NATO STANDARD

AEP-85

Low Burden Chemical, Biological, Radiological and Nuclear (CBRN) Protective Clothing

Edition A Version 1
OCTOBER 2016

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED ENGINEERING PUBLICATION

Published by the
NATO STANDARDIZATION OFFICE (NSO)

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION OFFICE (NSO)

NATO LETTER OF PROMULGATION

28 October 2016

1. The enclosed Allied Engineering Publication, AEP-85, Edition A, Version 1, LOW BURDEN CHEMICAL, BIOLOGICAL, RADIOLOGICAL AND NUCLEAR (CBRN) PROTECTIVE CLOTHING, which has been approved by the nations in the NATO Army Armaments Group, is promulgated herewith. The recommendation of nations to use this publication is recorded in STANREC 4738.

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4. This publication shall be handled in accordance with C-M(2002)60.

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
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RECORD OF SPECIFIC RESERVATIONS

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CHAPTER 1: PRINCIPLES

1.1. INTRODUCTION

The proliferation of chemical, biological, radiological and nuclear (CBRN) agents, weapons and their means of delivery pose an enduring major threat to NATO countries. The operating environment continues to evolve away from the apocalyptic nature of the Cold War into a more pervasive and irregular threat based in diverse theatres of operation with varying climatic conditions. The need for CBRN defence has not changed, but the requirements have evolved. These changes (relative to the traditional Cold War scenarios) have led to increased interest in CBRN defence systems that reduce the physiological burden[1] on the user.

1.2. PURPOSE

The purpose of this Allied Engineering Publication (AEP) is to assist in the development, setting requirements, evaluation and acquisition of a Low Burden Suit (LBS). AEP 85 should be used in conjunction with AEP 38 (which describes general requirements for CBRN suits) alongside the other documents listed below if a nation wishes to develop a LBS.

a. AJP-3.8 (A) (STANAG 2451) - Allied Joint Doctrine for CBRN Defence.

b. ATP-3.8.1 Vol 1 (STANAG 2521) - CBRN Defence on Operations.

c. ATP-3.8.1 Vol 2 (STANAG 2522) – Specialist CBRN Defence Capabilities.

d. AEP-38 (STANREC 4548) - Operational Requirements, Technical Specifications and Evaluation Criteria for CBRN Protective Clothing.

e. AEP-72 (STANREC 4726) - Recommended CBRN and Toxic Industrial Chemical (TIC) Challenge Levels.

f. ATP-65 (STANAG 2499) - The Effect of Wearing Individual Protective Equipment (IPE) on Individual and Unit Performance during Military Operations.

g. ATP-84 (8) (STANAG 2352) - CBRN Defence Equipment Operational Guidelines.

h. AEP-58 (STANAG 4653) – Combined Operational Characteristics, Technical Specifications, Test Procedures and Evaluation Criteria for CBRN Decontamination Equipment.

i. AEP-52 (STANAG 4625) Assessment of Effect Levels of Classical Chemical Warfare Agents Applied to the Skin to be Used in the Design of Protective Equipment.

j. AEP-73 (STANREC 4727) Combined Operational Characteristics, Technical Specifications, and Evaluation, Tests and Criteria for Protective Masks.

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[1] Physiological burden is used in this document to describe the adverse effect a clothing system may impart on the wearer. These factors may be either direct or indirect in their impact and will include (but are not limited to): thermal resistance, evaporative resistance, drape, bulk, mass, stiffness, design, mobility etc.

1.3. DEFINITIONS

Low Burden within the context of this document signifies a reduction of physiological impact to the person wearing CBRN IPE when compared to current standards stated in AEP-38, Operational Requirements, Technical Specifications and Evaluation Criteria for CBRN Protective Clothing. The physiological impact should be reduced to a level which is as low as possible. However, the protection should still be effective enough for task performance.

CBRN IPE also imposes other forms of burden (e.g. logistical, training, psychological etc.). Whilst it is recognised that these should be reduced as much as possible, they lie beyond the scope of this document.

In the context of this document the term NATO forces refers to NATO declared and other deployable forces of national armed forces, as well as civilians deployed in NATO-led operations.

1.4. CONCEPT FOR ACHIEVING LOWER PHYSIOLOGICAL BURDEN

The concept to achieve a lower physiological burden begins with determining if there are operational environments where a lower level and duration of protection against CBRN agents is acceptable. If this is the case lower burden materials may be used.

The use of LBS will have many benefits in terms of user confidence and the ability to conduct tasks in an asymmetric (low intensity) conflict due to similarity of use and familiarity with standard combat clothing. However future advances in technology may minimise any need for reductions protection performance to achieve reduced burden on the individual.

1.5. SCOPE

The scope of this document is limited to the suit and not all other IPE elements. Though the concepts described within this document should also be applied to other elements of IPE.

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1.6. LIMITATIONS OF THE LBS

The LBS is designed to be used to protect against a single low event as described in AEP-72, Chemical, Biological and TIC Challenge Levels, and summarized in Chapter 3 of this document, where the suit is intended to provide protection until the forces can exit the contaminated area.

