ALLIED
ENGINEERING
PUBLICATION

AEP-7
(Edition 5)

AEP-7

CHEMICAL, BIOLOGICAL, RADIOLOGICAL AND NUCLEAR (CBRN) CONTAMINATION SURVIVABILITY FACTORS IN THE DESIGN, TESTING AND ACCEPTANCE OF MILITARY EQUIPMENT

APRIL 2012

AEP-7
(Edition 5)

NORTH ATLANTIC TREATY ORGANIZATION

NATO STANDARDIZATION AGENCY (NSA)

NATO LETTER OF PROMULGATION

4 April 2012

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RECORD OF CHANGES

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

0101. Scope

1. This Allied Engineering Publication (AEP) provides the capability development and materiel acquisition community with guidelines, acceptance test procedures and acceptance criteria for designing military equipment. These guidelines are provided to ensure that materiel used on the battlefield will survive chemical, biological, radiological and nuclear (CBRN) hazards and can be operated by personnel in a protective posture. This publication is also provided to offer information regarding the impact of decontamination on design and materials. These guidelines do not dictate requirements for the layout, configuration or construction of military equipment nor for the selection of materials to be used for that equipment. Rather, it is aimed at familiarizing the designer of military equipment with the peculiarities of CBRN hazards and to take the proper actions in choosing designs and materials. The design or modification of equipment, structures or materiel must preserve functionality after exposure to CBRN hazards by reducing the retention or adsorption of contaminants, increasing their susceptibility to decontamination or allowing their continued employment by personnel wearing individual protective equipment.

2. In this document, the term “CBRN” will be used generically to refer to chemical, biological, radio-logical and nuclear contamination. This AEP does not cover the initial effects of nuclear weapons as this is discussed in AEP-4, which defines the nuclear hardening criteria; QSTAG 1031 covers the American, British, Canadian and Australian (ABCA) Quadripartite Standardization Agreement; and AEP-14 provides guidelines to improve nuclear radiation protection of military vehicles. And essentially this AEP-7 covers the nuclear contamination by radioactive fallout deposition and the effects of neutron activation as well as concerns pertaining to contamination by low level radiation (LLR).

3. CBRN contamination survivability is defined as the capability of a system and its crew to withstand a CBRN contaminated environment, including decontamination, without losing the ability to accomplish the assigned mission. Characteristics of CBRN contamination survivability are decontaminability, hardness and compatibility. These three terms will be described later in this document. To survive CBR contamination, materiel must meet criteria for all three characteristics.

4. The entire AEP-7 distinguishes among test acceptance criteria and test procedures, and important factors to consider in the design of military systems for CBRN contamination and decontamination. Also, this version introduces some concerns of possible presence of toxic industrial materials (TIMs) on the battlefield. While these particular aspects of warfare cannot be ignored, the procedures described herein for CBRN contamination survivability are comprehensive enough to deal with these hazards.

5. CBRN contamination survivability will be stated as essential characteristics in appropriate requirements documents and is used to design and test the survivability of mission essential (or critical) equipment under development. Once applied to a developmental piece of equipment, these characteristics cannot be modified by industry.

6. These considerations are engineering design criteria intended for use only in a developmental setting for new systems. They do not define doctrine or operational criteria for decontamination, establish protection criteria, provide guidelines on how to achieve the required survivability, establish test protocols, nor specify survivability in training environments.

7. CBR contamination survivability can also be achieved by including redundancy and re-supply, if the replacement items are readily available as logistic spares and if they are survivable in their storage configuration.

0102. Background

1. NATO forces can mitigate their vulnerability against CBRN hazards, but cannot completely remove the risk. A single use of a CBRN weapon/device against selected NATO forces could have strategy-altering consequences. The use of CBRN weapons/devices could result in combatant and non-combatant casualties of immediate significance. Contamination from a CBRN incident could affect a wide area. In every case, mitigating steps taken by NATO forces will require the balancing of imperatives related to operations and to force protection. It is also possible that, for operational reasons, some NATO elements may be expected to remain vulnerable to CBRN hazards or their effects such as in a Main Operating Base, an Air/Sea Port of Debarkation, or in and around a transportation centre point.

2. CBRN weapons and devices are primarily intended to kill or incapacitate people. Personnel of NATO forces will be forced to adopt protective measures, which degrade military efficiency and operational effectiveness, or deny use of units and materiel. To be relevant, responsive and effective NATO forces must possess a robust CBRN defensive capability. Military personnel must be equipped to operate effectively in a CBRN environment. Accordingly, materiel to perform mission-essential functions must be designed in such a way that it can be operated and remain functional in a CBRN environment. Radioactive materials are more likely to be employed to cause disruption, uncertainty, and psychological effects as the effects on personnel may not become apparent in the short term. CBRN contamination survivability is paramount.

0103. Philosophy

1. CBRN contamination survivability considers chemical, hardness, and compatibility characteristics in the assessment of the degree to which an item can survive in a CBRN environment. Another concept for consideration is mission essentiality, which requires that certain characteristics and tasks do not degrade

below a given level for the personnel and equipment to be able to accomplish the mission using their equipment at hand. These are known as mission-essential equipment. Furthermore, in order to properly use the acceptance criteria detailed in this AEP, one must understand mission essentiality, develop mission essential times and functions, and identify mission essential characteristics and associated mission essential personnel tasks. These parameters are required during the test and evaluation phase and therefore must be identified during the development phase.

2. Personnel surviving a CBRN incident must be able to continue using mission-essential (or critical) systems and equipment even though they are fully dressed with their individual protective equipment (IPE). When the mission permits, the systems and equipment should be capable of rapid restoration to a condition for all essential operations to continue in the lowest protective posture. This posture should be consistent with the mission and without long-term degradation of the materiel.

3. The determination that an item meets one or all criteria for CBRN contamination survivability is made after the evaluation of data generated from actual testing. Hardness and decontaminability testing must be conducted with real chemical agents, simulants for biological agents, open and/or sealed ionizing radioactive sources for radiological agents and simulants of nuclear fallout contamination. Under certain circumstances, hardness and decontaminability can be determined by the testing of small samples in order to avoid testing a large or expensive piece of equipment. This sample must incorporate all design features that could present decontamination problems. Once contaminated, items must be handled in accordance with national safety and security requirements. The aspect of compatibility can be studied without use of agents or simulants by exercises conducted by personnel with and without IPE. With regards to radioactive sources, personnel are exposed to penetrating radiation even if IPE is worn.

4. CBRN contamination is pervasive and can be widespread. However, equipment may be available for continued use in the mission and could be employed if the personnel can perform their tasks while protected from damaging health effects. Likewise, if equipment is not immediately damaged by CBRN contaminants, it should be capable of being decontaminated and restored to conditions such that the personnel can operate in protective clothing and such that the equipment does not experience long-term degradation. It may not be possible to protect personnel from penetrating radiation, and AEP-14 covers aspects of equipment design to provide shielding against long-term effects of ionizing radiation if inside a contaminated vehicle. The CBRN contamination philosophy is consistent with the needs of both user and materiel developer because it centres on the essential needs of the personnel. Performance levels of materials for contamination survivability are subject to regular review to take into account advances in material technology and improved equipment design.

CHAPTER 2
SYSTEM SURVIVABILITY APPROACH

0201. General

1. Defence systems require a CBRN defence capability to allow them to function and operate during a CBRN incident. An ideal system would have all required CBRN capability expected to ensure continued operation and allow completion of the planned mission. Systems with "ideal" CBRN capabilities may be expensive to produce and could be technically complex, and may be difficult and time consuming to test and evaluate. Similarly, the maintainability of such systems could be very expensive. Therefore, before the development of a system with an integral CBRN capability, it is important to define and prioritize the essential and the secondary CBRN defence capability.

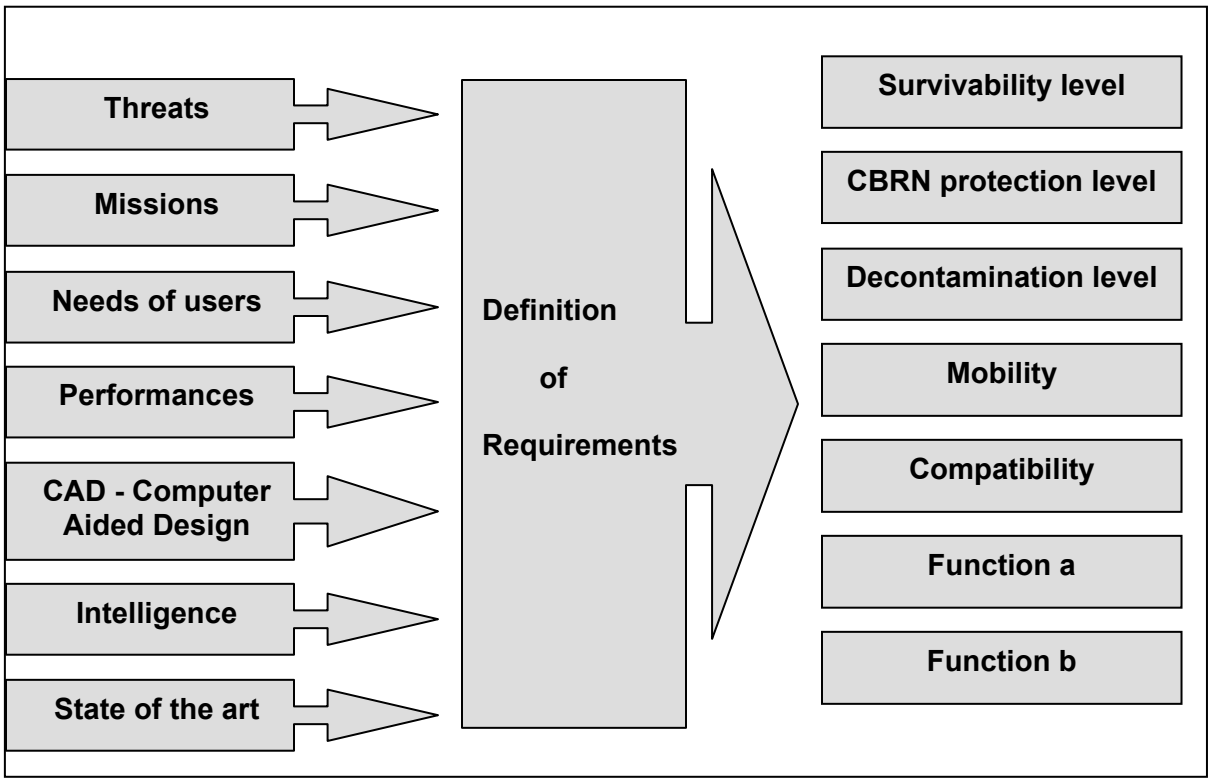


Figure 2-1. Development of CBRN System Survivability

2. Figure 2-1 presents the process to design a CBRN defence system. This process includes consideration of threats, missions, users, performance expected data from intelligence, information about materials and currently available technologies for use as requirements to define the different functions of the new system. The output data for the system would be the survivability level, CBRN protection level, decontamination level, mobility and compatibility as well as any other desirable functions (a, b), which can be the rate to shoot, battlefield communications, or any other.

3. The capability of a system to resist contamination and decontamination should reflect the requirement of the total system such as:

a. Mission (homeland, war in theatre, asymmetric war, anti terrorist missions).

b. Environment (mud, road, sand, water, urban site).

c. Climate.

d. Level of instruction of the personnel.

e. Mobility, transportability.

4. Different kinds of systems requiring a capability to operate in a CBRN environment include:

a. Individual warfighter.

b. Aircraft (planes and helicopters) interior and exteriors.

c. Sensitive elements of a weapon system.

d. Buildings and structures.

e. Naval ships and craft.

f. Sensitive equipment such as electronics and lenses.

g. Non-sensitive equipment (i.e., tactical ground systems).

5. Although large areas of planes, helicopters and aircrafts can be decontaminated by common solutions, parts of them are very sensitive and the action of common decontaminants can degrade their mechanical or electronic components. For these types of equipment, their sensitive elements should be identified at the design phase to allow specific hazard management countermeasures to be built in and appropriate decontamination processes to be identified and developed by specific tactics, techniques and procedures (TTPs) as described in Section 0209. Stand-alone sensitive equipment should be similarly identified and managed. Other systems include armoured fighting vehicles, transport vehicles and multiple rocket launchers. However, for each of these systems, appropriate decontamination processes can be identified during the design and development phase.

0202. Sensitive Equipment

1. Sensitive equipment (SE) includes those items that can not be decontaminated by commonly used methods such as aqueous or organic-based liquid decontaminants, without degradation of the item's performance. SE is also material

or equipment which can be considered as “critical” for mission performance, such as their functions being indispensable to the effective operation of the system. The decontamination of sensitive equipment should be planned early during the system design phase. The components and materials to manufacture the system should be as CBRN resistant as possible for survivability of the system and the crewmembers. Some materials are considered sensitive because of their chemical composition and position within the system, such as the interface between sensitive electronics. The SE may not be resistant to exposure to CBRN substances or amenable to common decontamination processes and the equipment performance could be degraded. Also, the decontamination solutions or other processes may not achieve effective decontamination of the equipment because the decontaminant cannot physically reach the contaminant on or within the SE to destroy or remove it, and a residual hazard remains. Many materials can be considered as sensitive and some are mentioned below.

a. Flight critical components within or on aircraft (helicopters, airplanes).

b. Computers and electronics.

c. Optical devices.

d. Part of the system (such as an aircraft) comprised of materials with particular vulnerabilities to CBRN agents or decontamination processes or solutions.

2. When the system is designed, sensitive equipment should be identified in order to plan for the operation of the equipment within a CBRN-contaminated environment. For example, a non-decontaminable item such as tires or canvas can be discarded and replaced in the field. Therefore, every effort should be made to render the entire system as resistant to CBRN as possible. With this in mind, suitable CBRN hardening measures and decontamination processes must be identified whenever possible. It is recognized that some systems contain more SE than others, such as helicopters. It is also acknowledged that the effective decontamination of SE is difficult. It may be necessary for developers to undertake test and evaluation on the identified SE to ensure that the proposed hazard management processes are indeed sound. Some decontamination methods with the potential to decontaminate some SE have already been identified (See Chapter 4):

a. Gaseous methods (e.g., hydrogen peroxide).

b. Enzymatic decontamination.

c. Soft decontamination solution (peracid).

d. Solvent-impregnated wipes.

3. The testing and evaluation of SE to withstand a CBRN challenge and be decontaminable will include criteria to measure the performance and operation of the SE in the total system pre- and post-decontamination.

0203. Restoration

1. The restoration of the system consists in conducting decontamination of the contaminated surfaces and replacing contaminated filters, if necessary, because of decreased reliability or functionality. These items should be decontaminated by more stringent decontamination processes to limit the risk of cross contamination and re-aerosolisation/resuspension and to ensure the safety of the persons in charge of handling or destroying the items. Another aim in restoration is to eliminate potential health hazards.

2. After restoration, the system should be able to work acceptably, with reference to its performance prior to contamination (see Chapter 7 Acceptance Criteria and Protocols).

3. If the performance of the restored system is reduced, the level of compromise can be determined for components, materials and also the whole system. Lists of equipment, which must be replaced or decontaminated, should be established during the concept phase for the system to define actions to be undertaken later.

4. The effect of incomplete decontamination on staff operating the system as well as those located close by should be assessed so as to allow appropriate protective measures to be put in place.

5. The expected level of survivability and restoration is dependent upon:

a. Ability to continue the mission using the system after a CBRN incident.

b. Survivability of the system.

c. Staff operating the system.

d. Staff in the vicinity of the system.

e. Efficiency of the decontamination and the likely outcome of the decontamination process.

0204. Decontamination Levels

1. Decontamination is the ability to reduce hazard levels to make 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. Definitions are found in AAP-21 (STANAG 2367) while STANAG 2426 CBRN Hazard Management Doctrine for NATO Forces describes the levels of active decontamination. In summary:

a. Immediate Decontamination is carried out by individuals upon becoming contaminated. It may include decontamination of personal clothing and/or

equipment. The aim is to save lives, minimize casualties, limit spread of contamination and sustain personal protection.

b. Operational Decontamination is carried out by an individual and/or a unit. It is restricted to specific parts of operationally essential equipment, materiel and/or working areas. This may include decontamination of the individual beyond the scope of immediate decontamination, as well as decontamination of mission-essential spares and limited terrain areas. The aim of operational decontamination is to remove or neutralize contaminants from the equipment, crew-served weapons, and vehicles that must be used by the unit in the execution of its operational role in order to limit the spread of contamination. As a minimum, the contact areas of weapons and equipment are decontaminated to restore immediate combat effectiveness.

c. Thorough Decontamination is carried out by units with capability to conduct this operation, with or without external support, to permit the partial or total removal of individual protective equipment and to maintain operations with minimum degradation. The aim is to totally remove or eliminate the toxicity of contamination to safe levels on personnel, equipment, materiel and/or working areas. This may include terrain decontamination beyond the scope of operational decontamination. This level of decontamination is conducted out of contact with the adversary.

d. Clearance Decontamination is the decontamination of equipment and/or personnel on temporary or permanent removal from an operation to a standard sufficient to allow unrestricted transportation, maintenance, employment and disposal. In such cases, national policies will dictate the level of cleanliness required upon completion of the decontamination. For more complex and extensive systems, clearance decontamination can be researched or developed.

0205. Equipment Survivability Approach

1. Under certain circumstances, hardness and decontaminability can be determined by the testing of representative test pieces in order to reduce the amount of testing required on large or expensive pieces of equipment. Such test pieces should incorporate all the design features of the represented equipment such as those which could present decontamination problems. Once contaminated, items must be handled in accordance with national safety and security requirements. Compatibility studies can be done without the use of agents or simulants in limited objective exercises conducted by personnel with and without protective clothing in a realistic environment.

2. CBRN contamination can be widespread and may immediately damage equipment or its effects may be delayed. Decontaminants and the decontamination process can cause immediate damage to certain sensitive equipment. Thus, it may be necessary to produce robust equipment that remains operational for continued use

in the mission even though it is contaminated. In certain cases the decontamination operation can only be conducted later on when time allows it and decontaminants are readily available.

3. Personnel operating the equipment should be able to perform their tasks while protected from toxic effects. Likewise, other equipment should be capable of being decontaminated and restored to conditions so that the personnel can operate in clothing consistent with the threat and so that the equipment does not experience long-term degradation. This philosophy is consistent with the needs of both user and materiel developer because it centers on the essential needs of the users.

4. Performance levels of materials for contamination survivability are subject to regular review to take into account advances in material technology and improved equipment design.

5. Figure 2-2 shows the three characteristics of CBRN system survivability.

0206. Decontaminability

1. Decontaminability is primarily the ability of a system to be cleaned to reduce the hazard to personnel operating, maintaining, or re-supplying a particular piece of equipment. Key words in this definition are the necessity to reduce the hazard to personnel although chemical and biological (CB) agents and radiological (R) material can themselves degrade equipment. However, decontaminability criteria are mainly related to physiological effects from CB agents and residual radiation. Criteria for agent decontamination should be related to toxicity data. Both vapour and contact hazards must be considered. For radioactive materials, decontaminability criteria relate to both the effects of penetrating radiation and the effects from contact with radioactive materials (skin contact or inhalation and ingestion).

