungal		
3.1.1 Durability - sticking	-	Sticking/blocking	air impermeable materials	ISO 5978
3.1.1 Durability - puncture	M	Protective clothing-mechanical properties-resistance to puncture		EN 863
3.1.1 Durability - tear	M	Tear properties of fabrics-Parts 1 -4		ISO 13937-1, -2, -3, and -4
		Rubber- or plastics-coated fabrics: Determination of tear resistance-Parts 1-2	air impermeable materials	ISO 4674-1 and -2
		Textiles-Test methods for nonwovens-Parts 3- : Determination of tear resistance	non-woven	ISO 9073-3 and -4
3.1.1 Durability - tensile		Determination of maximum force and elongation at maximum force using the strip method / the Grab method		ISO 13934-1 / -2
		Rubber- or plastics-coated fabrics - Determination of tensile strength and elongation at break	air impermeable materials	ISO 1421
	M	Textiles-Seam tensile properties of fabrics and made-up textile articles Parts 1-2		ISO 13935-1 and -2
3.1.2 Durability - shelf life	M	Resistance to micro-organisms/anti-fungal	some materials are much more susceptible than others - may not be necessary	CGSB-4.2/28.2

Triptych section	Mandatory or Desired	Test Method Description	Comments	Recommendation
	M	Packaging	as required by component materials and fabric construction	In accordance with national requirements for shelf life when not damaged - typically 10 years
3.1.3 Durability - laundering	M	Colour fastness-Part C01 : colour fastness to washing, domestic and commercial laundering, domestic and commercial laundering using a non-phosphate reference detergent incorporating a low temperature bleach activator, dry cleaning, bleaching, hot pressing		ISO 105, various sub-parts
		Dry cleaning and Finishing-Part 1: Method for assessing the fabric care		ISO 3175-1
	D	Mass loss after abrasion or laundering	product dependent	
		Textiles - Determination of dimensional change in washing and drying		ISO 5077 (EN 25077)
		Textiles- Determination of dimensional changes of fabrics induced by cold-water immersion		ISO 7771
	M	Textiles-Domestic washing and drying procedures for textile testing		ISO 6330 plus CGSB-4.2/58 or ISO 5077
3.2 Disposal	D			This Triptych
3.3 Labelling	M			This Triptych

SECTION II - TEST SCHEDULE AND TEST METHODOLOGIES

G201 Introduction

1. In the Triptych many parameters are mentioned that should be evaluated on the complete system. This section combines these human trials on total systems with the aim of improving evaluation efficiency and overview. Table G-2 gives the resulting schedule. Clothing parameters are determined either during a troop trial in the field, at a technical facility, or in a climate-controlled chamber trial. No complete test protocols are given. These are presented in the Triptych, Section 8.1.

2. This section also gives a generalised description of a field trial and a climate-controlled chamber trial.

Table G-2 – Suggestion to combine tests for non-CBRN properties.
Some tests can be performed in different settings

Parameter and corresponding part of Triptych Chapter 8 Section 8.3	Field Test	Technical Facility Test	Climate Chamber Test	Separate Test	Remark
2.2.4 Contamination Control Area (CCA) Procedures	X				
2.3.2 Comfort	X				
2.4.1 Performance reduction	X				8 subjects who all fit into the same size of the clothing system
2.4.5 Touch	X				
2.5.1 Compatibility	X				Parallel evaluation of the respiratory protection should be performed in presence of full protective system according to D/103.
2.8 Training	X				
2.2.1 Donning/Doffing uncontaminated clothing	X	X			
2.2.2 Open and closed state	X	X			
2.3.1 Fit	X	X			
2.4.8 Urination/Defecation	X	X			
2.3.4 Odour	X	X			