It should be noted that there may be training and psychological implications to consider with the introduction of a LBS (e.g. commander training, user awareness training and user perception of reduced protection).

1.7. OPERATIONAL ENVIRONMENT

The aim of the LBS is to achieve the criteria below with minimal degradation to mission performance, combat effectiveness or communications capability by reducing heat and physiological stress.

a. NATO Forces should be able to use a LBS in all operational environments throughout the battle space (land, sea and air) and in any climate. Therefore, the LBS should withstand environmental conditions associated with worldwide use and maintain operational capability.

b. It is envisioned that the LBS will be exposed to the environmental conditions discussed in the Allied Environmental Conditions and Test Publication (AECTP) (covered by STANAG 4370 - Environmental Testing) to include, as a minimum, temperature and humidity extremes, high/low operational and storage temperature, temperature shock, vibration, solar radiation, salt spray/fog, seawater, rain, blowing sand and rain, dust, sweat, fungus, transit drop, urine, decontaminants, as well as petroleum, oils, and lubricants (POLs) contaminants.

c. The LBS will enhance combat effectiveness compared to standard IPE by providing operationally relevant, individual protection throughout the battle space during operations (land, sea and air) in any climate, with reduced physiological stress.

d. The LBS will improve the ability of NATO forces to survive in environments that require the use of percutaneous protection. It is important to note that there will be instances where providing a lower, more operationally relevant, level and duration of protection against CBRN substances is preferable.

1.8. OPERATIONAL CONDITIONS

Commanders need to reconcile the vulnerability of their forces to CBRN hazards with the affiliated restrictions imposed by the use of protective measures, and the need to pursue the mission. Threat, vulnerability and risk analysis procedures, outlined in AJP-3.8 (STANAG 2451) Allied Joint Doctrine for Chemical, Biological, Radiological and Nuclear Defence (Annexes A, B and C) and ATP-3.8.1 Vol 1 (STANAG 2521 - CBRN Defence on Operations (Chapter 5), assist commanders in determining the defensive posture to be adopted in order to reduce degradation thereby maintaining operational efficiency. Factors for consideration include:

a. The local CBRN threat. Local commanders have some authority to determine the appropriate level of CBRN physical protection (e.g. by using a different clothing system or CBRN defence dress state, based on their assessment of local conditions, the required associated protective measures and the operational imperatives of the local situation.

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 substances, the physical protection afforded by their location will often dictate their defensive posture.

d. Duration. The duration of operations in a CBRN environment will depend on the whole CBRN capability and limitations of the force, not just on one system. The time spent wearing the clothing might be much longer than the time that protection is actually needed. For example, a cloud of agent may pass by quite quickly without leaving CBRN contamination, but this may not be clear until post-attack drills are completed. On the other hand, it may be possible and/or desirable to change out equipment in the middle of a task.

e. Non-CBRN Challenges. Non-CBRN challenges may affect the protection level offered by CBRN clothing. For instance, temperature and weather are crucial factors that influence the degree of thermal stress imposed by wearing IPE. Moreover, the location and nature of work will affect the environmental, physical and mechanical challenges to the clothing.

f. Contaminants. Contaminants such as POLs may affect the level of protection afforded by the CBRN clothing. Users should minimise surface contamination where possible.

CHAPTER 2: DESIRED CAPABILITY

2.1 BASIC PRINCIPLES

AJP-3.8, Allied Joint Doctrine for CBRN Defence, provides NATO strategic and operational commanders with fundamental principles for the planning, execution, and support of NATO operations for which the threat and/or risk of intentional or accidental use CBRN substances are either assessed or exist. These CBRN Defence principles provide a foundation for and guide the joint force in identifying required CBRN Defence capabilities.

Commanders should consider the effects of wearing IPE on the performance of individuals such as dehydration, restricted vision and less effective communications. The physiological and psychological effects of wearing IPE can affect the maximum continuous time that an individual can be reasonably expected to work in any type of operational environment. In most instances, work/rest cycles must be set up to maximize combat effectiveness.

2.2 NATO DRESS STATES

Ideally personnel will get sufficient warning of attack to adopt an appropriate dress state before arrival of the agent. This will ensure that IPE always provides appropriate protection and any wear is compensated for as soon as possible after an incident. The following is a description of the NATO Dress States, as described in AJP-3.8 and further discussed in ATP-65 (STANAG 2499) The Effect of Wearing CBRN Individual Protective Equipment (IPE) on Individual and Unit Performance During Military Operations:

NATO DRESS STATES	ITEMS OF DRESS			
	RESPIRATOR	SUIT	FOOT PROTECTION	HAND PROTECTION
ZERO	Issued and Carried	1st set ready 2nd set deployed		
ONE	Carried	Issued and Carried	Issued and Carried	Issued and Carried
TWO	Carried	Worn	Carried	Carried
THREE	Carried	Worn	Worn	Carried
FOUR	Carried	Worn	Worn	Worn
FOUR +	Worn	Worn	Worn	Worn