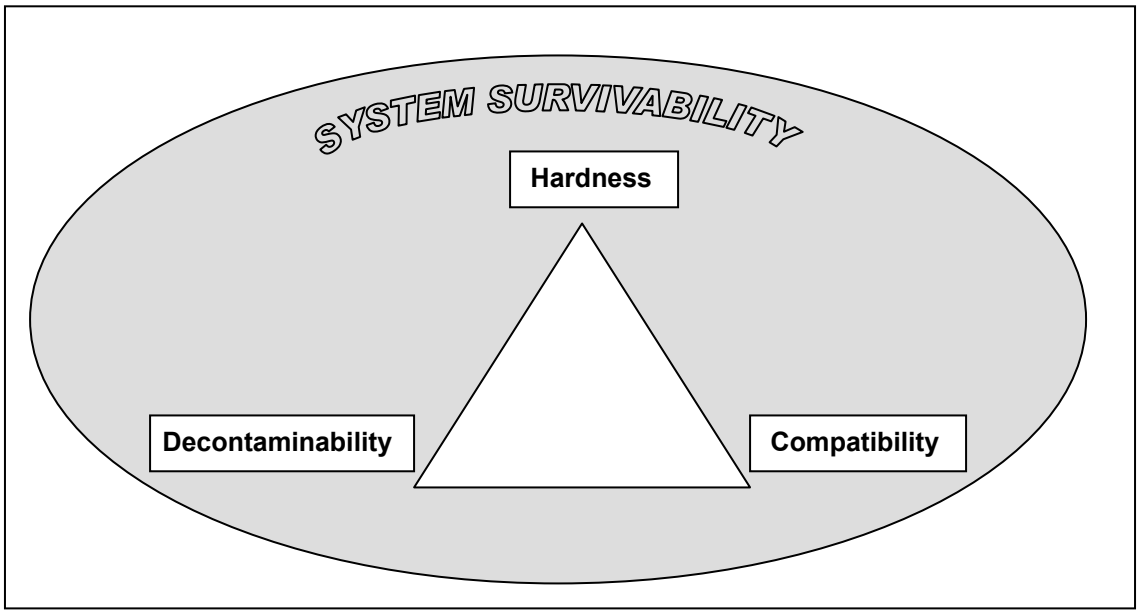


Figure 2-2. The Three Characteristics of CBRN System Survivability.

2. Even under a "fight dirty" concept of operations, where partial decontamination is the rule rather than the exception, decontaminability is required. If gross contamination is not removed as soon as operations permit, the contaminants could eventually breach the shield of the IPE. Furthermore, decontamination reduces the person's vulnerability when the shield is dropped to satisfy basic physiological needs or to replace components of the IPE ensemble. IPE provides negligible protection against penetrating radiation, gamma, neutron and some beta. Protection of crews inside vehicles is given in AEP-14. Thus, in this case, decontaminability criteria are related to the response of unprotected personnel.

3. Criteria for decontaminability were developed by analyzing toxicity data, determining agent concentration levels corresponding to a negligible risk to unprotected personnel (or a "best substantiated combat ineffectiveness threshold estimate" in the absence of sufficient data to calculate a negligible risk value); and relating contamination concentration to time, temperature, wind speed, and threat parameters.

4. Decontaminability is enhanced by considering the following:

a. Materials. Maximize use of materials that do not absorb CBRN contaminants and that facilitate their rapid removal with decontaminants readily available on the battlefield.

b. Design. The design of military equipment should be done in such a way to minimize CBRN contamination and to increase the effectiveness of decontamination processes. Incorporate designs that reduce or prevent accumulation of CBRN contamination and make the contaminated areas readily accessible for decontamination.

c. Design. The design of military equipment should be done in such a way to minimize CBRN contamination and to increase the effectiveness of decontamination processes. Incorporate designs that reduce or prevent accumulation of CBRN contamination and make the contaminated areas readily accessible for decontamination.

d. Contamination. Employ devices and means to reduce or remove the level of contamination, such as positive overpressure systems for vehicles, strippable/sacrificial coatings, packing for supplies and protective covers.

e. CBRN equipment. Ensure total system integration involving CBRN detectors, measurement, decontamination and contamination control devices. Considerations for integration of such devices at the earliest stage of the materiel acquisition process promote maximum achievement of effective contamination avoidance, control, removal, and decontamination confirmation.

0207. Hardness

1. CBRN hardening is defined as the design or modification of equipment, structures or materiel to preserve functionality following exposure to chemical, biological or residual radiation hazards by reducing the retention or adsorption of contaminants. Hardening of equipment increases their susceptibility to decontamination and allows continued use by personnel wearing individual protective equipment. Construction measures and selection of appropriate material could mitigate damaging effects by the decontamination process. Although closely related to decontaminability, hardening is a distinct characteristic. Decontaminability emphasizes the reduction of hazard to personnel through decontamination efforts, whereas hardening focuses on the condition of the equipment after it has been subjected to an agent and decontamination process.

2. Criteria for hardness were developed by analyzing vulnerabilities of construction materials to agents and decontaminants, considering mission profiles of classes of materiel designed to perform mission-essential functions; and determining allowable percentage degradations of quantifiable essential performance characteristics such as reliability, availability, and maintainability (RAM) standards. Criteria for hardening measures must be balanced against all mission-relevant requirements. In this sense, trade-off studies may be used to determine if items or parts of the equipment do not require one or more survivability characteristics.

3. Based on the operational mission profile identified in this document, the equipment (or an appropriate sample) to be tested and evaluated for hardness will be exposed to five contamination and decontamination cycles using one or more contaminants and associated decontaminating processes. The five-cycle testing should be conducted on the same piece of equipment to determine if degradation occurs due to the repeated contamination and decontamination procedure.

4. Nuclear hardening includes separate measures for electronic devices against the damaging effects of electromagnetic pulse (EMP) or radiation from a nuclear incident, and will not be covered in this document. Guidance on nuclear hardening criteria is given in AEP-4 and AEP-14 provides information on vehicle hardening.

0208. Compatibility

1. Compatibility in a CBRN environment is the ability of a system to be operated, maintained, and re-supplied by personnel wearing the full individual protective equipment (IPE), high-level Dress State. If a piece of equipment is completely hardened against CBRN contamination and decontaminants and can be easily decontaminated, it still should have the capability of being operated effectively by the user. Thus, in the development of equipment such as detection equipment designed to perform mission-essential functions, one should consider the combination of the equipment and personnel in anticipated CBRN protection.

2. Criteria for operational effectiveness in CBRN environment were developed by considering mission profiles of classes of equipment designed to perform mission-essential functions, and analyzing performance degradation of crew members operating the equipment while in protective ensemble or IPE, thus determining percentage degradations of mission-essential tasks.

0209. Survivability of Contaminated Personnel

1. Survivability of contaminated personnel should be considered at the origin of a new development or design of a military system. Contaminated personnel may have to interact with a system in a number of ways; for instance, if an attack has occurred without prior alert or intelligence information and has impacted on the system prior to the achievement of a protected configuration or from personnel who have already been contaminated and who have to enter and operate the system in full IPE. The contamination thus introduced obliges the users to continue to wear contaminated IPE until effective decontamination can be achieved or, in the worst case, for the duration of the entire mission. Personnel can be affected by penetrating radiation even when they are wearing IPE, which can slow down procedures. For agents, if decontamination is not conducted, more cross-contamination will spread to other specific parts of the system resulting in the requirement for more decontamination after the mission or during the restoration phase. The parts likely to be contaminated should be identified and evaluated in order to select materials which reduce the effects of toxic substances and are more easily decontaminated.

0210. Testing and Evaluation

1. The extent that a system is affected by CBRN contamination and subsequent decontamination processes should be evaluated using realistic testing to determine operational effectiveness and suitability of the system. Ideally, the evaluation of the hardness and decontaminability of a system should be conducted with real CB agents or non-radioactive simulant material. However, chemical and biological simulants

may be used if the results can be confidently related to those expected from real agents. Types of simulants and testing details are given in Chapter 6 paragraph 0605.

2. Although tests on components, subsystems and materials are cheaper to conduct than the evaluation of the whole system in facilities or in the field, the latter is the preferred option as it provides more confidence in the behaviour of the system in a realistic environment. Testing of an entire system with real agents should be well planned to achieve the desired results.

0211. Tactics, Techniques, and Procedures (TTPs)

1. The requirement guidance for joint doctrine and joint tactics, techniques and procedures (TTPs) is inherent in the utilization of joint forces in pursuit of NATO goals. Since NATO doctrine on decontamination is too generic, often the best approach is to develop special TTPs for certain systems or critical parts of the equipment. TTPs are a set of instructions written specifically for a system or item of equipment due to its complexity in design or its sensitivity to decontaminants and decontamination procedures. The ideal is to delineate procedures to accomplish field decontamination or simply to avoid contamination of an item or its critical parts in a CBRN environment. TTPs should identify those critical parts and provide detailed information as to what is the best approach to decontaminate the system, improve its survivability, and present training procedures for all military in joint forces operations. They are intended for the decontamination unit that comes to accomplish Thorough Decontamination on the entire system.

2. A set of TTPs is necessary when a survivability deficiency exists in a system. The ultimate goal is to protect the personnel by reducing contamination levels and allowing field operations to continue by unprotected personnel. The final output in a set of TTPs is a decontamination procedure specific for the system, followed by formal inclusion in the equipment training manual (TM) or field manual (FM). The TTP solutions to deficiencies can be very useful for incorporation into future version or re-design of the system thereby improving its survivability. The decontamination deficiency may be uncovered during test and evaluation of the military system, particularly for those more complex and sensitive equipment that can not be fully decontaminated using standard procedures. The existing procedures may not be recommended for use in new systems designed and equipped with electronics, computers, plastics, avionics, capillary spaces or hard-to-reach areas (such as cracks and crevices, screw threads, rivets, joints, and flanges). The sensitive equipment may become inoperable or damaged. Thus, modifications of critical tasks may be necessary through TTPs for the operator to conduct critical functions and ensure that the mission is sustained in a contaminated environment.

CHAPTER 3
CHEMICAL, BIOLOGICAL, RADIOLOGICAL AND NUCLEAR (CBRN) HAZARDS

0301. General

1. CBRN Threat. One of the principal threats to crisis response operations is expected to be from terrorists or guerrilla warfare, including deliberate attacks on NATO elements or facilities using CBRN agents or TIMs. Enemy attackers may not respect the international laws of armed conflict, and are likely to attack civilians or combatants. Attacks are not expected to be sustained, but could come as a surprise and could use novel agents or materials. These threats may occur in the front lines as well as in rear and support areas. Another potential threat is the deliberate release of TIMs to cause disruption to allied/coalition elements, or to limit their operational flexibility. Asymmetric attacks can occur with little prior warning, and commanders should consider this when conducting the risk assessment leading to the development of the CBRN defence plan. This is particularly important in determining the type and accessibility of IPE, collective protection, sensors, decontaminants and therapy.

2. Delivery Systems. Delivery systems will likely be fairly simple, but tube artillery or Multiple Rocket Launch systems could be adapted to use CBR warheads. Roadside bombs and improvised explosive devices (IEDs) will likely be used to create a CBR incident. Crop sprayers or aerosol generators could disseminate chemical, biological agents and/or radiological material. In addition, local naturally occurring diseases could be exploited by deliberately exposing NATO forces during operations, placing contaminated material in or near allied/coalition base areas, or by contaminating food and water resources.

3. Industrial Development. The increasing use of an ever-expanding range of toxic chemical, biological or radioactive materials in industry presents both a military and public hazard if such materials are released whether by accident, equipment failure or intentional release. TIMs contained within their manufacturing, storage and transport facilities do not pose a significant hazard unless ruptured by direct fire, artillery or placement of small explosive devices. However, their intentional or accidental release within an area of possible operation may affect the conduct of operations. The hazard resulting from the release of TIMs could result in the contamination of personnel, the environment, or key equipment and stores.

0302. Chemical Agents

1. A chemical agent is defined as a chemical substance which is intended for use in military operations to kill, seriously injure or incapacitate people through its physiological effects. Note: the term excludes riot control agents, herbicides and substances generating smoke and flame.

2. Toxic substances can attack different physiological systems and generally enter the human body by ingestion, inhalation or through the eyes and the skin. They

can be classified as nerve agents, vesicants, cyanogen (blood) agents, lung-damaging (choking) agents and toxic industrial chemicals (TICs)[1]. Chemical agent classes can be grouped into lethal, damaging and incapacitating agents, although there is not always a sharp dividing line between their effects. Chemical agents are highly toxic inorganic or organic chemical compounds or mixtures of such compounds that present themselves on the battlefield as a vapour, a solid or liquid aerosol, or slowly evaporating liquid droplets. Chemical agents are likely to be employed to produce casualties (non-persistent), or to contaminate ground and/or equipment (persistent). Both may have a similar effect on personnel.

3. In vapour form they may penetrate the interior of equipment but, in general, they will not damage equipment except in the cases where the agents are highly corrosive or where sensitive equipment is involved. As an aerosol (which settles on equipment) and, more pronounced, when disseminated as liquid droplets, they may, besides adhering to the surface, spread over the surface and penetrate capillary spaces (such as cracks and crevices, screw threads, rivets, joints, and flanges). Because of their solvating power, they may be absorbed into permeable and porous materials, such as rubbers, plastic, wood, paints, canvas, or others.

4. This absorption of chemical contamination into materials may cause changes in the properties of those materials, which may result in interference with the proper functioning of the equipment especially sensitive equipment. Therefore, use equipment materials that are resistant to chemical agents and that do not absorb them or cover materiel with agent resistant coatings. Another approach is to use secondary absorbent coatings that may be applied to the resistant structure to reduce contact hazards, prevent ingress of agent and aid subsequent active decontamination. These novel coatings absorb chemical agents and are removed as part of the overall decontamination process. Trials have shown that the use of these coatings in a binary decontamination process (such as active decontamination plus removal of the coating) can aid in the achievement of thorough decontamination of the hardened platform/equipment. (For more information see Section 0505, Removable Absorbent Coatings).

5. Personnel, after a chemical attack, are exposed to an inhalation hazard from vapour evaporating from the liquid or solid agent in their environment. This includes their equipment and a contact hazard to their bare skin from the surfaces of their equipment. They are therefore forced to wear their full IPE. In order for personnel to be able to continue their mission effectively, the equipment should be designed so that it can be operated, maintained, and resupplied by personnel wearing their full IPE.

6. Wearing of full IPE for a long time degrades performance (loss of dexterity, reduced vision, and reduced work capacity), thereby reducing the efficiency with which the mission is continued. Personnel should be able to reduce their protective

[1] *[AMedP-6(C)v3 and (EAPC, SCEPC)N(2007)0007]*

posture as soon as possible. Natural decay of the hazard (weathering) may take a long time depending on the persistence and stability of the agent and meteorological conditions. If materials used for the exterior parts of equipment are very absorptive to chemical agents and if the design incorporates many capillary spaces where the agent may accumulate, the inhalation and contact hazard to personnel will persist even after the free liquid on the surfaces has evaporated. It becomes essential that the equipment be well designed to limit contamination when the material is susceptible to absorption and adsorption of contaminants. If the new absorbent removable coatings (see paragraph 4) are employed then they should be removed in a binary decontamination process as soon as possible to avoid slow release (and possible build up) of agent vapour.

7. There is a second reason to use materials that do not absorb agents and to avoid cracks and crevices as much as possible. Besides weathering, a more positive measure to reduce the time that hazards persist is decontamination (See Chapter 4, Decontaminants and Decontamination Process). This is the removal and/or destruction of the agent. Among the decontamination methods, the use of solvent-based liquids is most common. These liquids are generally very aggressive and, when choosing materials for military equipment, the designer should also consider their resistance to decontaminants. Here again, the avoidance of capillary spaces, which will be poorly accessible to the decontaminants, is required. The decontaminants in use are fairly efficient in removing free liquid from surfaces. However, it may not be possible to remove the absorbed contamination without destroying the material itself. With robust platforms the use of removable coatings has been shown to assist in the decontamination process by preventing ingress and allowing residual agent to be removed in a solid matrix for subsequent disposal.

8. Many chemical agents, being powerful organic solvents, will dissolve many polymeric materials resulting in blisters and softened spots and, on some cases, become akin to thickened agents. These present a dangerous contact hazard, are difficult to decontaminate, and should be avoided by choosing materials for construction which are resistant or impermeable to chemical agents, or in the case of removable coatings, able to absorb agents without themselves being dangerously modified by these agents.

9. In the context of AEP-7, the classification of chemical agents as non-persistent or persistent is of importance. Persistence is a rather loosely defined measure for the evaporative behaviour of a chemical agent over time. Non-persistent agents are volatile liquids that, upon dissemination, present themselves as vapours by quickly evaporating from droplets. In temperate climates, the evaporation from a surface contaminated with small (<0.1 mm) drops is usually complete in 10-15 minutes. The evaporation time depends, in addition to the physical properties of the agent (volatility, surface tension, etc.), on a number of other factors, the most important ones being temperature and wind speed. An agent that is classified as non-persistent at room temperature may persist for very long times at much lower temperatures. In addition, the persistence of a volatile agent can depend on the agents' solubility in the coating on the equipment; if it absorbs into the surface rapidly, the agent could present an on-

going vapour hazard by degassing from the coating interior long after the surface liquid has evaporated and dispersed.

10. In biological or chemical warfare, persistency is defined as the characteristic of an agent that pertains to the duration of its effectiveness in the environment. AMedP-06(c) Volume 3 stresses the aspect of length of time that the agent will present an inhalation or contact hazard. Persistency is a function of such factors as agent properties (volatility, surface tension), meteorological conditions (wind, temperature, rain, atmospheric stability) and the physical and chemical properties of the surface upon which the agent has deposited. Chemical agents may be divided into two main types as follows: non-persistent and persistent agents.

a. Non-persistent agents disperse rapidly after release and present an immediate short duration hazard. They are released as airborne particles, liquids and gases, and intoxication usually results from inhalation.

b. Persistent agents continue to present a hazard for considerable periods after delivery by remaining as contact hazard or by vaporizing over a period to produce a hazard by inhalation.

11. The size of the drop has a large influence on the persistence time and therefore on the time available for interaction with the material. This will be in the form of liquid drops in the range of 200-5000 micrometres (μm). In order to evaluate the interaction effects, it is desirable to use the larger drop size irrespective of the contamination density. The effect of agents on the mechanical properties of bulk structural plastics is likely to be insignificant except for a few polymers where stress crazing under load is possible. Of much greater importance is the degradation of transparent polymers due to surface pitting and crazing. Such components as acrylic or polycarbonate lenses, instrument covers, windscreens, and cockpit canopies are particularly vulnerable. Some of the nerve agents hydrolyze upon standing in the liquid form in air to give hydrofluoric acid, leading to etching of glass and germanium surfaces.