Parameter and corresponding part of Triptych Chapter 8 Section 8.3	Field Test	Technical Facility Test	Climate Chamber Test	Separate Test	Remark
2.3.5 Noise	X	X			
2.4.2 Heat stress	X		X		
2.3.3 Skin Irritation and Toxicity	X			X	Also swatch and other tests.
3.1 Durability	X			X	
2.2.3 Doffing contaminated clothing		X			
2.4.3 Vision		X			
2.4.4 Hearing		X			
2.4.6 Identification		X			
2.4.7 Respiratory Detection		X			
2.7.2 Silhouette		X			
2.7.3 Noise		X			
2.1.1 Weight				X	
2.1.2 Packaged Volume				X	
2.1.3 Packaging				X	
2.5.2 Static electricity				X	Might be part of field trial as well.
2.5.3 Magnetic properties				X	Might be part of field trial as well.
2.6.1 Liquid resistance				X	
2.6.3 Flame and fire				X	
2.7.1 Camouflage				X	
3.2 Disposal				X	
3.3 Labelling				X	

Note: Technical facility tests might be combined with climate-controlled chamber trials using human volunteers.

SECTION III - TEST ENVIRONMENTS

G301 Field

While serving as a protective barrier between the user and his environment, clothing can also reduce his performance, by factors like the thermal physiological load, the weight, stiffness, and thickness of the system. Field trials are the best way to evaluate the performance reduction.

G302 Technical facility

Some tests need to be performed in a controlled environment, like a laboratory, but do not necessarily need a climate chamber.

G303 Climate chamber

1. In some cases the health of the user might be at risk due to the burden caused by the clothing. The most dominant burden on the user of protective clothing systems is the thermal physiological load. Climate-controlled chamber trials are the best way to evaluate this property.

2. A climate chamber should be used for tests for which a relevant, controllable and reproducible climate is needed. The climate chamber used should at least be able to control the following parameters (minimum range; accuracy):

   a. Temperature (15ºC – 50 ºC; 0.5 ºC),

   b. Relative humidity (10% - 80%; 2%) and

   c. Air flow (0.5 m/s – 2.5 m/s; 0.5 m/s).

G304 Safety

All human testing should be performed according to national medical ethical laws and guidelines. An approved human use protocol must be used when testing with humans. Care should be taken to avoid heat exhaustion/dehydration. The test should be stopped if the subject reaches a core temperature of 39 ºC, a heart rate of 80 percent of maximal, or when the subject declares that he is not able to continue the test.

G305 Preparations

Prior to the evaluations described in this section, a detailed description should be made of the potential users and the environment for which the clothing system is intended. For test-input or criterion decision the evaluation should at least include the following information:

   a. Anthropometric profile (Body sizes) of the users

   b. Climate (air temperature (ºC), relative humidity (%), solar radiation (W/m^2), latitude (º), wind speed (m/s)), see also AEP-38 Volume II, Section VI.

   c. Work rate (watts) of the users during their tasks

(1) ISO 9886

d. Duration of the tasks and the deployment in the suit

e. Work/rest schedule (if applicable)

(1) STANAG 2499 (ATP-65)

f. Critical skills (handling small objects, communication, operating machinery of vehicles, handling weapon systems, etc.)

g. A table with all tasks which need to be performed by the user with a percentage of loss in performance and increase in completion time.

h. A list of other clothing and equipment used with the clothing system (underwear, combat fatigues, boots, over boots, gloves, respirator, ballistic vest, helmet, load carriage system, weapons, etc.).

G306 Required / prerequisite for the methods

The prerequisites for this method are:

a. Test specimens: Complete IPE ensemble, 1 per test. Includes respirator, protective clothing, gloves, boots etc.

(1) To be worn with appropriate ancillary items such as underclothes and other operational equipment (if desired) when equipment integration is to be investigated.

(2) If the clothing system is intended to be used in combination with a cooling system, then the clothing system should be tested complete with the cooling system.

(3) All IPE will be chosen to fit the test platform according to manufacturer's sizing specifications.