2.3 CURRENT CAPABILITY

Most NATO nations provide CBRN protection through the use of a modular capability of tiered layered technologies as illustrated (illustrative and not to scale) in Figure 1 below:

a. **Combat Clothing.** STANAG 2333, Performance and Protective Properties of Combat Clothing, denotes the complete clothing ensemble; underwear, shirts, under-garments and foot wear plus garments such as ponchos and parkas.

b. **CBRN Protective Ensemble.** ATP-84 CBRN Defence Equipment Operational Guidelines, denotes that a protective ensemble is a suite of equipment that provides protection for the body and parts of the head which are not protected by the protective mask/respirator, against percutaneous biological and chemical agents, alpha and beta particles of radioactive fallout or radioactive contamination. The ensemble may be one-piece, or may consist of different items that provide hand and foot protection and can be an over- or an undergarment.

c. Impermeable Layer. This provides an incremental increase in protective capability typically achieved through the use of an additional barrier layer (generally air impermeable) significantly increasing user burden.

d. Gas Tight Suit. This represents specialist high level capability generally accompanied by self-contained breathing air. This affords the highest levels of protection but imposes significant burden and is generally only used by specialist troops.

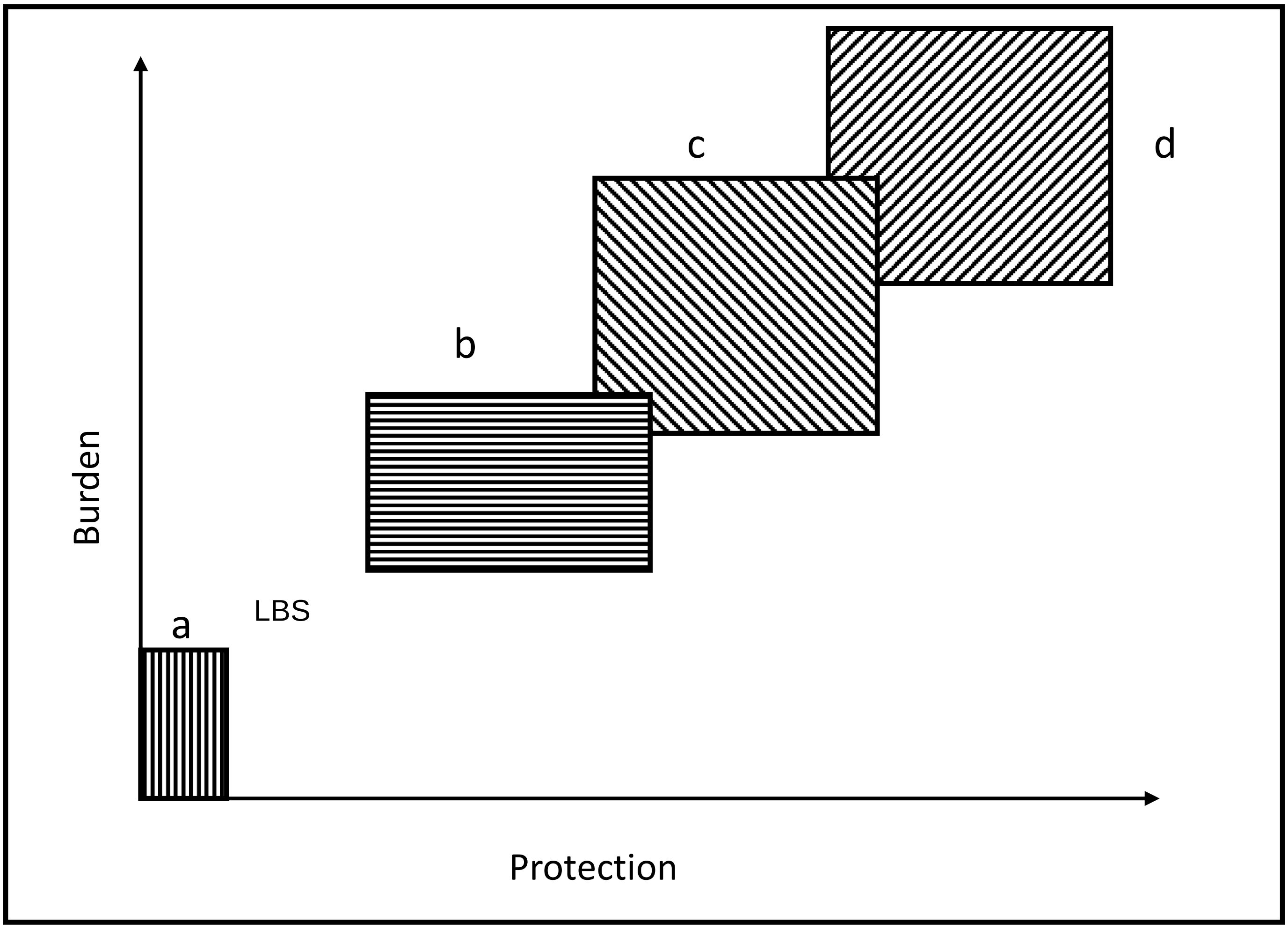

Figure 1. NATO CBRN Protective Capability:

2.4 DESIRED CAPABILITY

a. Capability Gap. The LBS is designed to bridge the protection and burden capability gap between Combat Clothing (a) and current CBRN IPE Suit/CBRN Protective (b) Ensembles to address the additional requirement of the operational environment. The LBS will enhance unit performance by providing operationally relevant, individual protection throughout the battle space during operations, whether on land, sea and air, with reduced physiological burden.

b. Operational Flexibility. LBS will offer commanders greater flexibility to respond to operational task, whilst affording appropriate levels of CBRN protection for less duration. 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. The LBS will provide commanders additional options for protection of the force by reducing performance degradation associated with physiological burden.

c. Physiological Burden. LBS will provide reduced physiological burden compared to current CBRN Protective Ensembles in use by NATO nations and aims reduce the physiological burden whilst achieving appropriate levels of protection. The LBS aims to provide this capability without degradation to mission performance and combat effectiveness that may result from physiological burden.

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CHAPTER 3: THREAT

3.1 FUTURE CBRN THREAT

NATO today faces a range of complex challenges and threats to its security. Based on the majority of current NATO intelligence estimates the probability of large-scale CBR aggression against NATO forces continues to be assessed as highly unlikely. However, an attack from beyond the Euro-Atlantic area involving unconventional forms of armed attack may occur sometime in the future. Therefore, present and future security challenges require NATO forces to be prepared to protect and defend against threats emanating from potential aggressors, non-state actors or terrorist groups. The increased risk of attack by asymmetric means could involve the use of CBRN weapons.

3.2 NATO STRATEGIC CONCEPT. CBRN protection counters a threat that has a low probability of occurrence compared with non-CBRN threats but has potentially an extremely high impact. The following assumptions characterize the future CBRN threat:

a. The use of chemical, biological and radiological agents on a large scale is, although possible unlikely;

b. Future attacks by non-state actors are likely to occur with little or no warning;

c. The spectrum of agents will become wider; the physical properties of compounds will vary, ranging from solids to liquids, through low and high volatility agents. The hazard spectrum is likely to change rapidly.

In an attempt to further characterise some of these threats AEP-72 (STANREC 4726), Chemical, Biological and TIC Challenge Levels, provides chemical agent challenge levels for asymmetric threats in order to determine protection factor requirements for a LBS. For the purposes of determining chemical challenges as the result of chemical attacks, it is necessary to establish descriptions of chemical attacks that might be experienced by NATO forces and installations. In the past the Chemical Biological Radiological Challenge Levels Team of Experts (CBRCL ToE) used the term scenarios. However, for the purpose of defining a threat for the use of the LBS, the CBRCL ToE used vignettes as a generic description of possible chemical incidents. Therefore, these are considered more of a snapshot incident within a campaign.

3.3 ASYMMETRIC (LOW INTENSITY CONFLICT) ATTACK VIGNETTES. The following three vignettes were considered by the CBRCL ToE to characterize an asymmetric (low intensity conflict) attack (further information can be found in AEP-72 volume 2).

a. Terrorist/Insurgence/Asymmetric Attack – Few Shells/Mortars/Rocket.
b. Terrorist/Insurgence/Asymmetric Attack – Few Canisters.
c. Terrorist/Insurgence/Asymmetric Attack – Small Aircraft Spray Tanks.

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CHAPTER 4: CHALLENGES AND TOXICOLOGICAL CRITERIA

4.1 CHALLENGE LEVELS FOR LOW BURDEN CBRN CLOTHING

Challenge levels for liquid and vapour are provided in AEP-72 Vol 2 table 12.10.Guidance for dosage profiles may be found in tables 12.8 and 12.9. The test battery of agents used may include those detailed in AEP-38 in addition to those agents mentioned in AEP-72.

Biological, Radiological and TIC challenge levels have not to date been developed for the LBS.

4.2 DURATION OF PROTECTION

a. **Essential.** The LBS shall provide percutaneous protection for at least 4 hours.

b. **Desirable.** The LBS should provide percutaneous protection for at least 8 hours

DURATION OF WEAR

a. **Essential.** The LBS shall provide percutaneous protection after 24 hours unchallenged wear.

b. **Desirable.** The LBS should provide percutaneous protection after 28 days of unchallenged wear.

4.3 PASS/FAIL LEVELS

The dermal toxicological criteria listed in Annex D of AEP-38 Vol 1, Operational Requirements, Technical Specifications and Evaluation Criteria for CBRN Protective Clothing, should be used to assess the performance of LBS.

4.4 TEST METHODOLOGY

The test methodologies listed in Annex F and G of AEP-38 Vol 1, Operational Requirements, Technical Specifications and Evaluation Criteria for CBRN Protective Clothing, should be used to assess the performance of low burden clothing if applicable. In the future, novel test methods may be developed specifically for low burden systems.

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CHAPTER 5: DESIGN FACTORS FOR LOW BURDEN CBRN PROTECTION

5.1 DESIGN FACTORS FOR LBS

The aim of the LBS is to deliver as much CBRN protection as possible while reducing the physiological burden to a level that is not significantly higher than the standard combat clothing.