12. All CBRN contamination survivability studies and experiments using chemical agents should be conducted with persistent agents. Persistent agents will remain on a surface long enough for absorption into the substrate to take place or to allow spreading and penetration into capillaries. Dissolution and spreading are temperature dependent and fortunately proceed slower at low temperatures. This is also a condition under which non-persistent agents remain longer on the substrate.

13. Examples of persistent agents are the nerve agent VX (boiling point, ~300^{o} C) which may take days or weeks to disappear by evaporation in temperate climates, and the nerve agent Tabun (GA) (boiling point, 247.5° C) or sulfur mustard (boiling point, approx. 217^{o} C) which may take, respectively, several hours or days to evaporate under similar conditions. Dissolving a small proportion of a high molecular weight polymeric material in the chemical agent may modify the physical properties and persistence. Upon dissemination these “thickened” agents present themselves in

larger drops than pure (neat) agents. Pure agents are generally disseminated as a fine spray with a mass median diameter at 250 μm while thickened agents will be found as drops with sizes up to 5000 μm. If disseminated as a fine aerosol, particle sizes may vary from 20 to 200 μm.

14. Contamination by chemical agents in liquid form may be direct or indirect. Direct contamination occurs when droplets dispersed by an artillery shell, a chemical bomb, or a missile directly hit personnel or equipment. This is similar to being hit by rain droplets; however, the density of agent droplets is much less. A reasonably high contamination density of 10 g/m^2, for example, represents theoretically a layer with a thickness of only 0.01 mm. Shielding against a direct hit by chemical rain is very similar to shielding against normal rain. Indirect contamination occurs when traversing a contaminated terrain or by transfer from contaminated personnel or loads. In these cases, contamination densities are generally much lower than in the case of direct contamination.

15. A list of chemical agents is included in the Chemical Weapons Convention.

16. Challenge levels for chemical agents are defined in AC/225 (Panel VII) D/312 dated 30 October 1995, Challenge Document Part 2: Chemical and Biological Challenges for Detection and Decontamination, AC/225 (LG/7) D/5 dated 27 November 2001, Chemical Agents Challenge Levels.

0303. Toxic Industrial Chemicals (TICs)

1. As previously mentioned, industrial chemicals pose significant toxic hazards and can damage the human body and equipment. The significant characteristics of these classes of compounds which lead to their inclusion in this document include the following:

a. TICs are used worldwide in very large quantities and are found in production and storage facilities, manufacturing, agriculture, petrochemical, mining, and other resource sectors, are sold to the general public in the retail area and are transported by rail and by road in large quantities.

b. Their legitimacy as they are often critical components and starting materials for other important compounds or materials in industry so their possession can be for legitimate purposes, even in large quantities.

c. The lack of capability and potential stealth in some military detector systems, which are often developed only for CB-agent detection, and are unable to detect other toxic industrial chemicals. Some recently-developed detectors, however, do possess some capabilities to detect some chemicals. On the other hand, due to safety concerns, methods and equipment for specific detection of toxic levels of many chemicals have been developed and are widely available in the civilian sector.

d. Their ease of use in that dissemination can easily be achieved through use of vaporisers, explosives or other means or by targeting storage or transfer facilities with explosives or munitions.

2. Many industrial chemicals are corrosive, flammable, explosive, or react violently with air or water (Table 3-1). These hazards may pose greater short-term challenges than the immediate toxic effects. Most, but not all, industrial chemicals will be released as vapour or highly volatile liquid and can have both short-term and long-term health effects. While the highly volatile chemicals will present an immediate personnel hazard, especially if they are flammable, they are not of primary concern to survivability and decontamination unless they can cause significant damage to mission essential or critical equipment since they will dissipate before there is a need or opportunity for decontamination. Nonetheless, exposure to these chemicals should be avoided if possible.

3. A list of TICs is available at the following link:

http://www.tc.gc.ca/canutec/en/guide/ERGO/ergo.htm

4. Challenge levels for TICs are defined in AC/225 (LG/7) D/0005 dated 26 February 2004. TICs pose a challenge to decontamination. Thus, during the development of new decontaminants and/or systems, one needs to ensure that the corresponding capabilities are also developed. In order to allow both industry and the official services to reduce testing of new decontaminants and decontamination systems to a justifiable degree, the voluminous list of TICs has to be shortlisted to include only relevant representatives of the whole ensemble.

a. From a chemical contamination survivability testing perspective, the operationally identified industrial chemicals have been grouped in a family of nine potential contamination hazards. This grouping yielded the following nine chemicals, covering the decontamination challenges of both CSG- and ITF-40's list members:

(1) Acrylonitrile;

(2) Carbon Disulphide;

(3) Dimethylamine (solution);

(4) Hydrogen Fluoride;

(5) Parathion;

(6) Phenol (solution);

(7) Phosphorus Trichloride;

(8) Sodium Cyanide; and

(9) Sulphuric Acid.

Table 3-1. Selected Toxic Industrial Chemicals

TIC Families	ID No #	ERG #	Fire or Explosion Potential Hazards
Sulphuric Acid	1830	137	• EXCEPT FOR ACETIC ANHYDRIDE (UN1715), THAT IS FLAMMABLE, some of these materials may burn, but none ignite readily. • May ignite combustibles (wood, paper, oil, clothing, etc.). • Substance will react with water (some violently), releasing corrosive and/or toxic gases. • Flammable/toxic gases may accumulate in confined areas (basement, tanks, hopper/tank cars etc.) • Contact with metals may evolve flammable hydrogen gas. • Containers may explode when heated or if contaminated with water. • Substance may be transported in a molten form.
Hydrogen Fluoride	1052	125	• Some may burn, but none ignite readily. • Vapours from liquefied gas are initially heavier than air and spread along ground. • Some of these materials may react violently with water. • Cylinders exposed to fire may vent and release toxic and/or corrosive gas through pressure relief devices. • Containers may explode when heated. • Ruptured cylinders may rocket.

TIC Families	ID No #	ERG #	Fire or Explosion Potential Hazards
Sodium Cyanide	1689	157	• Non-combustible, substance itself does not burn but may decompose upon heating to produce corrosive and/or toxic fumes. • Vapours may accumulate in confined areas (basement, tanks, hopper/tank cars etc.). • Substance will react with water (some violently), releasing corrosive and/or toxic gases. • Contact with metals may evolve flammable hydrogen gas. • Containers may explode when heated or if contaminated with water.
Phosphorus Trichloride	1809	137	• Except for the FLAMMABLE Acetic Anhydride (UN1715), some of these materials may burn, but none ignite readily. • May ignite combustibles (wood, paper, oil, clothing, etc.). • Substance will react with water (some violently), releasing corrosive and/or toxic gases. • Flammable/toxic gases may accumulate in confined areas (basement, tanks, hopper/tank cars etc.) • Contact with metals may evolve flammable hydrogen gas. • Containers may explode when heated or if contaminated with water. • Substance may be transported in a molten form.
Parathion	2783	152	• Combustible material: may burn but does not ignite readily. • Containers may explode when heated. • Runoff may pollute waterways. • Substance may be transported in a molten form.

TIC Families	ID No #	ERG #	Fire or Explosion Potential Hazards
Carbon Disulphide	1131	131	• HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames. • Vapours may form explosive mixtures with air. • Vapours may travel to source of ignition and flash back. • Most vapours are heavier than air. They will spread along ground and collect in low or confined areas (sewers, basements, tanks). • Vapour explosion and poison hazard indoors, outdoors or in sewers. • Those substances designated with a “P” may polymerize explosively when heated or involved in a fire. • Runoff to sewer may create fire or explosion hazard. • Containers may explode when heated. • Many liquids are lighter than water.
Dimethylamine (Solution)	1160	132	• May cause toxic effects if inhaled or ingested/swallowed. • Contact with substance may cause severe burns to skin and eyes. • Fire will produce irritating, corrosive and/or toxic gases. • Vapours may cause dizziness or suffocation. • Runoff from fire control or dilution water may cause pollution.
Acrylonitrile	1093	131P	• HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames. • Vapours may form explosive mixtures with air. • Vapours may travel to source of ignition and flash back. • Most vapours are heavier than air. They will spread along ground and collect in low or confined areas (sewers, basements, tanks). • Vapour explosion and poison hazard indoors, outdoors or in sewers. • Those substances designated with a “P” may polymerize explosively when heated or involved in a fire. • Runoff to sewer may create fire or explosion hazard. • Containers may explode when heated. • Many liquids are lighter than water.

TIC Families	ID No #	ERG #	Fire or Explosion Potential Hazards
Phenol (Solution)	2821	153	• Combustible material: may burn but does not ignite readily. • When heated, vapours may form explosive mixtures with air: indoors, outdoors and sewers explosion hazards. • Those substances designated with a “P” may polymerize explosively when heated or involved in a fire. • Contact with metals may evolve flammable hydrogen gas. • Containers may explode when heated. • Runoff may pollute waterways. • Substance may be transported in a molten form.

Source: Emergency Response Guide (ERG)

b. If a decontaminant or decontamination system proves efficient against those nine chemicals, it can reasonably be considered efficient against the complete list. For a rationale on the composition of this list, see the nine families approach in Annex C.

0304. Biological Agents

1. Biological agent is defined as a micro-organism which causes disease in personnel, plants, animals or causes the deterioration of materiel. Strategic level biological attacks are possible due to their target area characteristic, security through deniability, decreased chance of (adversary) collateral damage and sheer scope of allied resources required for consequence mitigation. Therefore, biological agents will likely be directed at populations, major military facilities, financial, cultural and political installations.

2. From an operational and tactical perspective, a biological agent release is a possibility given the incubation period of many agents, and the mobility of modern combat operations. However, any biological incident will present major problems for the Health Services Support (HSS) elements, and may impose demands on medical and other elements to assist in the care of civilians in the area. Medical surveillance of military personnel and local civilian health will likely become an important component of the biological detection system.

3. Advances in biotechnology now make possible the swift and covert production of significant quantities of biological agents, perhaps resistant to known detection and treatment means. Biological agent production technology need not be complex and manufacture can be relatively cheap, and on a small scale. With further advances in biotechnology and fermentation techniques, agents are likely to become even more readily available.

4. The major classes of biological agents include:

a. Bacteria. These are small single-celled micro-organisms, some of which are dependent upon host cells whilst others may survive independently in adverse conditions. Bacteria agents can cause disease in humans, plants and animals by invading the tissues, or by producing toxins. They are small free-living organisms, which have a structure consisting of nucleus material, cytoplasm and cell membrane. They reproduce by simple division and, unless they have been altered for antibiotic resistance, antibiotics can control bacterial agents.

(1) Rickettsiae. Rickettsiae are bacteria organisms but with some viral properties. Like bacteria, they possess metabolic enzyme and cell membranes and they utilize oxygen. They resemble viruses in that they grow only within living cells. Rickettsiae agents are normally sensitive to antibiotics.

(2) Chlamydia. Chlamydia are obligatory intracellular parasites incapable of generating their own energy source. Like bacteria, they are responsive to broad spectrum antibiotics, and similar to viruses they require living cells for multiplication.

b. Virus. It is a minute structure of protein coated nucleic acid. Viruses require living cells to replicate themselves, lack a system for their own metabolism, and are dependent on the cell of the host that they infect. Viruses are parasites that cause disease by damaging host cells. The host cells can be from humans, animals, plants or bacteria. Viruses are not sensitive to antibiotics, but may be treated by antiviral compounds.

c. Toxin. It is a poisonous product of a living organism and may also be synthesized. Toxins are chemicals of natural origin produced by an animal, plant or microbe, which can cause significant illness at levels much lower than the level required for lethality, and are militarily significant incapacitants. Toxins are not sensitive to antibiotics, but antidotes and detoxicants exist for some toxins. Simulants for toxins include caffeine for low-molecular toxins and BSA (bovine serum albumin) for protein-type toxins.

d. Fungi. Fungi are primitive plants, which do not utilize photosynthesis, are capable of anaerobic growth, and draw nutrition from decaying vegetable matter. Most fungi form spores, and free-living forms are found in soil. The spore forms of fungi are operationally significant, as are the toxins that they can produce. Fungal diseases may respond to various antimicrobials.

5. Biological agents are considered much more of threat to humans than to equipment. Protective clothing may protect personnel skin from the effects of biological agents. However, of great importance is the potency of many agents. A very small number of organisms can cause devastating effects. Therefore, adequate decontamination of equipment and personnel is of utmost importance.

6. The methods to avoid or reduce biological contamination are predominantly the same as for chemical agents. Smooth, non-porous materials should be used when designing equipment. Care should be taken to reduce the number and complexity of protrusions and wells on the equipment as these will trap biological agents and decontaminants.

7. Liquid or solid aerosols are the most likely delivery means of biological agents. As such, they are considered as surface contamination not damaging to materiel. Some biological agents do not present a persistent threat, but other biological agents such as anthrax spores are very persistent. Re-aerosolisation in an enclosed space may pose a hazard. In the same way, cross contamination in open or enclosed space can generate a great hazard and can disseminate the agent to non-contaminated materials or personnel. The following methods present a synopsis of potential biological agent dissemination:

a. Aerosol. The agent can be delivered as a liquid or a dry-powder fill. The dissemination can be performed using simple or complicated spray devices, using an explosive or ventilation systems to generate cool or warm air. Small particles will linger suspended in the air, larger particles will fall to the ground producing local contamination and respirable particles generated will present predominantly as an inhalation hazard travelling long distances downwind.

b. Contamination of food and water. Direct contamination of consumables, such as drinking water, foodstuffs or medications could be used as a means to disseminate infectious agents or toxins. This method of attack would be most suitable for sabotage activities and might be used against limited targets such as water supplies or food supplies of a military unit or base. Water purification systems significantly reduce this hazard, but supplies may be contaminated following treatment.

c. Use of arthropod hosts as vectors. Attempts might be made to spread typical vector-borne diseases by releasing infected natural (or unnatural) arthropod hosts such as mosquitoes, ticks or fleas. These real vectors can be produced in large number and infected by allowing them to feed on infected animals, infected blood reservoirs or artificially-produced sources of a biological agent.

d. Delayed generation of secondary aerosols. Long-term survival of infectious agents, preservation of toxin activity during extended periods and the protective influence of dust particles onto which micro-organisms adsorb when spread by aerosols have all been documented. The potential exists, therefore, for the delayed generation of secondary aerosols from previously-contaminated surfaces. To a lesser extent, particles may adhere to an individual or to clothing creating additional but less significant exposure hazards.

e. Person-to-person transmission. Humans, as unaware and highly effective carriers and infectious sources of communicable disease, could readily disseminate pathogens if they become ill and contagious.

8. An exemplary list of biological agents is currently available at the following links:

a. http://www.fas.org/irp/doddir/army/fm3-11-9.pdf;

b. http://www.bt.cdc.gov/agent/agentlist.asp.

9. Challenge levels for biological agents are defined in AC/225 (Panel VII) D/312 dated 30 October 1995, Challenge Document Part 2: Chemical and Biological Challenges for Detection and Decontamination, AC/225 (LG/7) D/57 dated 6 October 2000, Report of the Challenge Sub-Group on Biological Agent Challenge Levels.

0305. Toxic Industrial Biologicals (TIBs)

1. A TIB incident can occur from an attack or collateral damage at a facility producing or storing infectious material. Possible facilities include hospitals and other medical installations and research, production, storage or recycling facilities for the pharmaceutical or agricultural industries.

0306. Radiological Sources

1. Radiological sources may come in different varieties. They could be in a solid, liquid or gas form. Radioactive aerosols are most significant for inhalation hazard; powder is the most hazardous solid form. The primary hazard from some radiological agents is not the source itself but the ionizing radiation emitted by the source. Radiological aerosols (solid and powder) are most significant for inhalation hazard. Therefore, radiological sources are unlike CB agents and do not have to come in contact to the individual to be a hazard. Radioactive materials of special concern are covered in NATO work on scenarios (SAS-061). There are four common types of ionizing radiation: alpha, beta, gamma or neutron. The examples of radiological sources below are based on the type of ionizing radiation:

a. Alpha (α). Americium-241, Polonium-210, Radium-226, AmBe, PuBe, and Plutonium-238/239 are used in static eliminators, in well logging (Am-241/Be), pacemakers, lightning preventers, moisture detectors and gauges. The α particle has a large mass and consists of two protons, two neutrons, and no electrons. It is a highly charged particle emitted from the nucleus of an atom with a short distance of travel and can be stopped by the outer layer of skin. An α emitter is only an inhalation (internal) hazard.

b. Beta (β). Srontium-90, Krypton-85, Tritium, and Carbon-14 used in radioisotopes, thermoelectric generators (RTG), Brachytherapy, self-powered

lighting, fire arm optics and various gauges. The β particle has a small mass and is negatively charged. It has a limited penetrating ability and its range in air is approximately 3 m (10 feet). If ingested or inhaled, a β emitter can be an internal hazard. Externally, β particles are potentially hazardous to the skin and eyes.

c. Gamma (γ). Ceasium-137, Cobalt-60, Iridium-192, used in irradiators (food, blood/tissue and research), teletherapy, gauges (fixed and portable), brachytherapy and industrial radiography. γ radiation is an electromagnetic wave or photon and has no electrical charge or mass. γ rays are similar to x-rays, the only difference being their energy and origin, and have very high penetrating power. The range in air is several hundred meters (several hundred feet). γ rays are best shielded by dense materials, such as concrete, lead, or steel.

d. Neutron. Californium-252 is used in gauges and well logging sources. Neutrons ejected from the nucleus have no electrical charge and interact with matter either directly or indirectly. These particles have a relatively high penetrating ability and are difficult to stop. Neutron radiation range in air is several hundred feet and it is best shielded by materials with high hydrogen content, such as water or plastic.

0307. Malicious Distribution of Radioactive Sources

1. A radiological dispersal device (RDD) is defined as an improvised assembly other than a nuclear explosive device specifically designed to employ radioactive material by disseminating it to cause damage, fear or injury by the radioactive decay of the material. RDDs can be used to intimidate or deny access to an opposing force by contaminating an area, or to create illness or panic by contaminating food or water supplies. An RDD may be used for the strong psychological impact it has on personnel as well as civilian populations. It might function as either a terror or terrain-denial mechanism or both. More information on radiological devices is given in NATO AJP-3.8.1 Volume 1.

2. One type of RDD is often called “dirty bombs”. These may be as rudimentary as combining a home-made bomb with a radioactive source in a populated area. Medical sources, industrial irradiators and radioactive waste can easily be obtained for use as simple dispersal devices. Such a device can be easily developed and utilized by any combatant with conventional weapons and access to radio nuclides. The material dispersed can originate from any location that utilizes radioactive sources, for example, a medical radiotherapy clinic or an industrial complex. The radioactive source can be dispersed using conventional explosives and simultaneously scattered across the targeted area as debris, but may also be dispersed by non-explosive dispersal devices or means. Reactors can be used to produce specific radionuclides, although this may require more complex technology and sophisticated techniques. This type of device would cause conventional

casualties to become contaminated with radionuclides and make medical evacuation more difficult.