(4) Additional tests may be performed on preconditioned ensembles (for example, laundering, previous wear) if desired.

b. Donning/doffing instructions for ensemble.

c. Storage/care/laundering/decontamination instructions for ensemble if applicable.

d. Should a user group require a specific activity routine to be used because the standard routine of the method is deemed not sufficiently representative of activity type or level, an appropriate activity routine will be developed between the user group and the test specialist.

e. Equipment and methods to monitor human safety.

f. Questionnaires evaluating the parameters tested.

G307 Sensitivity / reproducibility

For whole system evaluation, it should be noted that the inter- and intra-person variability in human factors is high due to fit to the wearer, individual fitness level, and motor skills. Therefore all tests and analyses should be performed using a balanced within subject design. At least eight healthy, fit acclimatised subjects representative for the users of the clothing system should be used for human subject testing.

SECTION IV - FIELD TRIAL TO ASSESS HUMAN PERFORMANCE

G401 Introduction

1. This field trial description suggests a generalised method to evaluate the human performance reduction from multiple sources (weight, stiffness, design, etc) due to wearing an entire protective ensemble but excluding heat stress. To assess equipment compatibility the tests should also be performed with and without other equipment.

2. Other tests to be included in the field trial are described in Table G-2.

G402 Preparation

(See G305 and G306) The field environment should be prepared with the appropriate test equipment.

G403 Applicability / non-applicability

The test is applicable on a range of clothing representative of the national sizing system. It shall be used in the selection/qualification of the clothing to accept/reject based on operational criteria. It may also be used in the R&D phase to determine the effect of IPE design parameters such as materials, overall garment design including fit, and to determine integration with other equipment, aimed at ranking, comparing, or acceptability against criteria.

G404 Test set-up

The tests should be performed with at least eight healthy, fit acclimatised subjects representative for the users of the clothing system. All tests should be performed once with operational combat clothing and once with the clothing system.

Note: A suggestion to evaluate the Performance reduction involves the following tests:

Test	*Measurement*
20 meter sprint	*Time*
10 meter cat crawl	*Time*
Grenade throwing	*Distance*
10 x Take cover and stand up	*Time*
Climbing through a window	*Time*
Minnesota dexterity test	*Number of discs*
Range of motion (arm and legs)	*Angle*

G405 Analysis

The loss of performance is calculated as:

$$Loss\ in\ performance = \frac{(performance\ in\ clothing\ system) - (performance\ in\ combat\ clothing)}{(performance\ in\ combat\ clothing)} \quad (G.1)$$

G406 Criterion for the assessment of the suits

The user should be able to perform all tasks while wearing the suit in a non-contaminated environment (clothing in Open State). The user should be able to perform at least all critical skills while wearing the suit in a contaminated environment (clothing in Closed State), including enough sense of touch and being touched. The loss of performance during the task should not be greater than the criterion value decided on in national guidelines.

SECTION V - CLIMATE CHAMBER TRIAL TO ASSESS HUMAN SUBJECT HEAT STRESS

G501 Introduction

1. This climate chamber trial description suggests a generalised method to evaluate the heat stress caused by the clothing system. Heat and mass transfer of the human body to the environment is reduced by wearing protective clothing. As a result the core temperature of the user will rise, resulting first in a reduced cognitive and physical capacity and later in heat syncope and heat stroke.

2. A number of material properties are related to heat and mass transfer resistance: heat resistance, vapour permeability, air permeability, radiant reflectivity, and radiant heat transfer (see Section G102). Heat and mass transfer are also affected by clothing design properties like ventilation through openings and air layer(s) under the suit.

3. Technical facility tests, described in Table G-2, may be combined with the climate chamber test described in this section.

G502 Test platforms

1. A human test platform is usually preferred when the effect of clothing design parameters is being investigated, particularly in the later stages of design, because variations in human anthropometry are a critical factor in the performance of closures and in equipment integration and should thus be investigated.