Additionally, mobility, interoperability and integration are recognized as important characteristics that impact the physiological burden, comfort, mission performance, and survivability.

5.2 PHYSIOLOGICAL PERFORMANCE REQUIREMENTS

Guidance on physiological performance requirements is given in Annex A.

5.3 KEY USER REQUIREMENTS

5.3.1 CBRN IPE EQUIPMENT COMPATIBILITY

Essential. The LBS shall integrate with all other elements of CBRN IPE(including respiratory protection) currently in service, in accordance with ATP-3.8.1, Vol. 1, CBRN Defence on Operations.

5.3.2 MISSION COMPATIBILITY AND EQUIPMENT INTEROPERABILITY

Compatibility and interoperability ensures that soldier performance is optimized without affecting use of individual combat equipment.

a. Essential. The LBS shall allow greater or equal effectiveness in its use and during the performance of tasks using individual combat equipment that require visual, tactile, or auditory (send/receive communications) senses than that of the current CBRN clothing in use by NATO forces.

b. Desirable. The LBS shall allow the same effectiveness in the use of equipment that require visual, tactile, or auditory (send/receive communications) senses than that of the current combat clothing in use by NATO forces.

5.3.3 MATERIAL SURVIVABILITY

Essential. The LBS shall afford acceptable levels of protection for the required duration when exposed to contaminants (e.g. POLs, smoke, fumes and dust, salt water, urine and current decontaminants) during storage, and during challenged and unchallenged wear.

5.3.4 PERSONNEL SURVIVABILITY – AUDIO, VISUAL AND OLFACTORY SIGNATURE

a. Essential. The LBS shall not increase the audio, visual, or olfactory signature of the user when compared to current CBRN suits in use by NATO forces.

b. Desirable. The LBS shall not increase the audio, visual, or olfactory signature of the user when compared to standard combat clothing in use by NATO forces

5.3.5 PERSONNEL SURVIVABILITY – DONNING AND DOFFING

a. Essential. The LBS shall be able to be donned and doffed, either assisted or unassisted, without presenting a secondary hazard to the wearer or assisting personnel.

b. Desirable. The LBS shall be able to be donned and doffed unassisted without presenting a secondary hazard to the wearer.

5.3.6 FLAME RESISTANCE

Essential. The LBS shall protect personnel against the effects of flame and fire to the required national level when evaluated using the methods described in the International Organization for Standardization (ISO) 13506, Protective Clothing Against Heat and Flame, Test method for Complete Garments, Prediction of Burn Injury Using an Instrumented Manikin.

5.3.7 PACKAGING

Essential. Storage of the LBS may occur in outside areas and non-climatically controlled conditions. Therefore, packaging shall prevent the LBS from being adversely affected by storage under any climatic conditions or exposure to substances such as CBRN agents, salt spray, precipitation, ultra-violet (UV)/sunlight, petrol, oils and lubricants, etc. The LBS should be capable of operation after being stored in a temperature range of (-51°C to 71°C) as per APP21. Each LBS should be packaged in a separate protective packaging capable of withstanding the environment created by all means of transportation (with emphasis on strategic airlift). The type and size of the LBS, date of manufacture NATO, Stock Number (NSN) must be easily identified when packaged.

5.3.8 WASTE MANAGEMENT

Essential. The LBS should permit the unassisted user to urinate and defecate in accordance to AEP-38 Vol. 1.

5.3.9 MAINTENANCE AND FIELD EXPEDIENT REPAIR

Essential. Maintenance of the LBS should be limited to minor repairs of tears and/or punctures. While there are no NATO standardization requirements for a CBRN IPE Repair Kit, the design of the LBS should provide the means for a field expedient repair after minor damage allowing mission completion.

5.3.10 IDENTIFICATION

Essential. The LBS shall allow for the proper identification of the user in accordance to ATP 3.8.1 Vol 1, CBRN Defence on Operations.

5.4 MOBILITY

Mobility must be sufficient to ensure that CBRN IPE does not degrade mission performance. The ultimate determination of mobility is the ability to complete essential mission. The characterization of the LBS mobility should be based on its weight, stiffness, stretch and bulk (volume and thickness), as well as the impact these parameters will have in the time to complete a determined number of combat mission relevant activities.

This evaluation should be done using an established combat readiness course using human test subjects for evaluation of soldier equipment effects on physical performance. An example of this type of method is the Load Effects Assessment Program (LEAP). Annex B includes the general aspects of the LEAP.

a. **Essential.** The LBS shall demonstrate an improvement in weight, stiffness, bulk and nationally acceptable course/program (e.g. LEAP) time compared to current CBRN IPE.

b. **Desirable.** The LBS shall exhibit the same weight, stiffness, bulk and nationally acceptable course/program (e.g. LEAP) time compared to standard combat clothing.

5.5 FIT

Essential. The system shall be provided in a range of off-the-shelf sizes to fit the 5^{th} to the 95^{th} percentile of the user population (both females and males).