3. Depending on the nature of the release, dry radioactive material may be lifted into the atmosphere and carried downwind. Wet materials can be far more difficult to remove than dry deposits. People in the downwind area could then be exposed to radiation from the sources described in Table 3-2.

4. Radioactive sources may be distributed by placing the material in a populated or sensitive area. They can be sealed or unsealed radioactive materials. These sources are also known as “silent bombs” or as radiological exposure devices. This is of special concern because at very low levels of radiation there will not be any immediate outward signs of exposure. Table 3-3 shows methods of malicious distribution of radioactive source material.

0308. Nuclear Fallout

1. With respect to nuclear contamination survivability, residual nuclear contamination pertains to particulate fallout that rests on surfaces of materiel and personnel. The residual radioactive fallout contamination is a result of a nuclear detonation and may be a lingering and widespread hazard that severely limits military operations. Fallout emits several types of ionizing radiations: alpha (α), beta (β), and gamma (γ). The most significant radiation is γ radiation, which presents a serious personnel hazard because of its range and penetrating power.

2. Neutrons are important components of initial radiation and are covered in AEP-14. Contamination from residual radioactive fallout comes from the nuclear bomb debris and the activated earth dispersed by the nuclear explosion near or on the ground. Materials become radioactive when hit by neutrons, and produce a fairly high dose rate of γ and β radiation. This type of residual radiation is called induced radiation. Protective clothing will protect the skin from contact with radioactive particles and will protect from α and β radiation. The wearing of a mask protects against inhalation of radioactive material. Protective equipment provides very little shielding from γ-radiation. To keep the γ-dose low, the time of exposure must be kept as short as possible and decontamination should be carried out as soon as possible.

Table 3-2. Radiological Device, Radiation Sources and Types

Radiation Source Resulting from Radiological Devices	Dominant Radiation Hazards	Comments
"Cloudshine" from radioactive material suspended in the air	γ	A "puff" of radioactive material is most probable. A "plume" may form if there is a prolonged release because of fire or failure of containment system. It is an emitter of penetrating radiation.
"Groundshine" from radioactive material settled onto surfaces	γ or β	Groundshine can become a cloudshine hazard if disturbed by wind or traffic (re-suspension). Beta is a hazard for inhalation and skin contact.
Internalized radioactive material	α and/or β and/or γ	Radioactive material in a plume or puff, and/or contamination, including re-suspended material, can be inhaled or ingested. Alpha is an inhalation and ingestion hazard.
Personal contamination	γ or β	Radioactive material from a plume or puff settling on clothing, skin or hair.

3. Radioactive fallout is not the only type of nuclear contamination with which materiel developers should be concerned. Nuclear detonations can also produce neutron-induced γ activity in different types of materials depending on how close the materiel was to the actual detonation. Neutron-induced γ activity is commonly referred to as NIGA or induced radiation. This type of radiation will cause material to become radioactive and will make them impossible to decontaminate. Therefore, when developing a new or modified piece of equipment, care should be taken to use material that is not (or is less) susceptible to this type of radiation activation. One suggested method is to choose material that is low in iron or cobalt content or to use composites. While there is no guarantee that equipment will not become radioactive through neutron-induced γ activation, it will lessen the effects. Finally, while this publication does address nuclear effects, it only addresses that which is produced by nuclear contamination from fallout. As references, AEP-4 provides information on nuclear hardening criteria for military materials and AEP-22 gives guidance on transient radiation effects on electronics (TREE) at the tactical level.

Table 3-3. Malicious Distribution Methods, Radiation Sources and Types

Source Method of Distribution	Nature of Source	Dominant Radiation Hazards
Static placement	Dry particles	γ
Mobile release in small amounts	Dry particles or liquid	α and/or β and/or γ
Release into a water supply	Dry particles or liquid	α and/or β
Release over food supplies or food sources	Dry particles or liquid	α and/or β and/or γ
Release into buildings or building ventilation systems	Dry particles or gas	α and/or β and/or γ

4. Although the absorption rates for chemical and radiological/nuclear agents are different, the means and methods to avoid or reduce radiological fallout contamination are predominantly the same as for biological agents. It is very important to have smooth surfaces with as few surface structures as possible, where accumulation of the contamination can take place. In contrast to chemical agent contamination, radioactive contamination (particulate fallout, but also radionuclide in ionic form) generally rests on the external surfaces of equipment (metals, surface coatings, paint, plastics, etc). Many nuclides in fallout, such as caesium or iodine, readily exchange with substrate materials, especially in the presence of water. Even though contamination rests on the surface of these materials, a complete decontamination to zero is not possible. By using decontaminants like detergents and complexing agents, a decontamination level of at least 90% of the initial contamination can be achieved under field conditions. Some porous materials, such as wood, leather or some textile materials will be difficult to decontaminate. In the case of personnel decontamination, some cases may require removal of tissue.

5. One of the philosophical assumptions of this AEP is that any method which addresses chemical decontamination will have some effect on radiological/nuclear contamination with the exception of induced radiation. However, thorough radiological/nuclear decontamination may require additional measures, such as flushing with water.

CHAPTER 4
DECONTAMINANTS AND DECONTAMINATION PROCESSES

0401. General

1. Decontamination is defined as 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. It can be divided into two categories; passive decontamination (weathering) and active decontamination. This chapter addresses currently available decontamination technologies and recent developments. The applicability towards CBRN agents and TICs is presented, as well as the status of various commercialized decontamination techniques. Decontamination methods can be divided into three basic processes: physical, chemical and mechanical, which are discussed in Sections 0402 through 0404.

2. Physical methods of decontamination aim at removing the contaminants from contaminated surfaces, whereas chemical and mechanical energy methods aim at modifying the structure of the contaminants in order to reduce or eliminate the toxicity of the contaminants. For chemical agents, this modification is a change in the chemical structure of the agent molecules. For biological contaminants, it involves the destruction of the organisms. In the case of radioactive contamination, it may be dangerous to approach the contaminated object because of penetrating radiation, and remote handling techniques may be required. Chemical and energetic methods can also be used to detach radioactive materials from surfaces or to abrade surface material that has become radioactive through ion-exchange processes.

3. Traditional chemical decontamination technologies all have drawbacks continuing the need for an on-going search for improved methodologies. The ideal decontaminant (or the “silver bullet”) should be wide-spectrum, non-aggressive, non-toxic, environmentally friendly, not destructive to materials, stable in storage and, if premixing is required, have a reasonably long (hours) pot-life or post preparation effectiveness. It will rapidly neutralize all chemical and biological (CB) agents at the same time and remove radiological agents. It will preferably be ready to use without the need of previous mixing of various ingredients in the field, and it should place a minimal logistic burden in terms of storage and transportation requirements. Currently there is no single technology that meets all these requirements.

4. It is important to realize that the decontamination efficiency depends on various factors, not only the characteristics of the agent, but also the weather conditions and the type of material that is being decontaminated. Smooth surfaces painted with chemical agent resistant coating (CARC) are relatively easy to clean with an effective decontaminant, whereas the same decontaminant may not be able to sufficiently clean more complex structures with cracks or crevices or absorbing materials such as rubber.

5. The advantages and limitations of the methods are discussed in Section 0405. Table A-1 in Annex A provides a summary of commercially available chemical decontaminants with the corresponding category, active component, and structure. Table A-2 in Annex A provides a summary of decontaminants currently in use by the military forces of NATO and PfP countries.

0402. Physical Decontamination

1. Physical decontamination consists in either removing (relocating) or encapsulating CBR contaminants without actually destroying the agents. All materials used for the physical removal of CBR agents need to be treated as contaminated waste. Examples of physical decontamination include the following:

a. Rinsing (using water and/or organic solvents);

b. Heating (accelerated evaporation);

c. Adsorbents (removal with solid adsorbents);

d. Coatings (removal by strippable coatings); and

e. Brushing and vacuuming (radioactive particles)

2. **Weathering**. The simplest form of physical removal of contaminants is weathering (passive). Without any form of active decontamination, many C agents will eventually lose their toxicity over time by evaporation and natural destruction (weathering), depending on the characteristics of the agent, the weather conditions (wind, rain) and the type of material that is contaminated. B agents are killed more rapidly outdoors, especially under the influence of sunshine. However, sporulated bacteria are more resistant to ultraviolet (UV) radiation than non-sporulated bacteria. There are radioactive (R) contaminants with half-lives tens and even thousands of years. Some forms of R contaminants include organic iodine and caesium iodine, which require a different method of removal. During weathering the radioactive contaminants can interact with substrates in various ways, which greatly increases the difficulty of decontamination. Without active decontamination, remote areas with radioactive fallout contaminant should be assessed by a radiation safety specialist.

3. When active decontamination is required, the easiest method is rinsing the contaminated surfaces with water to remove CBRN agents. The efficiency of the rinsing methods will increase using high pressure, hot water, soap and brushes. Water will very slowly neutralize some of the C agents by hydrolysis. C agents tend to show greater affinity to organic liquids and thus rinsing with organic solvents normally results in improved physical removal. In addition, organic solvents also allow the extraction of ad-/absorbed agents from porous materials but may damage certain substrates and/or coatings. Sensitive equipment that will become damaged after contact with water may be decontaminated using organic solvents, such as

fluorosolvents. However, it should be recognized that the solvent will contain substantial amounts of residual agent which would pose a continuing hazard to nearby personnel.

4. Radiological decontaminants cannot destroy the radiation of R agents, but are effective in physical removal and containment. Various decontaminants have been developed for this purpose. Current commercial off-the-shelf (COTS) R decontaminants mainly consist of aqueous mixtures containing surfactants and complexing agents. It is recognized that some CB decontaminants partly consist of surfactants and may therefore also be effective in removing R contaminants. However, it is difficult to develop a decontaminant that is capable of removing all types of radio nuclides. When removal of R agents is not effective on, for instance, porous surfaces, the only alternative will be to remove the contaminated surfaces (sandblasting or grinding).

5. Thermal desorption of C agents can be achieved by the use of heated air which results in evaporation of the contaminant. With this method, the toxic agent is released into the atmosphere and this may present an increased vapour hazard. The technique may, for instance, be utilized for the cleaning of clothing. Furthermore, micro-organisms (B agents) are also killed by heat treatment.

6. Solid adsorbents are very useful in removing liquid C agents from surfaces. Activated carbon, certain polymer ion-exchangers and fuller's earth (a claylike substance rich in minerals) are typical examples of solids that adsorb agents and retain them, allowing for safe removal and subsequent disposal. The usefulness of solid adsorbents for the decontamination of large equipment or vehicles is limited due to the problems of application over large surface areas and to the effect of water on their adsorptive capacity. In addition, adsorbent powders have limited capability to remove agents from cracks and crevices due to their particulate nature. Also, as noted above for solvent rinsing, the adsorbed agent is not detoxified so the solid powder might form an inhalation hazard for some time.

7. A reactive sorbent first adsorbs the C agent and then chemically detoxifies it, but cannot address B-agents. Reactive sorbents have been prepared by soaking simple sorbents in alkaline solutions, effectively "loading" the matrix with caustic material. Once sorbed into the sorbent matrix, the agent encounters the alkaline medium, reacts with it, and is destroyed. A second approach for reactive sorbents is to prepare a polymeric material with reactive groups attached to the polymeric backbone. In this case, the agent is sorbed by the polymeric matrix, encounters the reactive group, and is neutralized by it (such as the US M295). A third approach is to use microcrystalline reactive metal oxides such as aluminum oxide or magnesium oxide (such as in the US M100).

8. Catalytic sorbents are similar to reactive sorbents in that both contain reactive sites that react with and neutralize the C agents. In the case of catalytic sorbents, the reactive site is regenerated during detoxification of the agent while, in the case of reactive sorbents, the reactive group is rendered inert after reacting with the agent.

Examples of catalytic sorbents are polyoxometalates sorbed into a sorbent polymeric matrix and polymeric materials containing reactive sites that are covalently bound to the polymer chain.

9. Strippable coatings can basically be used in two ways for decontamination purposes. (a) When a plastic membrane or coating is sprayed on the surface, the resulting coating may seal and contain the contaminants for a period of time if required. Contaminants can be removed when the coating is stripped off the surface. (b) Alternatively, the coating may protect clean surfaces from becoming contaminated. The next step is to peel off the coating, thus removing loose surface contaminants. Strippable coatings are especially useful on geometrically complex surfaces that would otherwise lead to the entrapment of agents in certain areas such as underneath screws, or areas difficult to decontaminate. Section 0505 gives more information on removable absorbent coatings.

0403. Chemical and Biological Decontamination

1. Chemical and biological (CB) decontamination solutions are usually mixtures that contain substances that react chemically with CB agents creating less toxic or non-toxic compounds. The aim is to modify the structure of the contaminants in order to reduce or eliminate the inherent toxicity of the compounds. For C agents this modification is a change in the chemical structure of the agent molecules. For B contaminants this is the destruction of the cell or inactivation of biological agents. R agents cannot be neutralized and can only be physically removed from contaminated objects. However, some CB decontamination solutions are effective in the removal of R material.

2. Most of the current CB decontaminants can be considered as reactive solutions. Often, as in the case of oxidation or hydrolysis of C agents, the reactions occur immediately with the evolution of heat and gases. Many reactive chemicals will interact with metallic containers and coated surfaces to corrode the surfaces, and with human, animal and vegetative tissues to damage the tissues.

3. Chemical decontamination solutions discussed below are based on oxidation (chlorine-based decontaminants and peroxides), nucleophilic substitution (alkaline hydrolysis and oximes), reactive gasses, decontamination by particles and enzymatic decontamination. Due to specific nature of most chemical agents, hydrolysis and oxidation are the principle reaction mechanisms that allow efficient decontamination. Table A-1 in Annex A summarizes commercial available decontaminants that are based on the principles described below. Table A-2 in Annex A summarizes the decontaminants that are currently in use by the military forces of NATO and PfP countries.

a. Oxidation:

(1) Chlorine-based decontaminants. Sodium hypochlorite (NaOCl, common bleach) and calcium hypochlorite [$Ca(OCl)_2$], chlorinated lime or bleaching

powder) were among the first oxidants used in chemical decontamination processes for CB agents and are still in use today. Hypochlorite ions (HOCl, hypochlorous acid or active chlorine) are generated by an alkaline aqueous solution of NaOCl or $Ca(OCl)_2$. Hypochlorite is effective in the decontamination of most CB agents but is corrosive to surfaces. Besides the degradation of C agents, HOCl in solution will oxidize many organic and inorganic TICs in water, including ammonia, organic nitrogen compounds (amides, amines, etc), multiple C-C bonds, and cyanides. HOCl is also a powerful disinfectant. It is able to penetrate through the (bacterial) cell wall in a similar way to water. It is generally considered that the lethal action of HOCl after diffusion through the cell wall in organisms is due to the chlorination (oxidation) of cell proteins or enzyme systems. Commercial decontaminants that are based on chlorine or on compounds that release active chlorine (so-called chlorine donors) are summarized in Table A-1 in Annex A.

(2) Peroxides. The peroxides are strong oxidants that offer an "environmentally" friendly alternative to the toxic and corroding chlorine-based decontaminants. An additional advantage is evident for the development of cold-weather solutions, since the freezing point of 50 % hydrogen peroxide (H_2O_2) is -40 °C. Nerve agents react nearly instantaneously with the peroxy anion (OOH^-) in basic solution, to form the non-toxic alkyl methylphosphonic acids. The effectiveness increases when hydroxyl free radicals (OH^-) are present. For example, non-dissociated H_2O_2 is not fully effective in neutralizing VX, as not all chemical bonds contributing to the potency of this threat agent are broken by peroxide alone. However, hydroxyl free radicals are very effective in neutralizing VX and other C agents. For this reason, H_2O_2 is often combined with other reagents to increase its activity and effectiveness. The oxidation of sulfur mustard (HD) requires the presence of activators such as carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) or molybdate (MoO_4^{2-}). The combination of peroxide/activator oxidizes HD into the non-toxic sulfoxide (HDO) and, to a small extent, into the toxic sulfone (HDO_2). A peroxy compound that is commonly used, and often added as a supplemental oxidizing agent in mixtures with H_2O_2, is peracetic acid or peroxyacetic acid. Peracetic acid is effective against all microorganisms, including bacterial spores due to its high oxidizing potential. It can be used over a wide temperature range (0 to 40 °C).

b. Nucleophilic Substitution:

(1) Alkaline hydrolysis. Strong bases, such as calcium hydroxide $Ca(OH)_2$, calcium oxide (CaO), sodium hydroxide (NaOH) and potassium hydroxide (KOH), produce a high concentration of hydroxide anions (OH^-) upon mixing with water. These compounds, when in solution, are effective in hydrolyzing C agents. However, during hydrolysis of VX there is a competing reaction leading to formation of desethyl-VX, also known as EA

2192. This compound is comparable to VX in its toxicity. Depending on the conditions, up to 14% of EA 2192 will be produced during an alkaline hydrolysis. In addition, the solubility of VX in a basic solution is low, which will affect the reaction rate.

(2) Alkoxides. Strong bases, such as NaOH, can also be dissolved into an organic solvent forming a very strong basic solution. Upon mixing of a strong base with an alcohol, the conjugate base of the alcohol or alkoxide ($R\text{-}O^-$) is formed. The most well known member of this technology is Decontaminating Solution Number 2, or DS2. DS2 is recognized as the military bench mark for effective CB decontamination, but is no longer manufactured because of its corrosive nature to rubber, paint, plastics, sensitive equipment, its toxicity and environmental effects. Other non-aqueous decontaminants based on alkoxides can be found in Table A-1 in Annex A.

(3) Oximes. These are known for their therapeutic use against nerve agent poisoning, acting as reactivators of inhibited acetyl cholinesterase. These oximes comprise of one or two quaternary amines and one or two oxime moieties (-C=N-OH), such as obidoxime, HI-6, and pralidoxime (2-PAM). Oximes are also used for (skin) decontamination. RSDL® (Reactive Skin Decontamination Lotion, E-Z-EM Inc., Lake Success, NY, USA) contains 2-3-butanedione monooximate as the active ingredient.

c. Reactive Gasses:

(1) Gaseous and vapour phase technologies have been developed for the decontamination of sensitive equipment and building interiors contaminated with B agents. The technologies were used during the *B. anthracis* postal letter recovery operations in the United States in 2001. Although effective, the gasses are, in general, toxic. These techniques require that the contaminated area be completely sealed to prevent the escape of reactive gas or vapour. The gas or vapour is injected into the sealed area and allowed to remain there for the period of time required to ensure neutralization. Vapour techniques briefly discussed below are ethylene oxide, chlorine dioxide, vapourized hydrogen peroxide, paraformaldehyde, ozone and methyl bromide.

(2) Ethylene oxide (C_2H_4O) can be used for the sterilization of critical items in an off-site area. Since the compound is flammable and very damaging to human health, it is not suitable for large scale use such as the fumigation of buildings.