2. Additional benefit is also derived from human feedback on other aspects of design performance such as comfort, fit, thermal burden, and ease of donning/doffing.

3. A mannequin platform is useful when a highly controlled/repeatable or rugged test platform is required (in particular, repeated tests with a change in a single environmental parameter, early R&D) or

where there could be ethical concerns with human subjects (e.g. long duration tests > 2 hours, extreme temperatures).

a. The mannequin platform shall attempt to replicate representative human anthropometry and motion to the extent possible, including appropriately tissue-like sealing surfaces near closures.

b. The mannequin platform should be able to generate heat and sweat.

c. The mannequin platform should be able to perform a walking movement pattern.

G503 Preparation

(See G305 and G306) Sensors shall be used to measure heat stress related physiological parameters on the human test platform.

a. thermal sensors for skin and/or gastro intestinal tract, like a rectal probe, an oesophageal probe or a pill according to ISO 9886, and

b. heart rate sensors, like a 3-lead ECG or a device that can measure the heart rate with the same accuracy.

G504 Applicability / non-applicability

1. The test is applicable on a range of clothing representative of the national sizing system. It shall be used in the selection/qualification of the clothing to accept/reject based on operational criteria. It may also be used in the R&D phase to determine the effect of IPE design parameters (e.g. materials, overall garment design including fit), and to determine integration with other equipment, aimed at ranking, comparing or acceptability against criteria.

2. While the methodology does assess the performance of peripheral items such as gloves and boots as part of the clothing system, the sensitivity of the method might not be enough to distinguish between models of these peripheral items. These might better be evaluated with (sub) system tests on non-human platforms.

G505 Test set-up

1. The climate chamber air temperature, relative humidity and air movement shall be set and controlled to values predefined in G305.

2. At least eight healthy, fit acclimatised subjects representative for the users of the clothing system shall perform the activity routine. As a minimum, triplicate testing shall be performed with a mannequin platform.

3. All human subjects should perform the tests in all clothing conditions according to a balanced design. Each subject should perform all tests at the same time of the day. The subjects can serve as their own control in a repeated measurements test design. At least three days should be between replicate tests of one subject.

4. In the climate chamber the subjects should perform a test protocol of which the intensity, the work – rest schedule and the duration have been determined prior to the test, G305. To control the metabolic rate the subjects should exercise on a treadmill at a defined speed and angle or at an ergometer at a fixed energy output. Their metabolic rate should be checked by measuring the oxygen consumption.

5. Heart rate and core temperature should be closely monitored during the tests. Skin temperatures should be measured at minimal four (but preferably more) skin locations according to ISO 9886.

6. Comfort should be assessed by asking the subjects before, during (with a 5 minute interval), and after the exercise protocol to rate their comfort (ISO 10551), thermal comfort (ISO 10551), and perceived exertion (Borg) using subjective scales.

7. All measured parameters should be analysed with an interval of not more than 10 minutes. In addition, the time until the subjects reached a defined core temperature (38.5 ºC) should be included.

8. If a mannequin platform is used the test should be performed at the required test conditions, sweat rate and activity routine, according to the operating instructions of the mannequin. Usually the heat and mass transfer from the mannequin platform to the environment is measured. Thermo physiological models can be used to convert this data into human use information about the change in core temperature over time with a given work rate.

G506 Analysis

Sensor readings and questionnaire results are collected and averaged.

G507 Suggested criteria for the assessment of the clothing

1. For a population of labourers, an average core temperature over the population of 38.5º C was proposed as a limit value (Malchaire, 2002). Because a military population can be regarded as a more homogeneous and fit population, an average core temperature (over the population) of 38.5 ºC can be used as a limit which would be predicted by using a thermal physiological model. Individual users can be allowed to work until a core temperature of 39 ºC, but this requires monitoring devices and medical supervision, and is outside the scope of this document.