5.6 DISPOSAL

Essential. Uncontaminated clothing shall be disposed of in accordance with normal operational practices, e.g. landfill, incinerator, rendering to rags prior to landfill, etc.

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ANNEX A: GUIDANCE AND METHODS FOR MATERIAL AND CLOTHING TESTS FOR THERMAL BURDEN

1. Introduction. CBRN protective clothing may have a serious physiological impact on the end-user. The aim of this annex is to give recommendations regarding the evaluation and characterization of the thermal burden of CBRN clothing.

2. Approach. An evaluation of thermal burden involves at least one of the following:

a. Biophysical measurements of thermal insulation and moisture permeability of textiles using a guarded hot plate and of the garments using thermal manikins.

b. Biomedical modeling to predict physiological (body temperatures, sweating rate and heart rate) strain expected of soldiers wearing a particular garment configuration under conditions of environmental (temperature, humidity, air motion, radiant lead) and metabolic (work, rest) stressors.

c. Human physiological testing of clothing worn by soldiers exposed to a variety of controlled laboratory field and environmental and metabolic stressors. Human volunteers can also provide feedback on user acceptability.

3. Biophysical measurements. The initial testing of clothing begins with a biophysical evaluation of the textile material, followed by evaluation of the actual clothing on a thermal manikin. The currently fielded textile materials and clothing systems are typically used as controls (baseline) for comparative evaluations. Two methods are used: the thermal characteristics of textile samples are measured using a guarded hot plate and the thermal characteristics of clothing are determined using a thermal manikin.

a. Thermal Test Methods

- **Guarded Hot Plate.** This method measures the dry and wet (evaporative) heat transfer through a single or multiple layered textile materials to determine insulation and permeability values. It can quickly evaluate and rank a large number of similar materials.

- **Thermal manikin.** This method measures dry and wet heat transfer of clothing worn by a heated, sweating manikin in a controlled environmental chamber. The standard procedure used in operating the thermal manikin include regulation of its surface at a constant temperature, and controlling ambient temperature, relative humidity, and air velocity in the climatic chamber housing the manikin. This method also allows for the evaluation of heat transfer characteristics on a complete ensemble as it is designed to be worn. It accounts, not only for the properties of the specific textiles, but also for garment design and on the manikin form, as well as the added influence of combat equipment, such as body armor.

b. Standards. Table 1, below, the pertinent tests and standards for the conduct physical (fabric thickness and weight), as well as biophysical assessment of the thermal burden of clothing. In addition, essential and desirable levels of performance are specified.

The following tests are performed on each of the clothing layers individually (1)				
Test	Standard	Performance Value (2)		Unit
		Essential	Desired	
Fabric thickness	ISO 9073-2	< 1.5	< 1.0	mm
Fabric weight	ISO 9073-1	< 500	< 200	g/m^2
Air permeability	ISO 9237	> 150	> 500	mm/s (3)
Thermal resistance (R_{ct})	ISO 11092	< 0.04	< 0.02	m^2 K/W
Evaporative resistance (R_{et})	ISO 11092	< 15.0	< 7.0	m^2 Pa/W
The following tests are performed on a fully dressed manikin (with all clothing layers)				
Test	Standard	Performance Value (2)		Unit
		Essential	Desired	
Thermal manikin – I_{cl} value (dry)	ISO15831	< 0.21	< 0.17	m^2 K/W
Thermal manikin – R_{ecl} value (sweating)	ASTM F2370 - 05	< 50	< 40	kPa m^2/W

(1) Do not test on area's with pockets.
(2) Suggested alternative performance values are [Essential]: lower than current CBRN general purpose clothing and [Desired]: no higher than current combat uniform.
(3) Measured at 200 Pa (a 20 cm^2 test area is recommended).

Table 1. Tests standards for the thermal assessment of clothing.

4. Biomedical modeling. Presents a means of estimating physiological burden over a variety of environmental and metabolic conditions. The models may be empirical, which use mathematical functions fitted to actual data obtained from human studies; or rational, which are based on accepted physical laws and physiological principles.

5. Human physiological testing. This type of assessment can be conducted independently or in conjunction with biophysical evaluations and biomedical modeling. It is the only way to obtain accurate data on how clothing impacts the physiological strain of a given military scenario.
User acceptability can only be obtained by human testing, ideally under conditions that closely simulate operational scenarios. This is because textile properties may change when garments are worn, especially with movement, changing body temperatures, or sweat absorption. There is no single standard covering all aspects of human participant trials. However, ISO 9886, Ergonomics - Evaluation of Thermal Strain by Physiological Measurements, gives guidelines for assessing thermal strain by physiological measurements.

a. Considerations

- **Human test volunteers:** investigators must adhere to national guidelines established for research on humans which provides information and explanations about conditions, standards and safeguards that must be followed.

- **Laboratory and field assessments**: Both of these should be carried out as they asses different characteristics of the garments.

- **Test subjects:** volunteers selected should be healthy, fit for duty, and medically cleared to participate in the study. They need to meet test-specific criteria (such as limits on use of alcohol, nicotine, dietary supplements, or medications). Volunteers who have suffered from prior heat illness should be excluded.