(3) Chlorine dioxide (ClO_2) should be generated on site where remediation occurs due to the instability of the gas. However, the instability of ClO_2 has a beneficial effect since it rapidly decomposes after treatment. ClO_2 can also be used in its aqueous form. For this purpose, the compound should

also be generated at the use site, typically using sodium chlorite ($NaClO_2$) as the reactant.

(4) Vapourized hydrogen peroxide (VHP) has been used for more than a decade to sterilize clean rooms and pharmaceutical processing equipment and, more recently, to decontaminate *B. anthracis*-contaminated buildings. The vapour is generated from a concentrated aqueous solution of hydrogen peroxide (30 % H_2O_2). Modified VHP (mVHP) was developed by STERIS and the US Army Aberdeen Proving Ground, MD, USA. The mVHP makes use of low levels of ammonia which renders the technology reactive towards C agents (HD, GD and VX) and B agent simulants.

(5) Paraformaldehyde is used for routine decontamination of laboratories and biosafety hoods in clinical and research laboratories for a broad spectrum of B agents, including *B. anthracis* spores. The formaldehyde gas has also been used for the successful remediation of numerous laboratories and buildings. Formaldehyde is carcinogenic to animals, and probably to humans as well, and it is genotoxic in a number of assays.

(6) Ozone (O_3) is a reactive form of oxygen that is a strong oxidant with documented ability to kill spores, bacteria and viruses. However, ozone has not been used for remediation of buildings contaminated with CB agents. The technology is promising and could be considered for further evaluation in the future.

(7) Methyl bromide is approved for use as a pesticide under controlled conditions. However, it is forbidden to be used on a large scale since it is an ozone-depleting compound and has potential severe human health effects. It is used as an innovative compound for the B agent decontamination of building interiors.

d. Decontamination by Particles. Several decontamination formulas are based on metal oxide particles. M100 SDS (Sorbent Decontamination System, Guild Associates Inc., Dublin, OH, USA) uses a sorbent powder for decontamination, which contains metal oxides (aluminum, sodium) together with other compounds, and destroys C agents by oxidation and hydrolysis. The absorber is designed to be rubbed onto a surface, thus removing the liquid C agents. FAST-ACT (NanoScale Materials Inc., Manhattan, KS, USA) is a formulation based on nanoparticles containing ‘nanoactive’ titanium dioxide and magnesium oxide. The dry powder is claimed to be effective for neutralizing a wide range of industrial chemicals in either liquid or vapour form, with the added capability to destroy C agents. FAST-ACT destroys C agents through hydrolysis and dehydrohalogenation. Nerve agents (VX and GD) are hydrolyzed with the formation of surface bound metal phosphonates. HD undergoes hydrolysis to form surface bound metal alkoxides. Oxidation can be performed by contact of the C agent with titanium dioxide deposited on the support of the material. TiO_2 reacts with light to generate strong oxidizer

products which oxidize the C agents into less or non-toxic subproducts. Efficiency with B agents is claimed.

e. Enzymatic Decontamination:

(1) An environmentally friendly alternative to aggressive chemical decontamination solutions is the use of enzymes. Up until now, research has focused on enzymes like Organophosphorous Hydrolase (OPH) and Organophosphorous Acid Anhydrolase (OPAA) for the destruction of G-type C agents by catalytic hydrolysis. These enzymes were reported to be incorporated into sponges for skin decontamination and into fire fighting foams. The enzymes were commercialized by Genencor International (Palo Alto, CA, USA) in the decontaminant DEFENZ™, which is also claimed to destroy VX in limited laboratory applications.

(2) Recently, different enzymatic approaches towards the destruction of VX, HD and B agents have been reported, for instance by the enzymatic generation of peracetic acid, though none are currently available in commercial products. All-Clear (Kidde Firefighting, Angier, NC, USA) is the only decontaminant formulation that utilizes an enzyme and biocide foam mixture, making it effective against some nerve and B agents.

0404. Directed Energy Decontamination

1. Directed energy methods for decontamination, such as photochemical, ultra violet radiation, plasma, and microwave radiation have all been demonstrated to disinfect surfaces. As energy transfer methods, all of these systems can kill bacteria, bacterial spores and viruses, given sufficient time and power. Some of the technologies are also able to destroy chemical agents including industrial chemicals.

2. Atmospheric plasma decontamination (APD) can be applied for the destruction of biological organisms. By passing energy through air, the molecules are ionized generating both positively- and negatively-charged reactive species. The interaction of these ions, along with the associated ultraviolet light, kills the microorganisms. APD is applicable to the cleaning, and perhaps disinfection, of small areas and electronic equipment. Plasma-based systems with high gas velocity dispersal systems have been shown to evaporate C agents off surfaces, so they should be used with appropriate engineering control to prevent creation of aerosol and vapour hazards.

3. A microwave reactor was developed by CHA Corporation (Laramie, WY, USA) for the destruction of C agents in rinsing water of military vehicles. The microwave process combined with granular activated carbon has a strong potential to destroy B agents in water.

0405. Advantages and Limitations

1. Many different approaches have been developed for the removal and decontamination of CBRN agents. There is no single, ideal decontaminant suitable for clean-up of every agent in every operational situation. The choice of a decontamination method depends on various factors, mainly being the type and the condition (solid, liquid, vapour) of the agent, the contaminated object (such as a military vehicle, sensitive equipment or building interior), and the operational situation and location, such as international operations or homeland security.

2. Some important factors concerning physical decontamination process include:

   a. The solubility towards CBRN agents.

   b. The ability to remove (rinsing, evaporation, sorption) CBRN agents.

   c. The sorption capability towards C agents.

   d. The sorption ability for large surface areas.

   e. The permeability for CBRN agents of the strippable coatings.

   f. The reactivity (if any) of CB agents with decontaminant.

   g. The accessibility to remove entrapped CBRN agents.

   h. The compatibility of different materials and surfaces in the equipment.

   i. The health hazards (vapour and contact risk) before and after removal of CBRN agents

   j. The climatic and environmental effects (temperature, humidity).

3. Some important factors concerning chemical decontaminants are:

   a. The solubility towards CBRN agents.

   b. The reactivity and specificity towards CB agents.

   c. The contact time between the decontaminant and the CB agent, especially in the case of reactive gasses.

   d. The adhesion properties towards different orientated surfaces.

   e. The accessibility towards entrapped CBRN agents.

   f. The compatibility towards different materials and surfaces of the solutions.

   g. The stability of the decontaminant, especially in the case of enzymes (temperature, pH).

h. The health hazards (vapour and contact risk) of the decontaminant before and after use against CBRN agents.

i. The access to water if that is necessary for preparation of decontaminant solutions.

j. The climatic effects (temperature, humidity).

k. The environmental effects.

l. The compatibility with other equipment such as chemical detectors used to warn of an agent attack or to verify the effectiveness of a decontamination action.

m. The ease of removal after application and reaction.

n. The pot and storage lives of decontamination formulations.

4. Some important factors concerning directed energy decontamination are:

a. The reactivity of the technology towards CB agents.

b. The specificity of the technologies and applicability towards sensitive equipment.

CHAPTER 5
DESIGN GUIDELINES

0501. General

1. CBRN contamination survivability can be enhanced by several means at the design level. Attention to equipment design and careful consideration of material selection provide the maximum return on investment in terms of logistics and reduced burden on the soldier. When these aspects are not maximized, operational considerations should be made. Operational workarounds can include use of protective covers or implementation of procedures to reduce contamination transfer or exposure to contamination or procedures developed in TTPs for specific systems. Additionally, incorporation of CBRN defence related equipment such as collective protection facilities, detection devices, and contamination control devices enhance the survivability of equipment and personnel.

2. Materiel developers can contribute considerably to alleviating the operational and logistical burden caused by contamination. Contamination survivability requirements must be taken into account in the initial phases of development. The prospects of a successful retrospective hardening of materiel are poor, particularly if the system has already been introduced into the forces. Likewise, it is not feasible to harden equipment retrospectively by changing its design.

3. Ensuring materiel survivability should always be a balance between risk and cost, thus a realistic level of hardening can be determined at a very early stage in the design phase. It is necessary to establish the probability of contamination and the risk to the user and maintainer by virtue of a model of its deployment under CBRN threat conditions. Important in this respect is whether the equipment is used under some form of cover. Man-associated equipment may be considered to fall into one of three operational modes as detailed in the following subparagraphs.

4. Outdoor Equipment. Equipment kept permanently outside is vulnerable to on-target CBRN attack and may be contaminated during use. Both immediate (level 1) and operational decontamination (level 2) have to be carried out on this equipment by the operators and will be followed by thorough decontamination. This equipment must satisfy the following contamination survivability requirements.

a. Operable by personnel in full IPE (compatibility).

b. The external surfaces of the equipment should be resistant to functional damage by contamination and decontaminants (hardness).

c. The physical design and configuration of the equipment, particularly of the area contacted by the users shall permit effective decontamination (decontaminability).

5. Under-Cover Equipment. Equipment permanently under cover, which is always operated in protected areas, should not become contaminated by direct

attack. Provided that the operator or other personnel adopt suitable operating procedures to prevent the transfer of contamination to the equipment, and appropriate packaging is used when the equipment is in transit, the probability of contamination is acceptably low. The equipment should still be designed with hardness to CBRN agents and ease of decontamination in mind. It should be constructed of materials resistant to contamination and decontaminants.

6. Deployed Equipment. Equipment deployed from protected areas used for operational reasons are likely to become contaminated in CBRN environments. On its return to cover, particularly if the return is to an area provided with collective protection, an effective decontamination procedure is necessary if the integrity of the protected area is to be preserved. Likewise, the design and materials guidelines with respect to hardness, decontaminability and compatibility are valid.

0502. Contaminant Effects on Materials

1. Data show that contaminants can alter the properties of materials. Typical affected properties include mechanical, chemical and electrical parameters. Sulfur mustard has been shown to reduce the tensile strength of various elastomers such as neoprene, ethylene propylenediene, acrylic rubber, and ethylene acrylic by as much as 25 to 40 percent. When acrylic is stressed, it swells, exhibits hazing, and shows slight crazing when exposed to sulfur mustard. For example, polycarbonate is a transparent material and becomes opaque after being exposed to the sulfur mustard. Chemical properties such as permeation and diffusion rates change when exposed to contaminants. Permeation data should be analyzed for applicability to individual components. Test data show effects on electronics that include corrosion on circuit elements when exposed to chemical agents. Exposure of acrylic conformal coatings to sulfur mustard resulted in reduced resistivity thus increasing conductivity. Materiel exposed to the effects of nuclear detonations can become radioactive through the exposure to neutron radiation, thus making it impossible to decontaminate. Most activated materials will have a relative short half-life and radiation levels will decrease quickly.

0503. Permeability of Materials

1. Permeability of penetrable materials is a main concern when dealing with chemical contamination, and is a very important factor with respect to radioactive fallout or B contamination. Many R contaminants are highly soluble and are intense beta and gamma emitters whose radiation readily passes through clothing. This may cause beta “burns”, which are incapacitating particularly if the R contaminant is in direct contact with bare skin. The absorbed contamination must be physically removed from contact with the skin.

2. Immediately after contamination, the chemical agent on the surfaces of exposed permeable materials will start to disappear by two main processes (hydrolysis or other decomposition processes are not considered). One process is evaporation, which depends, in addition to the physical properties of the agent, on

such factors as temperature of the surface and the wind-speed. Also, the surface tension of a given chemical agent deposited on permeable material of interest shall be considered as a pertinent factor since it can influence the spreading of the chemical agent droplets over the surface and thus the area affected by the respective spots. The other process is absorption into the body of the material. Although the decontaminants may remove the free liquid remaining on the surface quite efficiently, they are not able to neutralize the absorbed agent. Therefore, it is of great importance to carry out the decontamination as soon as possible. This is not always possible due to operational constraints and, consequently, part of the absorbed contamination will remain present after decontamination. Subsequent desorption constitutes a continuing residual vapour hazard to personnel in the vicinity, in particular when ventilation is restricted. Besides the inhalation hazard, direct contact of bare skin with the contaminated material is dangerous because chemical agents can easily pass from the material to the skin. It is very important, therefore, to select materials for the exposed part of equipment which do not absorb chemical agents. One criterion for selecting materials is the rate of absorption and/or desorption. Unfortunately, these data for materials are generally not readily available. For certain generic types of materials, data in the form of amount of chemical agent absorbed under given standardized conditions are available. These are useful for ranking the materials according to their absorption of agents. Other data available illustrate the increase in weight or thickness or visual changes after a given time of immersion of a test strip in chemical agent. This is not a simulation of the real situation of contamination after a chemical incident, but again, these data could be used in a relative sense. The absorption characteristics of some materials are outlined below.

a. Bare metal, Glass, and glazed Ceramics. These surfaces are impermeable and can be decontaminated readily to a level at which desorption is negligible. However, corrosive products, which can appear on bare metals, might increase adversely the adsorption of agents, thus making the subsequent decontamination more difficult.

b. Finishes. Alkyd and acrylic paints absorb chemical agents and subsequent vapour desorption can continue for up to several weeks. However, some catalytically hardened paints based on cross-linked binders (two-pot, not air drying) such as polyurethane and epoxy paints are much more impermeable to chemical agents and can confer better resistance to permeable and porous substances.

c. Fabrics. Materials such as canvas, cotton, wool, leather, etc., rapidly absorb large quantities of chemical agents. Special coatings such as butyl rubber, or lamination with chemical resistant foils such as Teflon, can be used in many applications to reduce the permeability. Uncoated fabric is extremely difficult to decontaminate. Additionally, many decontaminants will damage fabric to the point where it is no longer useful. Due consideration should be given to this when designing equipment that utilizes fabric.

d. Wood. This material is absorbent unless protected by a chemical agent resistant finish, and is almost impossible to decontaminate.

e. Rubbers. Rubbers vary widely in their absorptive properties. Fluorinated rubbers (Viton) and butyl rubber are the most agent resistant while silicone rubber is generally the most permeable. Table 5-1 shows data on the relative permeability of sheet rubber (this table is an illustrative example for comparison purposes only). Table 5-2 also lists some absorptive properties of rubbers.

f. Plastics. Most plastics also vary widely in their absorption of chemical agents and individual plastics vary in their properties from one manufacturer to another (due to variations in molecular weight, degree of branching, plasticizer and crystalinity). The molding and forming processes involved in the fabrication of components also have an important bearing on the surface properties of the polymer. Data from tables should be treated as qualitative only and confirmatory tests should be carried out on the particular candidate materials chosen. PTFE (Teflon, Fluon, etc.) is practically impermeable. Polyolefins (polypropylene and polyethylene) are less so, but still quite agent resistant. Plasticizers tend to make materials more permeable so that plasticized PVC is one of the most absorbent of the common plastics. The properties of glass-reinforced plastic (GRP) are determined by both the nature of the plastic used and by the type of surface finish attained during the manufacturing process. Epoxy resins are normally more agent resistant than polyester-based systems. These data can be determined for GD as well, since especially fluorinated polymers absorb larger quantities of G-agents.

Table 5-1. Permeability of Rubber and Plastic Materials to 1 mg Droplets of Sulfur Mustard (HD)

Material	Penetration Time (Hours)	% Chemical in Material After		Duration of Desorption
		½ hour	1 hour	
PVC, (Polyvinyl chloride)	0.4	59	74	> 4 DAYS
HYPALON, (Chlorosulfonated polyethylene)	1 - 2.5	22	52	> 4 DAYS
NEOPRENE, (Polychloroprene)	0.5 - 2.0	17	30	2 DAYS

BUTYL RUBBER (Polyisobutylene)	24	10	10	1 DAY
VITON, (Fluoroelastomer)	72	0	1	< 1 DAY
NOTES: Penetration time was the time taken for enough agent to penetrate through the sheet materials to exceed an appropriate level on the other side. Desorption time was the time for the desorption rate to fall to an appropriate level.				

g. Table 5-2 shows the amount of agent absorbed in elastomeric material two hours after the contaminant was placed on the material at 20° C. After two hours of agent residency, the surface contamination was removed and the amount of absorbed chemical agent determined. The absorption values below are for comparison only and should not be used on their own.

Table 5-2. Absorption of Sulfur Mustard (HD) and VX by Elastomers

Material	**Absorption (mg/m^2)**	
	HD	**VX**
BUTYL RUBBER (Polyisobutylene)	2500	2200
DALTOFLEX, (Polyurethane rubber)	15.0×10^4	6.8×10^4
HYCAR, (Copolymer butadiene-acrylonitrile)	17.9×10^4	$6\text{-}7 \times 10^4$
HYPALON, (Chlorosulfonated polyethylene)	17.8×10^4	7.8×10^4
KELTAN, (Olefinic thermoplastic rubber)	1.4×10^4	6.6×10^4
NATURAL RUBBER	7.3×10^4	ND
NEOPRENE, (Polychloroprene)	14.6×10^4	15.9×10^4

POLYBUTADIENE, (Buna 30)	ND	5.7×10^4
PVC with plasticizer, (GP 62)	1.1×10^4	21.4×10^4
VITON, (Fluoroelastomer)	240	0.9×10^4
Note: “ND“ means Not Determined		

h. Table 5-3 shows the amount of agent absorbed by various polymeric materials two hours after the contamination was placed on the material at 20° C. These polymeric materials were selected for testing because they can be used as construction materials and may find application for military equipment. After two hours the surface contamination was removed and the amount of chemical agent determined. Where applicable the international abbreviations for the materials (International, Standards Org. ISO/TCCI Plastics) have been used. The very high values for absorption of sulfur mustard by PS, ABS and POC are due to the agent dissolving the plastic.

Table 5-3. Absorption of VX and Sulfur Mustard (HD) by Various Polymeric Materials

Material (tested by)		**Absorption (mg/m^2)**	
		HD	**VX**
PS	Polystyrene	91870	125
PVC	Polyvinylchloride	2792	24
DARVIC	PVC (ICI Ltd., UK)	2981	ND
PERSPEX	Polymethylmethacrylate (ICI Ltd., UK)	2992	9
ABS	Copolymer acrylonitrile butadiene/styrene	217400	117
PA 6	Nylon 6 (Polyamide)	23	NIL
AKULON	Nylon 6 (AKZC, The Netherlands)	133	102
RILSAN	Nylon 11 (Organic S.A., France)	35	10

Material (tested by)		Absorption (mg/m^2)	
		HD	VX
PE ld	Low Density Polyethylene	430	343
PE hd	High Density polyethylene	338	129
PP	Polypropylene	116	23
TEFLON	Polytetrafluoroethylene (DuPont de Nemours, USA)	NIL	NIL
DELRIN	Polyacetal (DuPont de Nemours, USA)	119	55
PENTON	Chlorinated Polyether (Hercules Inc., USA)	244	22
PC	Polycarbonate	33650	40
HOMALITE	Polyacrylate (Homalite Corp, USA)	165	ND
GUP	Polyester/glass fiber	100	ND
PPO	Polyphenyleneoxide (AKZO, The Netherlands)	565	9
NORYL	Modified Polyphenyleneoxide (AKZO, The Netherlands)	70	24
ARNITE	Polyethylene terephthalate (AKZO, The Netherlands)	25	ND
TPX	Methylpentene polymer (ICI Ltd., UK)	213	ND
Note: “ND“ means not determined.			