2. The scores for comfort and thermal comfort should on average deviate not more than 1 point from the scores while wearing combat clothing under the some conditions. The perceived exertion should not increase by more than 2 points compared to wearing combat clothing under the same conditions.

GLOSSARY OF ABBREVIATIONS

A

AAP	Allied Administrative Publication.
AATCC.	American Association of Textile Chemists and Colorists.
AEP	Allied Engineering Publication.
AJP	Allied Joint Publication
APR	Air Purifying Respirator.
ASTM.	American Society for Testing and Materials.
ATP	Allied Tactical Publication.

C

CBRN	Chemical, Biological, Radiological and Nuclear.
CCA	Contamination Control Area.
CFU	Culture Forming Unit.
CGSB	Canadian General Standards Board.
COLPRO	Collective Protection.
CSG	Challenge Sub Group (of JCG CBRN).
CWA	Chemical Warfare Agent.

D

DIN	Deutsches Institut für Normung.

E

EN	European Standard.
EOD	Explosion Ordinance Disposal.

I

IPE	Individual Protective Equipment.
ISO	International Organization for Standardization.

J

JCG CBRN Joint Capability Group CBRN Defence (formerly LG7).

L

LLR Low Level Radiation.

N

NATO North Atlantic Treaty Organisation.

NBC Nuclear Biological and Chemical.

NFPA National Fire Protection Association (USA).

NPSG Nuclear Protection Sub-Group (of JCG CBRN).

P

PAPR Powered Air Purifying Respirator.

POL Petroleum, Oil and Lubricant.

Q

QSTAG Quadripartite Standardization Agreement (USA, GB, CAN and AUS).

R

R&D Research and Development.

S

STANAG Standardization Agreement.

T

TIC Toxic Industrial Chemical.

TIM Toxic Industrial Material.

Note. This list or abbreviations contains abbreviations and acronyms commonly used in joint and multinational CBRN defence operations. It is not exhaustive and a comprehensive list of abbreviations is contained in document AAP-15.

GLOSSARY OF TERMS

A

activity

The word activity is used in several ways throughout the document. With respect to a technical characteristic of radiation, activity means the rate of disintegration of a radioactive substance per unit of time.

acute toxicity

The degree to which an agent leads to a short-term toxic effect on the person exposed.

aerosol

A suspension of solid or liquid particles in a gaseous medium, usually air. Particle size is usually measured in microns. (AAP-21)

aerosolisation

The production of a cloud of solid or liquid particles in air or other gaseous medium. (AAP-21)

B

beta particle

A nuclear particle emitted by many radionuclides during decay. Beta particles have a few meters range in the air, but poor powers of penetration. Where deposited on the skin or taken into the body, they may cause significant injury. (AAP-21)

biological agent

A microorganism, which causes disease in man, plants, or animals, or causes the deterioration of material. (AAP-21). Toxins could also be included in this term.

biological warfare agent

See biological agent.

C

calibration

Means of establishing the ratio between the output of a measuring device and the real value, obtained from a reference material.

challenge sub group

A NATO group formed under the authority of the Joint Capability Group on CBRN Defence (formerly LG7).

chemical agent

A chemical substance which is intended for use in military operations to kill, seriously injure, or incapacitate man through its physiological effects. The term excludes riot control agents when used for law enforcement purposes, herbicides, and smoke and flames. (AAP-21)

In this document the term chemical agents indicates all chemicals that pose a toxic challenge, and covers both chemical warfare agents and toxic industrial chemicals.

chemical warfare agent

Preferred term: chemical agent. (AAP-21)

In this document the term chemical warfare agent refers to the classical chemical warfare agents.

Chemical Biological, Radiological, and Nuclear Defence

Plans and activities intended to mitigate or neutralize adverse effects on operations and personnel resulting from: the use or threatened use of chemical, biological, radiological or nuclear weapons and devices; the emergence of secondary hazards arising from counter-force targeting; or the release, or risk of release, of toxic industrial materials into the environment. (AAP-21)

In this document the term CBRN Defence refers to all measures designed to defend against CBRN Incidents.