- **Preliminary measurements:** anthropometric data are recorded, including age, height, weight, body composition, and fitness level.

- **Exercise-Heat Acclimation:** before beginning any trials for clothing evaluation during heat stress, volunteers should complete 5-10 days of exercise-heat exposures (heat-acclimation).

- **Cold Acclimation: i**s typically not required before conducting experimental trials in the cold because physiological adaptations to cold stress are much smaller and occur more slowly than adaptations to heat.

- **Familiarization:** before experimental testing begins, volunteers will be fitted to and familiarized with all clothing. This familiarization typically includes walking on the treadmill to determine workloads (approximate workloads are estimated using prediction models.

b. Environmental conditions. Laboratory **c**onditions are controlled for dry bulb temperature, dew point or wet bulb temperature, and wind speed. For field experiments dry bulb temperature, dew point, wind speed and solar load or mean radiant temperature should be recorded.

c. Physiological measurements

- **Core temperature:** should be made at the same anatomical location without bias from external environmental conditions. Methods used:

  - ❖ **Ingestible telemetric core temperature pill:** typically given 4-8 hours before testing to ensure that it has moved out of the stomach. Transit time varies, which can be a problem when a series of trials are scheduled.

  - ❖ **Suppository telemetric core temperature pill:**

  - ❖ **Flexible rectal thermometer.**

  - ❖ Alternative methods (e.g. double temperature sensor) where available and calibrated may also be acceptable.

- **Skin temperature:** it is measured at a minimum of three sights, then a weighted skin measurement is calculated.

- **Heart rate:** it is traditionally measured using bipolar electrodes, but rarely remain in place due to high sweat rates. A more reliable method is the use of an electrode band worn around the chest with a signal transmitted to wristband receiver.

- **Metabolic rate:** often measured during the preliminary measurement phase. If the clothing test requires wearing a respirator, it cannot be collected during testing. Therefore, the metabolic value collected during familiarization is used as the approximate work load.

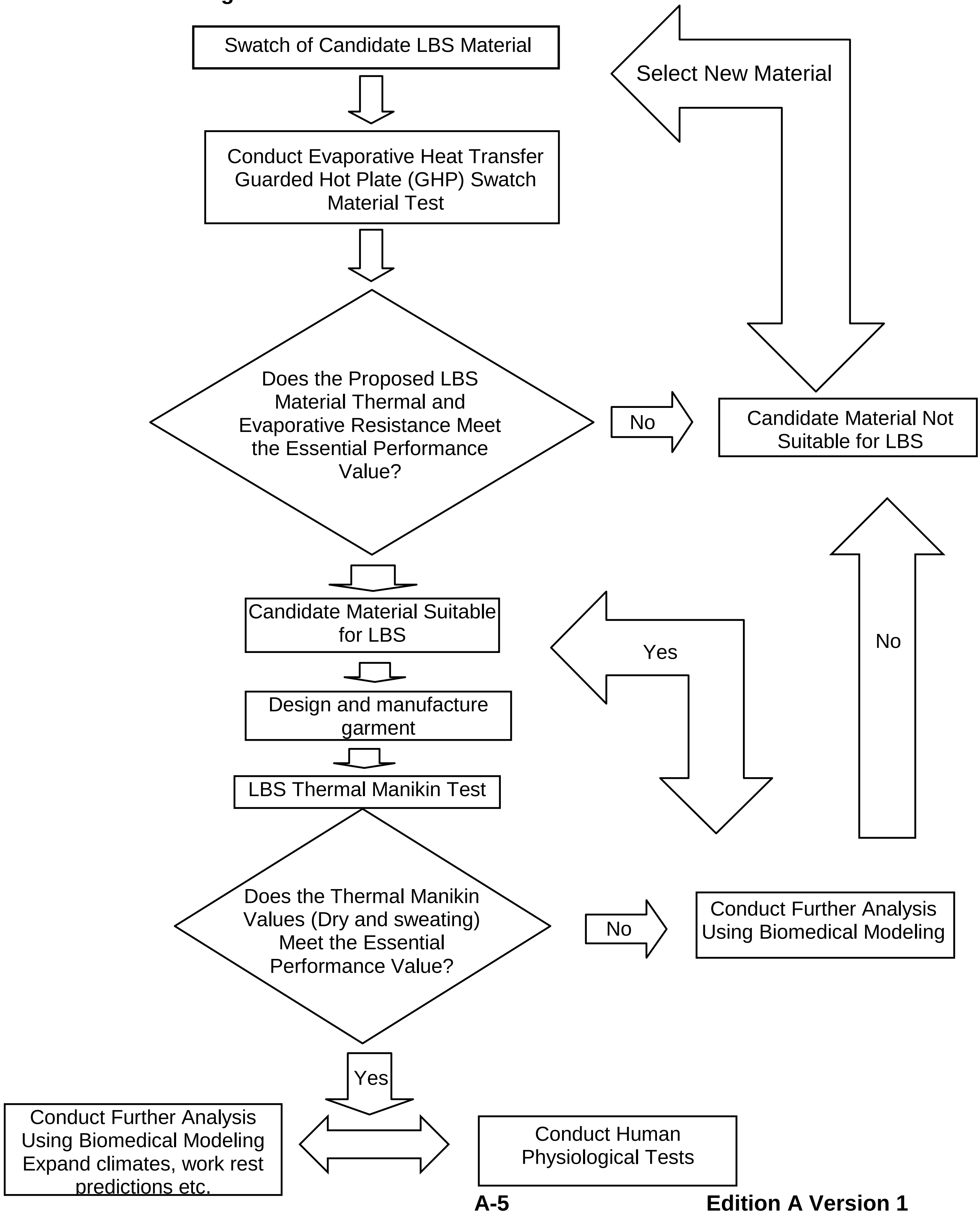
- **Nude and dressed weights:** are recorded before and after every environmental exposure. Food and fluid ingested and any elimination from the body are also recorded after obtaining the initial nude weight. These values, corrected for respiratory water loss, are used to calculate total sweating rate, as well as evaporative cooling from the clothing being tested.