0504. Materiel Design

1. Two aspects of materiel design that have a major impact on CBRN survivability are the material itself and the equipment design. These aspects are illustrated in Figure 5-1. The pair of illustrations on the left shows the difference in material selection between non-permeable (a) and permeable (b) materials exposed to chemical agent. The pair of illustrations on the right show the impact during design where cracks/crevices are eliminated (c), thus making the contamination more easily

reached and removed as opposed to a design (d) where agent entrapment and accumulation is facilitated.

2. **Decontaminability.** In general, any feature that can trap or retain agents or represents poor design with respect to contamination and decontamination. Such features not only tend to hold contaminants and thus represent potential hazards to personnel, but are also difficult to clean adequately. Efforts should be made to eliminate or reduce the number of such features in order to improve the overall decontaminability of the equipment. Crevices where hatches meet deck-plates, exposed springs connected to hatch-covers, and constricted areas under tie-downs are representative of entrapment and hard to clean features. Switches, controls, meters, connectors, screw threads, rivets, are other examples of places where agent can accumulate and/or which are poorly accessible to decontaminants. The following paragraphs give general guidelines for construction modifications to minimize penetration of liquid C agents into capillary spaces and to facilitate decontamination. It is appreciated that these preferred constructions may not always be applicable and that situations occur that cannot be remedied by changes in construction. For example, the use of switches or connectors cannot be avoided. Often times a judicious choice of sites for these accessories is effective in minimizing the problem. The use of disposable covers for equipment should be considered with transparent instrument panels.

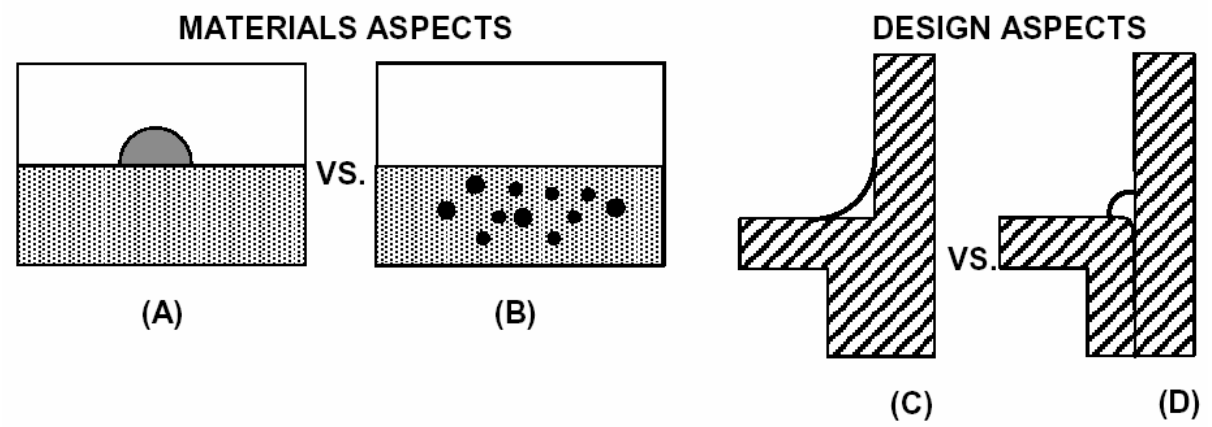


Figure 5-1. Proper Material Selection and Design to Enhance CBRN Survivability

3. **Hardness**. Guidelines were given in the preceding text regarding the choice of materials used in design. The choice of material is related to hardness because the material should survive the decontamination process. It may well be that the material which is to be preferred from a contamination survivability point of view is not applicable for mechanical or other reasons. If canvas must be used, the item needs to be designed so that the canvas is easily removable with a minimum of handling. If absorbing elastomers must be used, they need to be shielded (by coatings, covers,

etc.) to the greatest extent possible from contaminants, or they need to be designed as easily replaceable items, which can be discarded with a minimum of contact by personnel. Figures 5-2 to 5-21 illustrate general features that have been observed on numerous items of military equipment. Next to each undesirable configuration [left figure noted as (a)] is shown a suggested modification [right figure noted as (b)] which would reduce the contamination problem and would facilitate decontamination.

4. **Compatibility.** The equipment should be designed to enable operation by personnel wearing the full IPE with minimum loss of efficiency. Therefore, the designer should give consideration to the following:

a. Sharp edges and corners should be avoided to prevent damage to the CBRN protective suit and gloves.

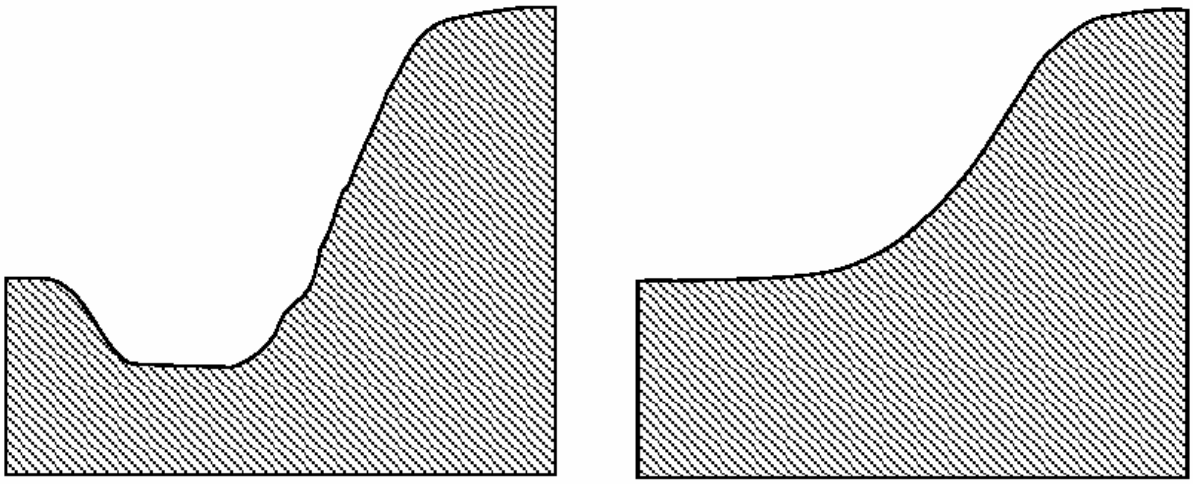
b. All deployment activities, operation of controls, adjustments, maintenance functions, etc., requiring manipulation by hand must be readily performed with the CBRN gloved hand. Table 5-4 below shows suggested minimum spacing for controls to enable free manipulation with a low risk of incorrect operations. The control spacing is more important than control size.

c. All deployment activities, operation of controls, adjustments, maintenance functions, etc., must be readily performed by the operator wearing his respirator. Due allowance should be made for the operator's limited field of vision. For focussing optical systems, an eye relief of at least 30 mm should be allowed.

Table 5-4. Suggested Spacing for Accurate Manipulation With a Gloved Hand.

Control Type	Geometry	Spacing (mm)
Push button	Between button centres	15
Toggle switch	Between adjacent centres	20
Rotary controls	Clear annulus around periphery of control knob	25

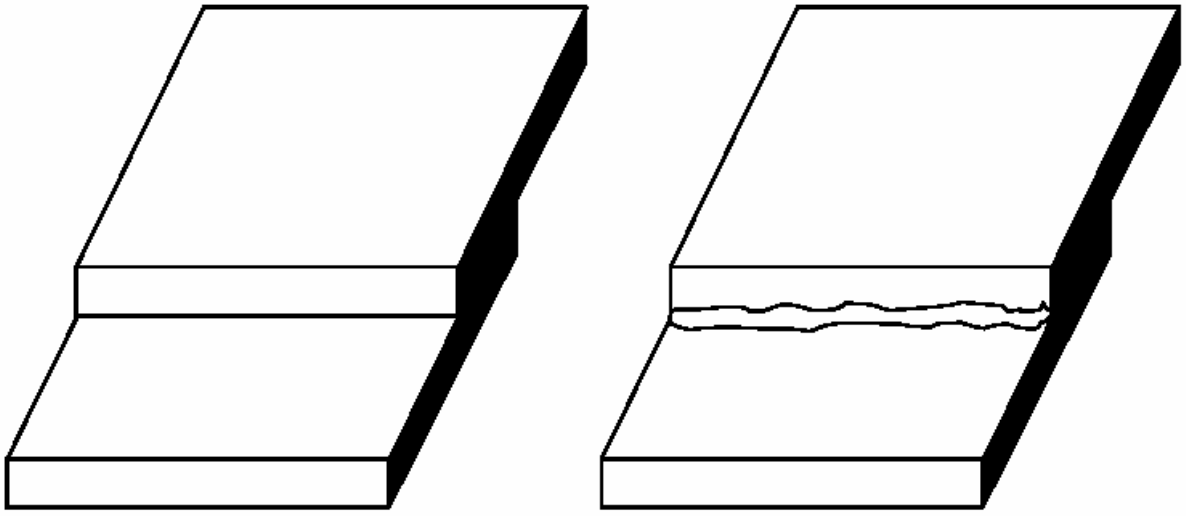
d. General Surface Shape. Figures 5-2 to 5-21 depict the impact of cavities in design. Deep surface concavities trap liquid chemical agents and prevent access and run off during decontamination [Figure 5-2(a)]. The deeper and narrower the concavity, the greater is the possibility of trapping the contaminant and the more likely it is that chemical decontamination will be ineffective. The surface design should be as plain and simple as possible. Use radiuses corners and edges especially where internal corners are unavoidable. Surfaces should be smooth to avoid crinkled and textured finishes.



5-2(a) **5-2(b)**

Figure 5-2. Enhanced CBRN Survivability as a Result of Proper Material Selection and Design

e. Eliminating the concavity by making it shallower or wider, filling it with a non-absorbent material, or shielding it will prevent entrapment of contaminant and will increase the effectiveness and efficiency of the overall decontaminating process [See Figure 5-2 (b)].



5-3(a) **5-3(b)**

Figure 5-3. Lapped Surfaces

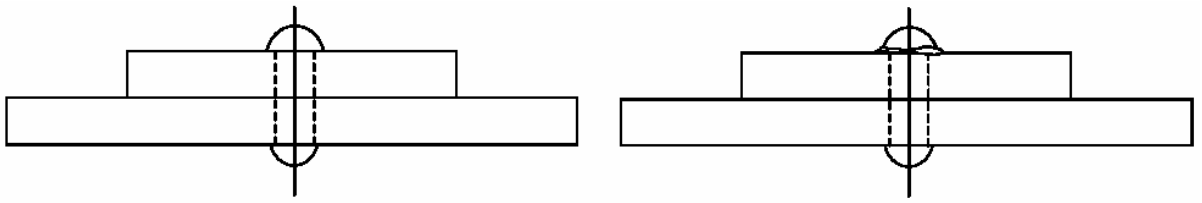
f. Lapped surfaces (Figure 5-3) are typical of sheet-metal panels, cabinet walls and doors, compartment covers, and some deck plating. The lapped items may be bolted or riveted together, or one may merely be laid atop the other [Figure 5-3 (a)]. Such a configuration results in a crevice between the sheets

that can trap contaminant and that is impossible to chemically decontaminate without removing at least the top sheet.

g. If one item must be lapped over another, the top item should be made easily removable to facilitate decontamination. Alternatively, the crevice between the items should be sealed by welding if the installation is permanent [Figure 5-3(b)]. Otherwise the crevice should be sealed with non-absorbent paint or a strippable sealing compound, as shown; or a preformed seal should be incorporated in the lower surface of the upper sheet, near the edge, which forms the crevice.

h. Joints and Fasteners:

(a) Permanent fasteners, such as rivets, may loosen due to vibration, working of the fastened panels, or faulty installation. Contaminant can be drawn into the capillary under the fastener head and even under the shank into interior spaces [Figure 5-4(a)]. Decontamination by chemical means is impossible.

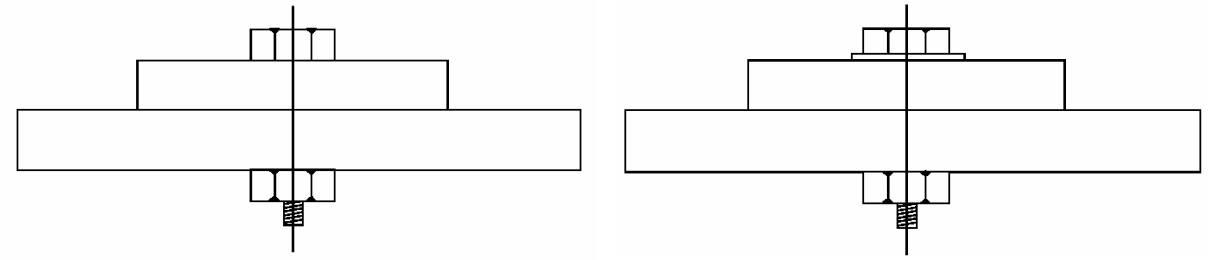


5-4(a) **5-4(b)**

Figure 5-4. Joints and Fasteners

(b) Wherever feasible, permanent fasteners should be eliminated by using one-piece constructions or by welding [Figure 5-4(b)]. Otherwise, installed fasteners should be sealed by non-absorbent paint or by strippable, disposable coatings.

(c) Although these latter techniques come more under the purview of maintenance than of design, they should be called for in design specifications and used in the initial construction and final assembly of the equipment.



5-5(a) **5-5(b)**

Figure 5-5. Removable Fastener, Protruding

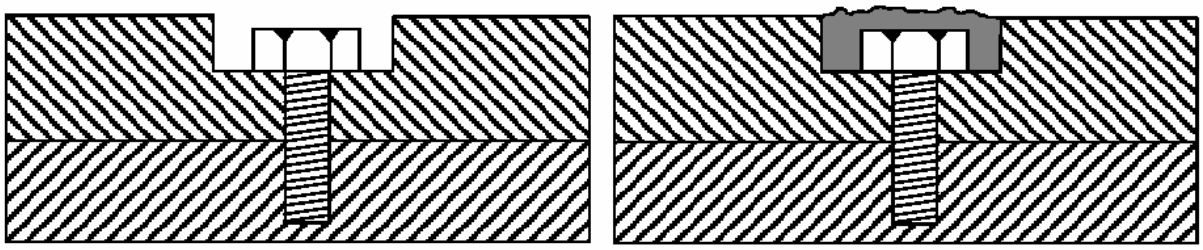
(d) Removable fasteners work loose during equipment operation and are frequently lost and not replaced in the field. Contaminants can be drawn under the fastener head and into the bolt hole [Figure 5-5(a)]. When the hole is threaded, and especially when it is a tapped, blind hole-decontamination by chemical means is difficult if not impossible.

(e) For some uses, a seal or flexible metal washer can be installed under the fastener head, as shown [Figure 5-5(b)], to prevent the entrance of material into the bolt hole and to help keep the fastener tightly in place. However, this is not a universally practical solution. Other alternatives are to make the fastener easily removable, and to provide access from both ends of the bolt hole (eliminate blind holes) to make decontamination more effective. More permanent solutions include incorporating an O-ring seal into the under surfaces of the fastener head; eliminating the need for removable fasteners; and using quick-release fasteners to minimize the potential contact time during removal.

i. Removable Fastener Recessed:

(1) Recesses around fastener heads are impossible to decontaminate thoroughly without removing the item that contains the recess [Figure 5-6(a)]. Furthermore, a recess ensures that the fastener head is contaminated and may contribute to contaminant being drawn under the head of the fastener.

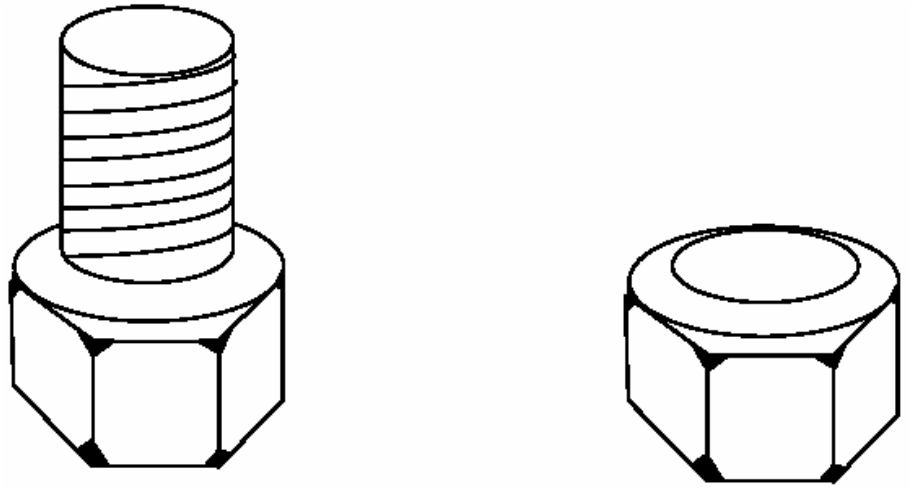
(2) Wherever feasible, recesses should be eliminated and the bottom surfaces of fasteners made flush with the top surface of the fastened item or a metal cap, incorporating a seal, can be used to cover the recess [Figure 5-6(b)]. The recess may be filled with non-absorbent sealer or filler, which must be smoothed over to eliminate entrapment areas. With this latter approach, the filler must also be strippable or otherwise removable to allow access to the fastener head.



5-6(a) **5-6(b)**

Figure 5-6. Removable Fastener, Recessed

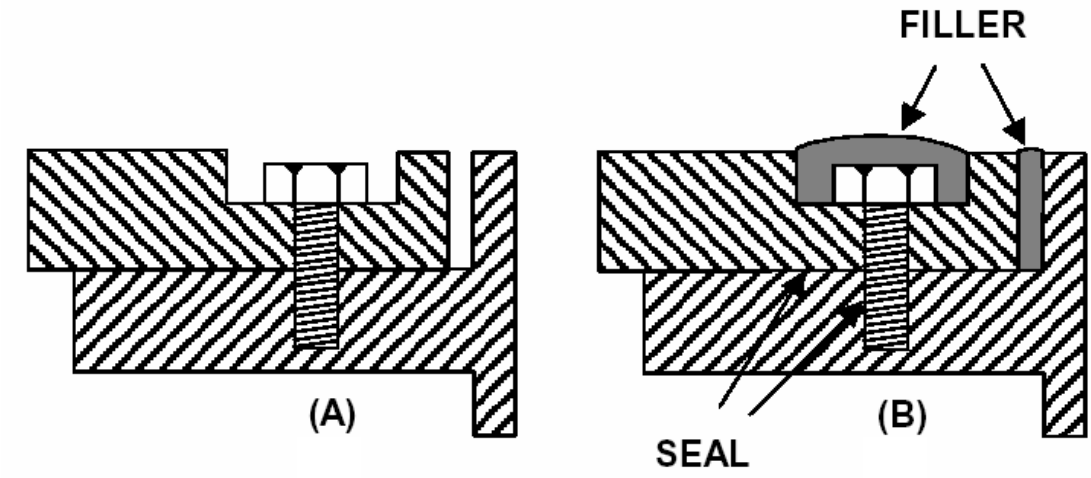
(3) Bolts longer than their function requires, are used frequently, exposing various lengths of thread to contamination. The thread grooves trap contaminant, particularly when they contain grease or dirt, and represent capillaries that can draw contaminant and decontaminant into nut recesses (Figure 5-7a).