Chemical, Biological, Radiological and Nuclear (CBRN) Weapon

A CBRN weapon is any device designed to create a nuclear explosion or to deliver nuclear material, radioactive sources, a biological agent, toxin, or chemical agent.

Chemical, Biological, Radiological or Nuclear (CBRN) Incident

An occurrence resulting from: the use or threatened use of chemical, biological, radiological or nuclear weapons and devices; the emergence of secondary hazards arising from counter-force targeting; or the release, or risk of release, of toxic industrial materials into the environment.

closed state

The state defining use of a suit by closing it and securing all closures and fittings.

clothing item

Any piece of IPE worn on the body aimed at protecting the skin against CBRN and other toxic challenges.

clothing system or clothing

The total combination of all clothing items worn on the body aimed at protecting the skin against CBRN and other toxic challenges. When clothing consists of several layers the combination of these layers are considered to be one material system and should be tested as such unless otherwise defined.

collective protection (COLPRO)

Protection provided to a group of individuals in a CBRN environment, which permits relaxation of individual CBRN protection. (AAP-21)

concentration × time

A measurement of exposure to an agent, expressing the concentration of the compound multiplied by the duration of exposure. Usually abbreviated as Ct and expressed in milligrams per cubic metre multiplied by minute ($mg.min/m^3$).

Frequently expanded to reflect the likely effects on a target population e.g. Lethal Concentration Time $(LCt)_{50}$ - the Ct that will kill 50% of the exposed group- or Incapacitation Concentration Time $(ICt)_{50}$ - the Ct that will incapacitate 50% of the exposed group. (AAP-21)

contamination control area

In collective CBRN protection, an area before the toxic-free area in which personnel can remove and doff contaminated individual protective equipment with reduced risk, and where equipment and supplies can be decontaminated. It includes the airlock(s), vapour hazard area, changing booth(s) and liquid hazard area. (AAP-21)

contamination

The deposit, absorption or adsorption of radioactive material, or of biological or chemical agents on or by structures, areas, personnel or objects. (AAP-6)

contamination density

Amount of (liquid) CBRN agent per surface area (g/m^2).

convective flow

The airflow through air permeable material resulting from incident wind.

D

decay

The progressive reduction in intensity or viability of a chemical, biological or radioactive agent or material with respect to time. (AAP-21)

decontamination

The process of making any person, object, or area safe by absorbing, destroying, neutralizing, making harmless, or removing chemical or biological agents, or by removing radioactive material clinging to or

around it. (AAP-6)

In this document decontamination is the cleaning of contaminated clothing in specially designed facilities after it has returned from field use.

Decontamination is also applied as the cleaning of test equipment.

detection

In this document detection means the quantification of an amount of challenge agent or the qualification of the presence (e.g. of breathing).

detector

In this document a detector is any device aimed at quantification of an amount of challenge agent.

diffusive flow

Condition where flow through the material is limited down to pure diffusion due to air flow resistance which could originate from either the total material combination or from the small distance to the body.

dispersion

The dissemination in liquid, vapour, solid or gaseous form of chemical, biological or radioactive agents or materials arising from CBRN Incidents (AAP-21)

dosage and dose

For clarity reasons the term dosage has been used in the document, whenever concentration×time is indicated. Dosage can be expressed as mg min/m^3 or particles min/m^3 or CFUs min/m^3 or Bq min/m^3.

The term dose has been used for all other units of exposure.

dress state

In this document the term Dress State refers to the level of IPE donned for personal protection, according to national regulations.

E

effective dose

In the radiological field, the sum of the products of each equivalent dose (in Sievert, Sv), received by and committed to an organ or tissue, with the appropriate tissue weighting factor accounting for the different sensitivities of different organs and tissues to the risk of injury resulting from irradiation.