- **Subjective measurements:** at set intervals during the environmental exposure, subjects may be asked to rate their perception of effort, thermal sensation, or thermal comfort.

A Flowchart for the Evaluation of Thermal Stress is included for guidance in Figure 1 of this annex.

6. Standardization documentation. There is no single standard covering all aspects of human participant trials. However, ISO 9886, Ergonomics -- Evaluation of Thermal Strain by Physiological Measurements, gives guidelines for assessing thermal strain by physiological measurements.

Figure 1. Flowchart for the Evaluation of Thermal Stress



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Annex B: GENERAL ASPECTS OF THE LOAD EFFECTS ASSESSMENT PROGRAM (LEAP)

1. Introduction. The standard combat clothing, individual combat equipment, CBRN suits and IPE have an impact on in the performance of combat missions by NATO forces. The mobility of the NATO forces is a critical attribute in accomplishing the wide variety of missions in a CBRN environment. To remain effective the commander may have the option of using the standard CBRN suit or the LBS when facing a symmetric or asymmetric threat. Both, the standard CBRN suit and the LBS have to be compatible with national individual combat equipment, as well as the CBRN IPE. Since the use of these suits contribute to the soldier's burden, it is necessary to use an objective and reliable method to measure, evaluate, and understand how these elements affect the ability of the NATO forces to execute combat missions tasks.

2. Approach. The LEAP consists of a series of obstacles and mission-relevant activities traced to physically demanding tasks to resemble challenges that NATO forces would face in combat situations. Human test subjects navigate stairs, ladders, tunnels, windows, walls and balance beams. They also perform a myriad of mission-related tasks, including load transfers, simulated casualty drags, low crawls, high crawls, back crawls and sprints. These tasks are condensed into a single course. The performance of the human test subjects, including subjective opinions, provides insight into their range of motion, comfort, mobility and endurance, as impacted by the configuration of the standard combat clothing, individual combat equipment, CBRN suits and IPE worn.

3. Development. Information from subject matter experts (SMEs) via focus groups and design workshops resulted in a preliminary LEAP concept that identified general combat tasks and mobility requirements. Further reviews and input from SMEs resulted in a down-selection to combat tasks that were deemed critical to soldiers in the areas of mobility, lethality, and survivability. Different measurable attributes of human performance, such as speed, agility, and power were identified and related back to these specific combat tasks. Subsequent focus sessions resulted in the identification of a series of specific combat-related tests that could produce measurable performance attributes. These combat-related tests were then assembled into a detailed conceptual obstacle course design, which was reviewed, revised, finalized, and eventually physically constructed. Topics such as specific obstacle dimensions, order of obstacles/tasks, course duration, method of measurement, soldier safety, and transportability of the obstacle course were all addressed during this iterative spiral design process. Once physically constructed, the obstacle and accessory stations used in the LEAP were verified through testing with human subjects prior to being employed in subsequent performance data collection efforts.

4. Availability and Use. The LEAP was adopted and is in use by the United States (Marine Corps-LEAP), Canada (CAN-LEAP) and Australia. The United Kingdom also has plans to build a system at its infantry school in Warminster.

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4. AEP-38 (STANREC 4548), Operational Requirements, Technical Specifications and Evaluation Criteria for CBRN Protective Clothing.

5. AEP-72 (STANREC 4726), Recommended CBRN and TIC Challenge Levels.

6. ATP-65 (STANAG 2499) The Effect of Wearing CBRN Individual Protective Equipment (IPE) on Individual and Unit Performance During Military Operations.

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9. ISO 13506, Protective Clothing Against Heat and Flame, Test Method for Complete Garments, Prediction of Burn Injury Using an Instrumented Manikin.

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12. ISO 9237, Determination of the Permeability of Fabrics to Air.

13. ISO 9886, Ergonomics, Evaluation of Thermal Strain by Physiological Measurements.

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17. AEP-52 (STANAG 4625) Assessment of Effect Levels of Classical Chemical Warfare Agents Applied to the Skin to be Used in the Design of Protective Equipment.

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