5-7(a) **5-7(b)**

Figure 5-7. Removable Fastener, Exposed Thread

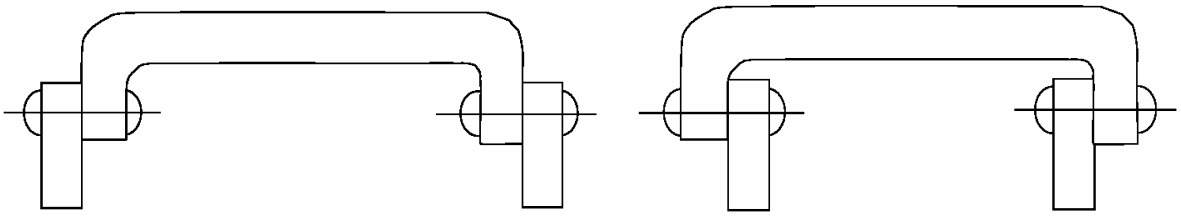
(4) Bolt lengths should be specified to be as short as possible. To prevent access to contaminant, nuts should include an internal seal [Figure 5-7(b)]. Alternatively, the entire nut and the exposed end of the bolt can be covered with non-absorbent strippable sealant.



5-8(a) **5-8(b)**

Figure 5-8. Enclosed Equipment Joints

(5) On enclosed, sealed equipment, use sealant on joints and on fastener threads - avoid blind holes. Recesses around fastener heads may be filled with a non-absorbent filler which must be smoothed over to eliminate entrapment areas [Figure 5-8**(**b)]. The filler must be strippable if access to the fastener head is required.



5-9(a) **5-9(b)**

Figure 5-9. Closure, Cover/Cap, Overlapping

(6) An inset cover may be bolted as shown in Figure 5-9(a), screwed in, or simply pressed into place, but regardless of how it is secured, the cap will allow contaminant and decontaminant to concentrate in the interface between the cap and flange. If the interface is not completely sealed, agent has access to the area under the cover.

(7) If the inset configuration must be used, the cover-sidewall interface can be sealed with non-absorbent paint after the cover is installed, although this does not improve the basic design. A better approach is illustrated in Figure 5-9(b) above. Overlapping, rather than insetting, the cover promotes runoff and makes the item easier to decontaminate. Furthermore, the exposed cover-sidewall crevice is eliminated. The design would be improved by not using through-the-wall fasteners and by incorporating a seal in the cover.

j. Horizontal Surface:

(1) Chemical contaminants tend to collect on horizontal surfaces and so access covers, closures, caps, etc., with lapped or inset joints on top surfaces should be avoided [Figure 5-10(a)]. Put access covers underneath equipment whenever possible [Figure 5-10(b)]. If an access cover must be located on a top surface use an easily decontaminable construction such as Figure 5-10 (c).

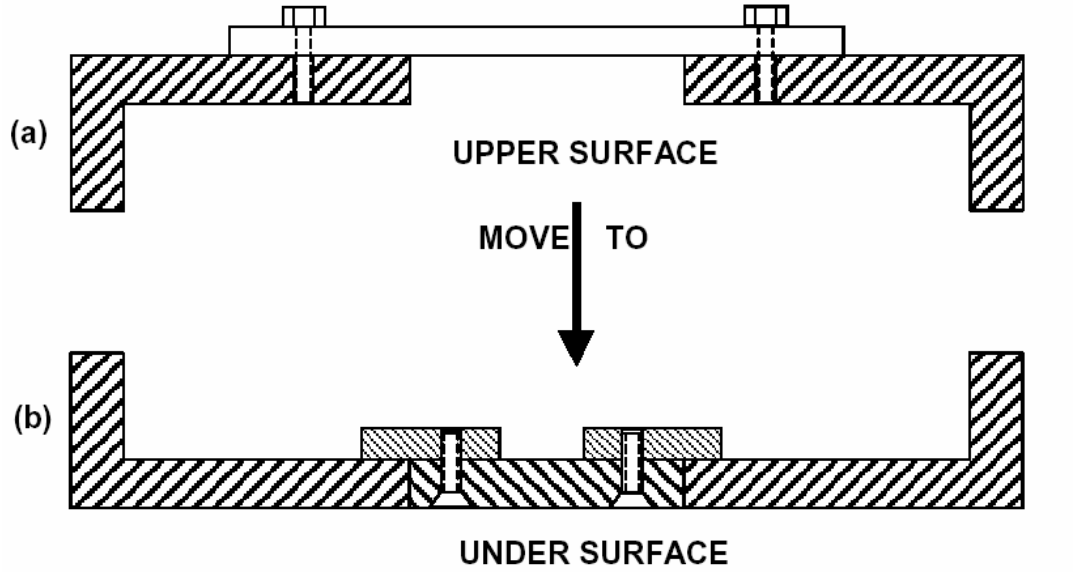


Figure 5-10 (a) and (b). Horizontal Surface

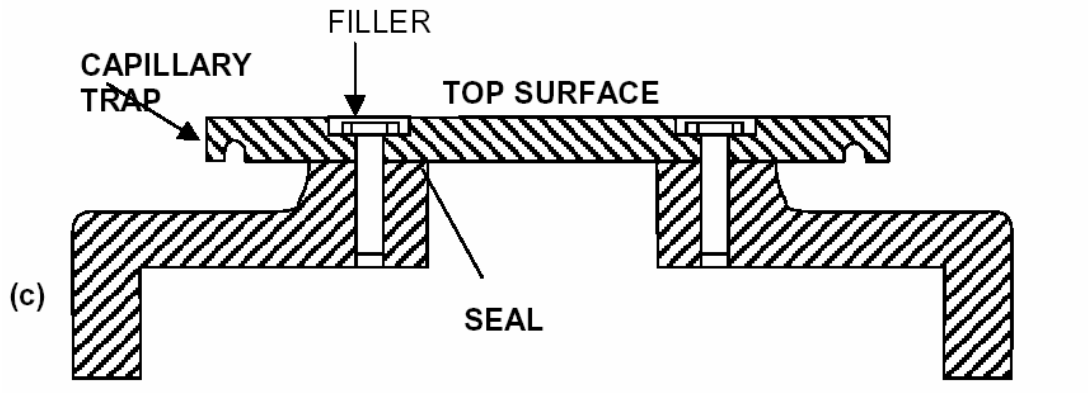
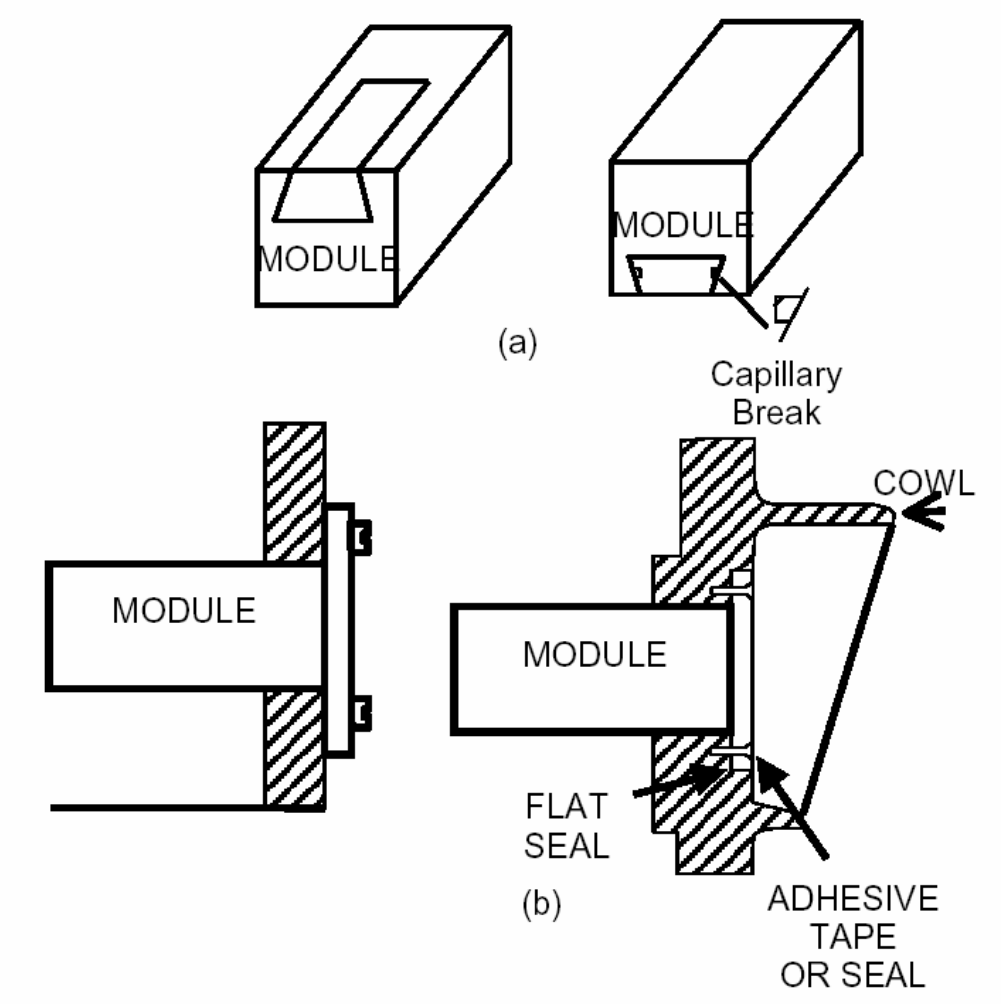


Figure 5-10 (c). Horizontal Surface

(2) Locate removable modules (battery, processors, etc.) on the underside of handheld equipment [Figure 5-11(a)]. Mould in capillary breaks on deep joints. Use internal catches. On large equipment protect removable

modules with cowls [Figure 5-11(b)]. Mount the module flush and seal the joint with a strippable sealant or adhesive PVC tape (PVC tape will absorb chemical agents and must be stripped and disposed of during decontamination).



5-11(a) **5-11(b)**

Figure 5-11. Control Panels

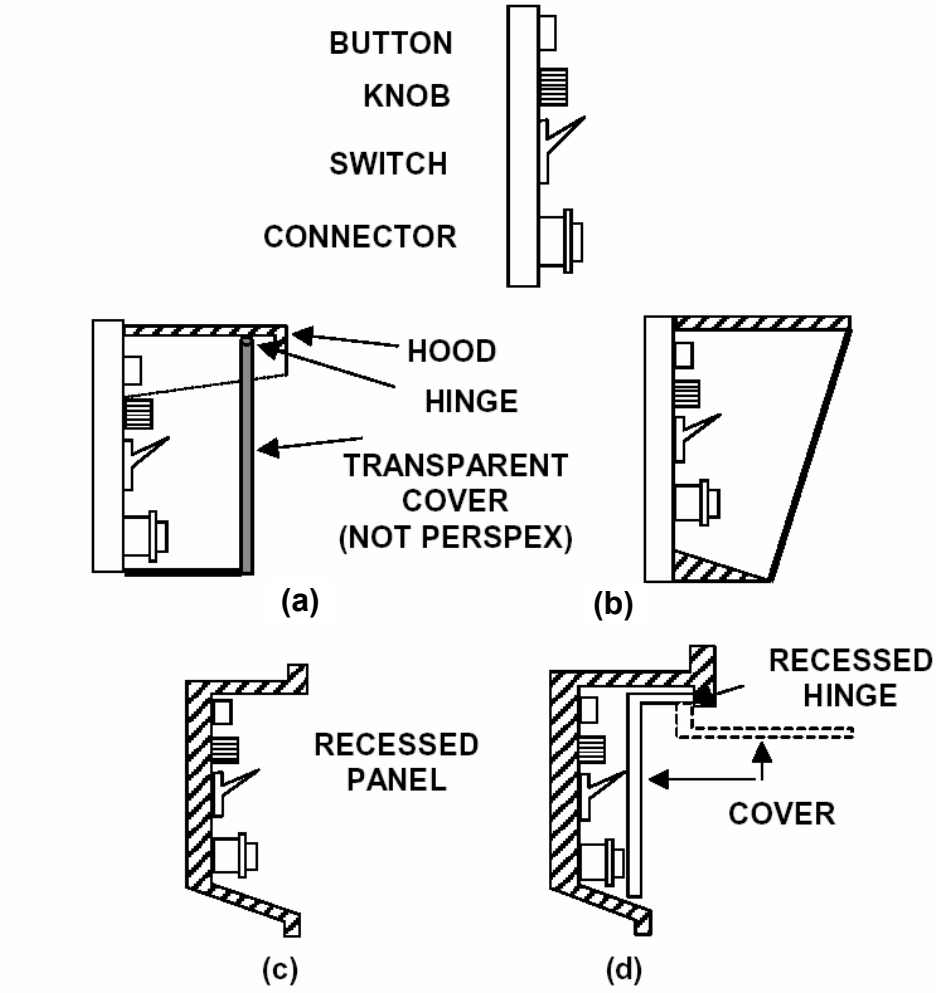


Figure 5-12. Control Panels

(3) Some protection is given to control panels by cowls [Figure 5-12(a)] or recessing [Figure 5-12(c)]. Better protection is given if a transparent cover (not Perspex) is added as shown in Figure 5-12(b) and Figure 5-12 (d). The cover may be hung or hinged so that its own joint with the equipment is behind the cowl or recess.

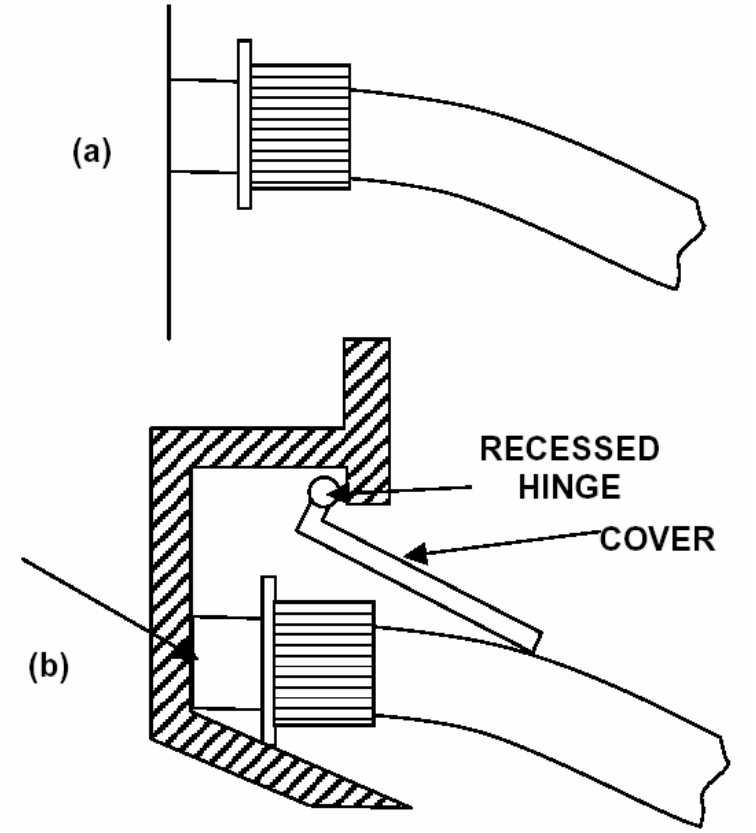


Figure 5-13. Cable Outlets

(4) Recessed cable outlets are shielded from a contamination environment. The hinged cover in Figure 5-13 provides contaminant/decontaminant run off both with and without the cable connected.

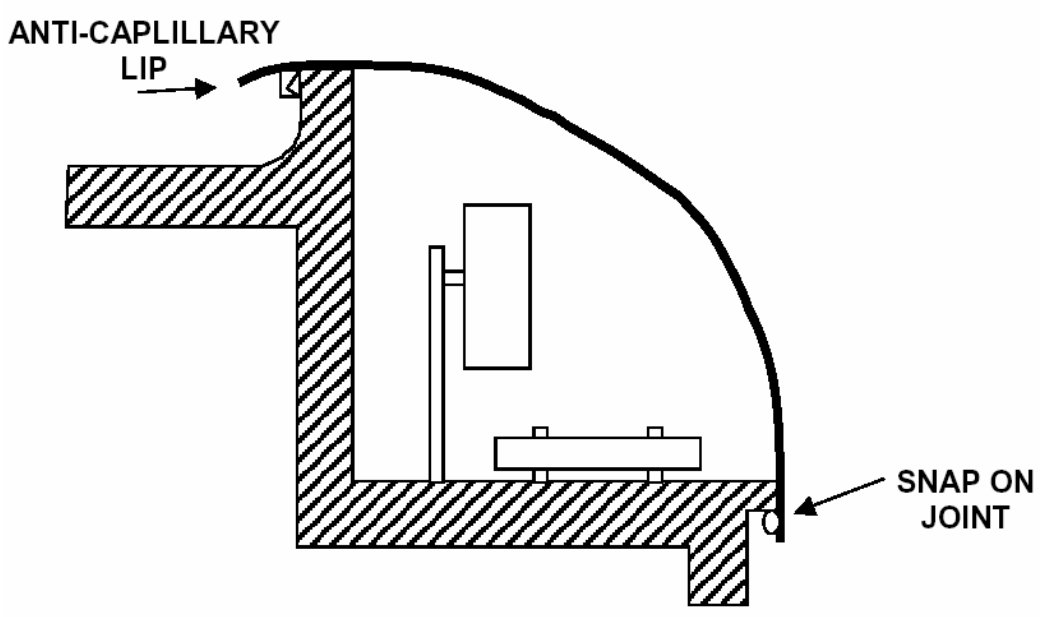


Figure 5-14. Fairing Over complex Components

(5) Thin sheet metal or non-absorbent plastic fairings, Figure 5-14, can shield complex external hardware.