The equivalent dose is the product (in Sievert, Sv), of the absorbed dose received from a specific type of radiation, and the appropriate radiation-weighting factor accounting for the different potential for injury from that type of radiation. (Nuclear Safety Orders and Directives).

The absorbed dose is the quotient, measured in grays (Gy), obtained by dividing the energy absorbed (in

J) through exposure to radiation by the mass of the body (in Kg), or part thereof, that absorbed the radiation.

F

fallout

The return to lower atmospheric levels and to earth of radioactive substances projected at high altitude and contaminated particulate matter and debris absorbed into the cloud of a nuclear burst.

fission

The process whereby the nucleus of a heavy element splits into (generally) two nuclei of lighter elements, with the release of substantial amounts of energy. (AAP-6)

G

gamma radiation

A nuclear electromagnetic radiation of sufficient energy to cause ionisation, emitted by many radio nuclides during decay. Gamma rays have a range of several kilometres in the air and are highly penetrating; they are primarily an external hazard. (AAP-21)

gray (Gy)

Unit of absorbed dose of ionizing radiation. Ordinarily used to assess impacts of the operational exposure of personnel to gamma radiation. May also be expressed as a dose over time (dose rate) e.g. in centi- or milli-gray per hour (1Gy = 1Joule (J) per kg). (AAP-21)

I

Immediate decontamination

Decontamination carried out by an individual upon becoming contaminated, to save life and minimise casualties. This may include decontamination of some personal clothing and/or equipment. (AAP-6) It is not aimed at decontamination of protective clothing materials, which can adsorb the agent or the decontaminant.

incapacitating

Preventing a person to perform a task.

incident wind

Condition where realistic wind speed blowing perpendicular to the clothing is simulated. For air permeable materials not in close contact to skin this will result in a (convective) flow through the material.

individual CBRN protection

Protection provided to the individual in a nuclear, biological and chemical environment by protective clothing and/or personal equipment. (AAP-6)

individual protection

Used in the text to indicate individual CBRN protection.

individual protective equipment (IPE)

The personal clothing and equipment required to protect an individual from biological and chemical hazards and some nuclear effects. (AAP-6) This ordinarily includes but need not be limited to the respiratory protective device, whole-body covering and simple detection, decontamination and first aid devices.

inside clothing /material

The side of the clothing/material that is facing the skin.

L

LC_{50}

The concentration of a chemical or biological agent or dose of radiation, which has been calculated to cause death in 50% of a defined population within a certain exposure time (to be specified).

LC_{Lo}

The lowest reported concentration of a chemical or biological agent or dose of radiation, which has been calculated to cause death in a defined population.

LD_{50}

The dosage or dose of a chemical or biological agent or the dose of radiation, which has been calculated to cause death in 50% of a defined population.

liquid-liquid test

A test in which the challenge agent is applied as liquid and subsequently penetrates the clothing in liquid form.

liquid-vapour test

A test in which the challenge agent is applied as liquid and subsequently penetrates the clothing in vapour form.

M

material layer

Is stated as a single layer.

material

Combination of layers as it is used in a clothing item. A suit can consist of different layers like different individual material layers, each colour or other material treatment, each type of seam, each type of zipper including the material it is sown in, etcetera.

When clothing consists of several layers, the combination of these layers is considered to be one material and should be tested as such unless specifically defined otherwise.

median lethal dose

The amount of chemical agent that would kill 50 % of exposed, unprotected and untreated personnel.

N

nerve agent

A potentially lethal chemical agent, which interferes with the transmission of nerve impulses. (AAP-6)

nuclear agent

Radioactive fission products of a nuclear bomb which can result in casualties due to the short and long term effects of the radiation.

nuclear warfare agent

See nuclear agent.

nuclear weapon

A complete assembly (i.e. implosion type, gun type or thermonuclear type) in its intended ultimate configuration, which, upon completion of the prescribed arming, fusing and firing sequence, is capable of producing the intended nuclear reaction and release of energy. (AAP-6)

Thermonuclear is an adjective referring to the process (or processes) in which very high temperatures are used to bring about the fusion of light nuclei, with the accompanying liberation of energy. Fusion is the process whereby the nuclei of light elements combine to form the nucleus of a heavier element, with the release of tremendous amounts of energy. (AAP-6)

O

operation

Group of military actions to obtain a specified goal.

open state

The state defining use of a suit without closing it and securing all closures and fittings.

outside clothing /material

The side of the clothing/material that is facing the outside environment and the challenge agent.

P

particulate

Particulate as an adjective means consisting of small particles. Particulate as a noun is used as an abbreviation for "particulate suspension in" (for instance in air or liquid).

personal protection (CBRN)

Personal protection is the employment of policies, doctrines, procedures or equipments to provide individual, collective, and casualty protection and medical countermeasures which will enable personnel to survive and operate in a CBRN environment. (AAP-21)

physiological burden

The physiological influence (stress and discomfort) on the human body by use of protective clothing.

protective clothing

Clothing especially designed, fabricated, or treated to protect personnel against hazards caused by extreme changes in physical environment, dangerous working conditions, or enemy action. (AAP-6)

R

radiation

The emission by a nuclear substance, the production using a nuclear substance, or the production at a nuclear facility of an atomic or subatomic particle. It includes, but is not limited to: alpha particles, beta particles, gamma rays, neutrons, and x-ray radiation. (Nuclear Safety Orders and Directives)

radiation dose

The total amount of ionizing radiation absorbed by material or tissues, expressed in centigrays (cGy) or Sieverts (Sv). (AAP-21)

radiological agent

Radioactive material, which can result in casualties due to the short and long term effects of the radiation.

radiological warfare agent

See radiological agent.

radiological weapon

An improvised bomb, missile, shell, rocket, or other dissemination device capable of delivering radioactive material.

re-aerosolisation

The production of a cloud of solid or liquid particles in air or other gaseous medium by mechanical movement, which removes already, deposited particles from surfaces.

residual contamination

Contamination, which remains after steps have been taken to remove it. These steps may consist of nothing more than allowing the contamination to decay normally. (AAP-6)

S

scenario

Is the dynamic description of the actions before and after the incident.

sievert

Unit of ionizing radiation used for measurement of radiation dose. Ordinarily employed to assess the effects of long-term or whole-life exposure of personnel.

simulant

A substance, which for safety or ease of use is applied instead of a dangerous substance with approximately the same behaviour for the property to be simulated.

solar radiation

In this document solar radiation is used as the energy received per surface unit over a specific period of time. It is expressed in W/m^2.

swatch

A piece of material with correct size to fit in the test equipment. The piece is cut from the material to be evaluated.

T

task

Any individual act to be performed during a military operation.

test equipment

Laboratory equipment for evaluation, validation and/or certification.

test platform

The support for the item being tested, e.g. human or mannequin in a system test.

thermal radiation

The heat and light produced by a nuclear explosion. (AAP-6)

threat

The will and capability of an enemy to deploy force.

toxic industrial material (TIM)

A generic term for toxic or radioactive substances in solid, liquid, aerosolised or gaseous form. These may be used, or stored for use, for industrial, commercial, medical, military or domestic purposes. TIM may be chemical, biological or radioactive and described as Toxic Industrial Chemicals (TIC), Toxic Industrial Biologicals (TIB) or Toxic Industrial Radiologicals (TIR). (AAP-21(B))

toxin

The poisonous product of a living organism; may also be synthesised. (AAP-21)

V

vapour-vapour test

A test in which the challenge agent is applied as vapour and subsequently penetrates the clothing in vapour form.

vignette

Is a static description of an incident in its environment.

virus

A minute structure of protein-coated nucleic acid. Viruses require living cells to replicate themselves and are dependent on the cell of the host that they infect. (AAP-21)