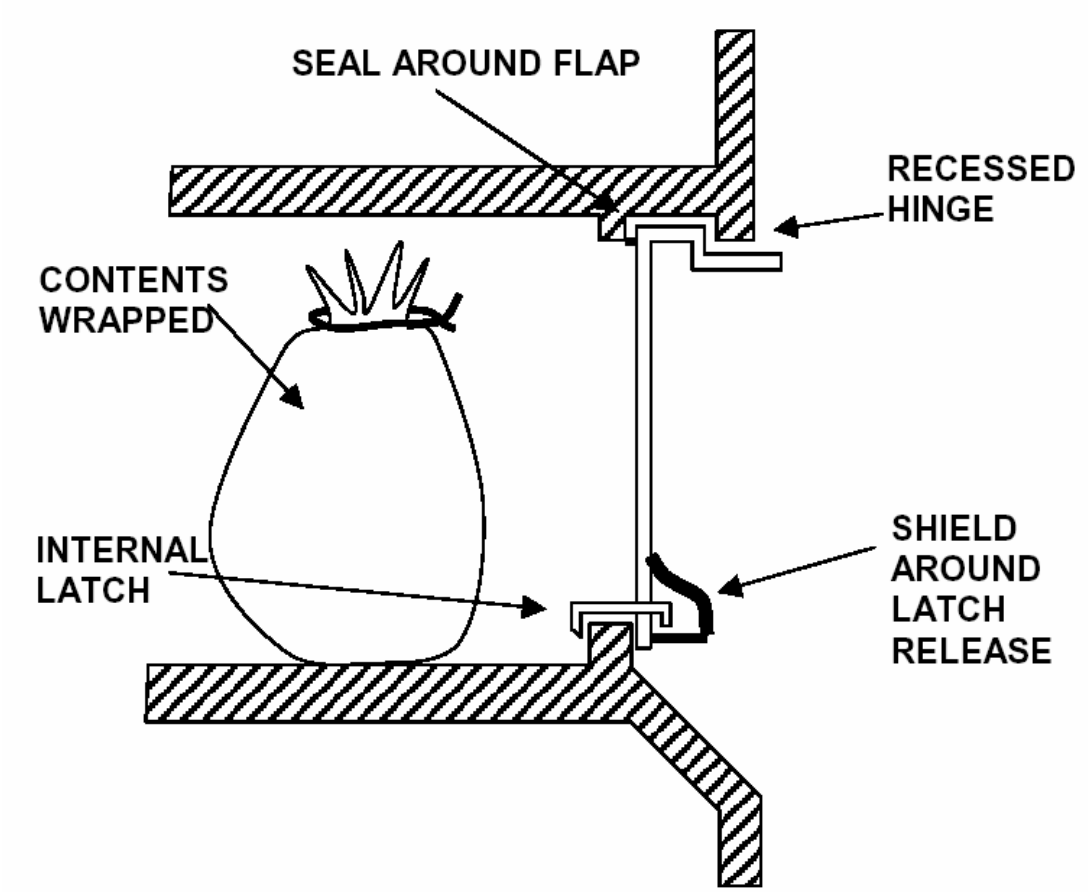


Figure 5-15. Storage Compartment

(6) Sealed storage compartment with positive internal latch. Control panels could also be sealed in this way by using a transparent flap, Figure 5-15.

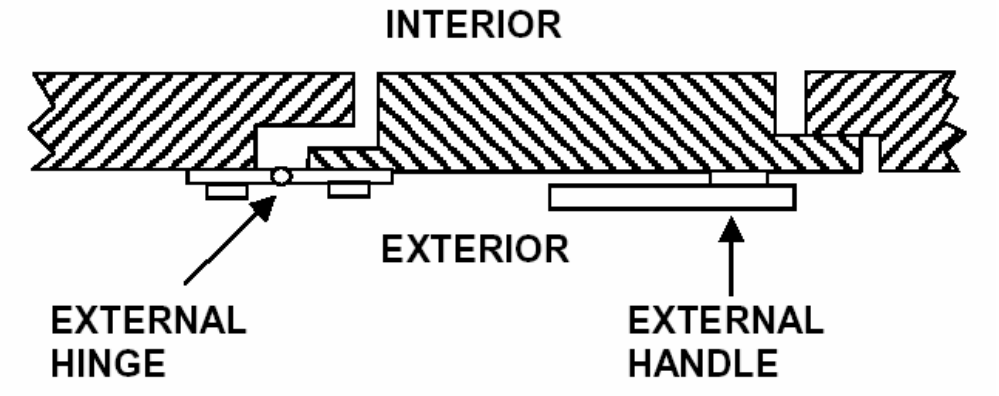


Figure 5-16. Door Mechanism

(7) Avoid doors with vertical hinges and external handles [Figure 5-16]. If such a door is unavoidable, use an internal hinge and shield the handle. A cowl over the door would give some protection to the seal [Figure 5-17].

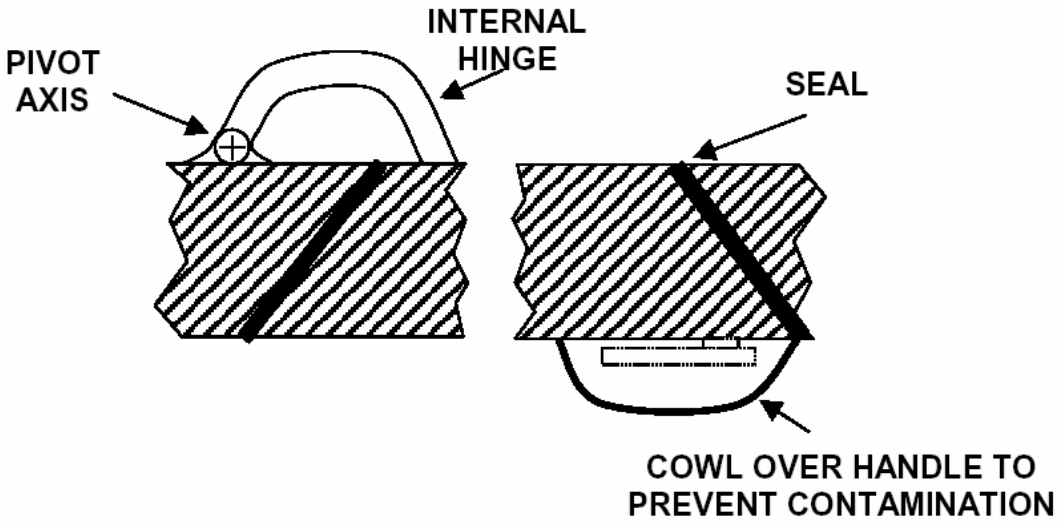


Figure 5-17. Handles

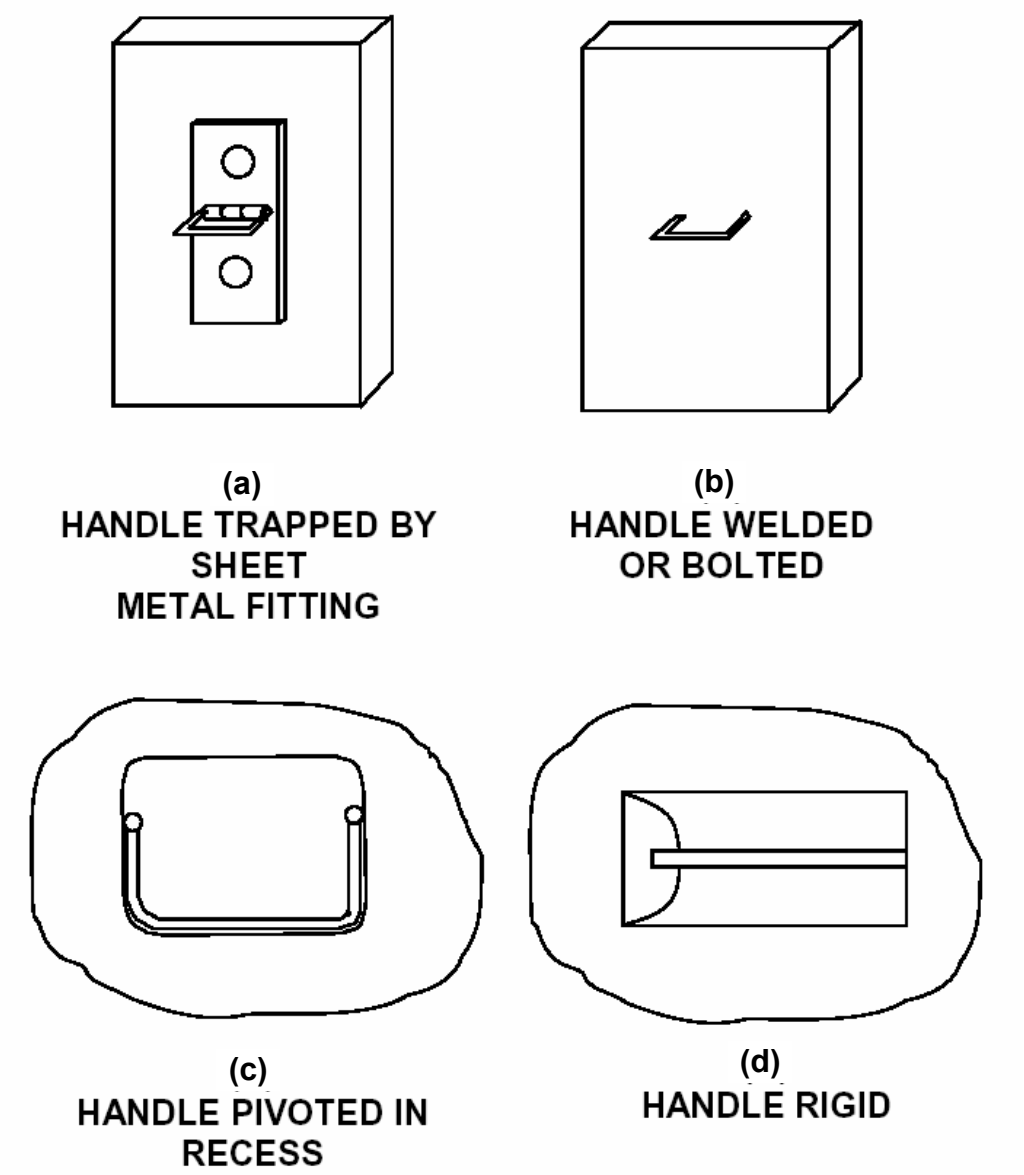


Figure 5-18. Handles

(8) Short, rigid handles welded or otherwise sealed [Figure 5-18(b) and (Figure 5-18(d)] to a surface will not trap contaminant and will be easier to clean than pivoted handles [Figure 5-18(a)] and [Figure 5-18(c)].

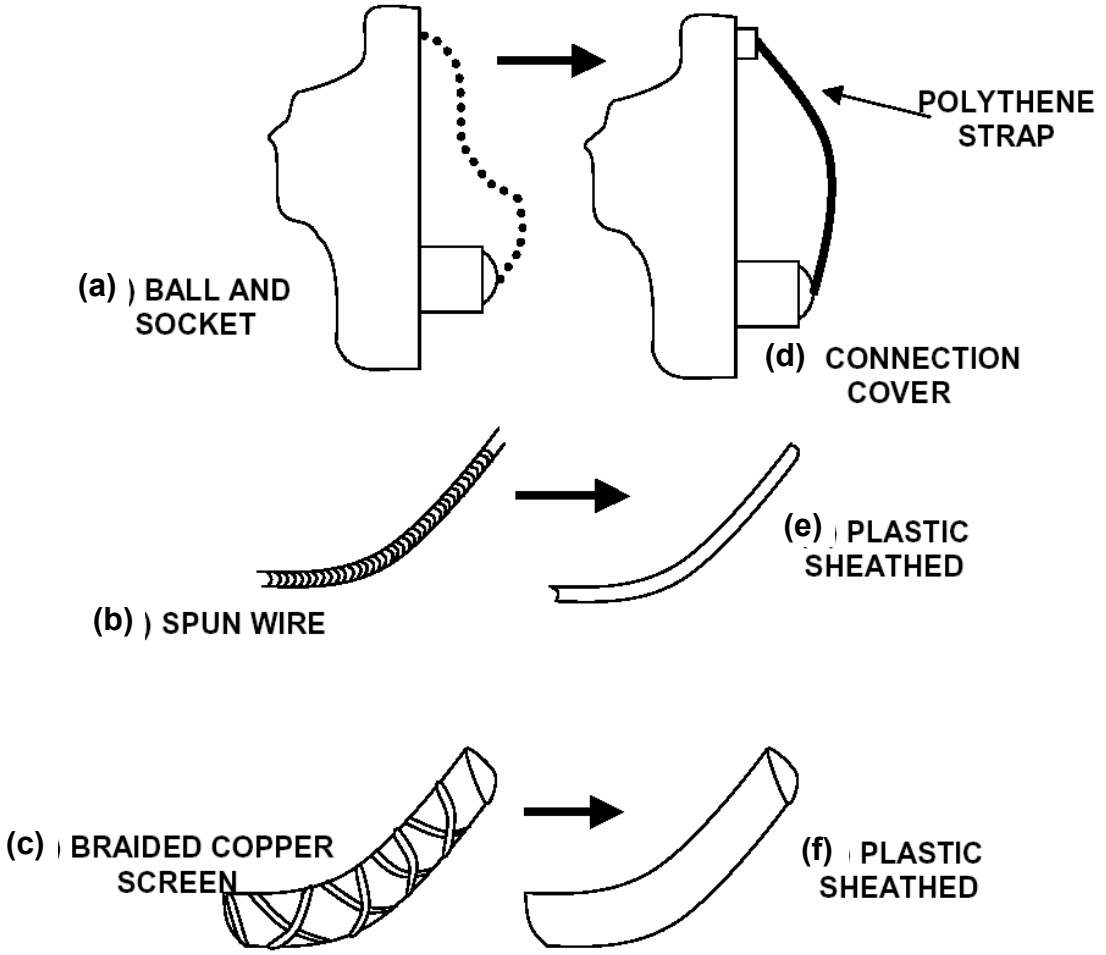


Figure 5-19. Chains, Wires, Cables, Etc.

(9) Avoid exposed links such as chains, spun steel wire cables and electrical cables with exposed braided copper or steel wire [Figures 5-19(a), 5-19(b), and 5-19(c)]. Non-absorbent plastic sheathing will protect wires and cables. Substitute agent-resistant plastic straps or sheathed weight chains [Figures 5-19(d), 5-19(e), and 5-19(f)].

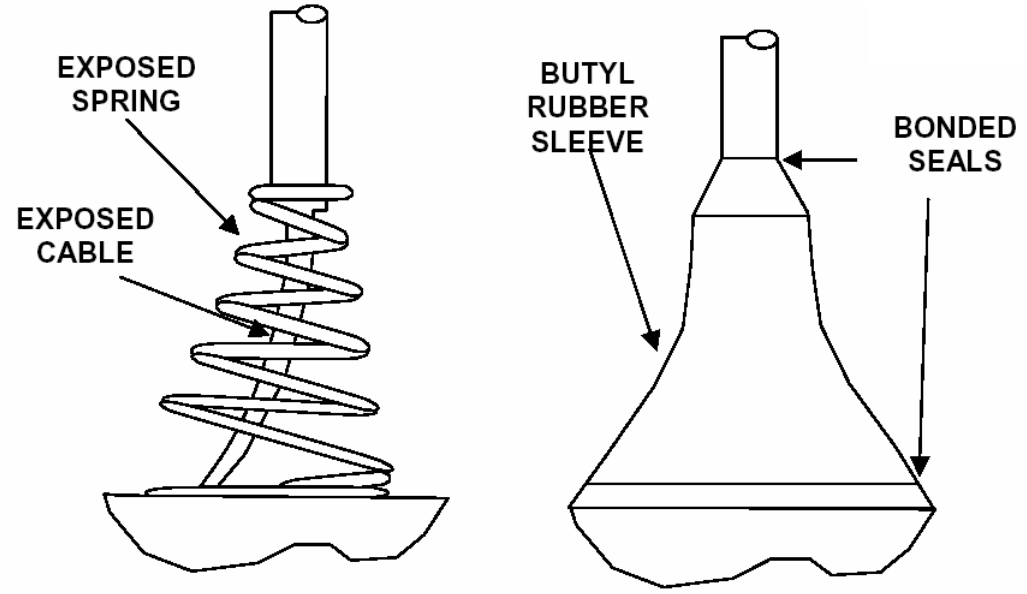


Figure 5-20. Accessories, Aerial Support Spring

(10) Complex and flexible items such as aerial support springs and suspension mountings [Figure 5-20(a)] can be covered with a bonded butyl rubber boot or sleeve [Figure 5-20(b)].

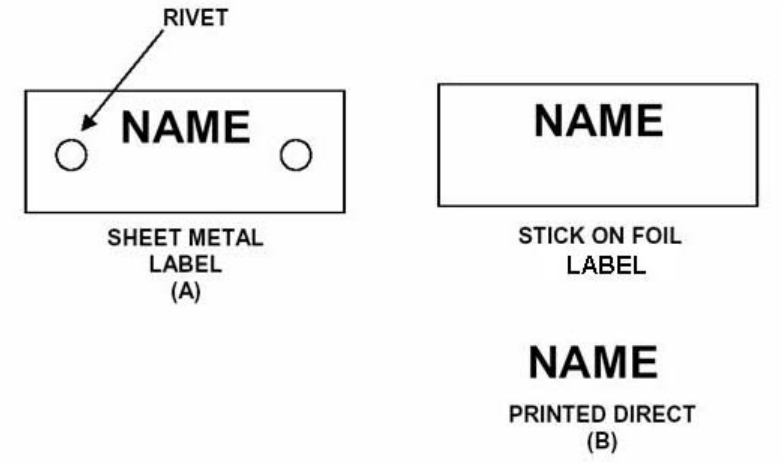


Figure 5-21. Manufacturers Name Plates

(11) Manufacturers' name plates [Figure 5-21] have been found to be great potential entrapment areas for chemical agents on military equipment. Use labels sealed to the surface or painted directly onto the surface [Figure 5-21(b)] as opposed to plates, which must be attached [Figure 5-21 (a)].

0505. Removable Absorbent Coatings

1. Removable absorbent coatings for use on military equipment are a development of industrial coatings used routinely to protect such items as new cars in transit or in the clean up of releases of radiological particulate within the nuclear industry.

2. Current removable coatings with military application are essentially passive in that they absorb and retain chemical agent or cover up or sandwich particulate hazards. The latter is particularly useful in terms of reducing the hazard from reaerosolised solid particulate agents. However, it is already possible to incorporate biocidal elements into coatings and future developments of coatings will contain active elements that can actively destroy and or neutralize contamination. An incremental step towards this goal would be to add an active decontaminating function to the peelable coating, such that this coating itself binds and progressively destroys chemical agents that impinge upon it. The benefits would be to reduce the hazards of continued operation after a chemical incident, and also those of subsequent removal and disposal of the coating. Systems that require or are complemented by a liquid decontamination adjunct are also considered relevant. Three types of functionality are required by the new active coatings.

a. Peelable paint film, with open pore structure allowing agent to be imbibed from the surface and transmitted to adsorbent/catalyst particles contained within the paint.

b. Adsorbent particles with a pore size and polarity to selectively bind molecules of agent in the presence of water and common cleaning materials.

c. Catalyst sites within the adsorbent structure that will neutralize all classes of C and B agents, in combination with other formulation constituents and possibly assisted by liquid decontamination treatments.

3. For self-decontaminating paint, a resin that does not swell in the presence of agents appears preferable. The paint should also have a relatively high build, giving coating thickness of 200-400 microns, in order to accommodate enough adsorption capacity for the NATO standard challenges.

4. As stated earlier current militarily relevant strippable coatings are passive. Current TTPs indicate that the coating would be used in a binary decontamination system, such as following a chemical agent challenge the equipment would be conventionally decontaminated, the removable coating would be removed and disposed of (hazardous waste). The removable coating could then be simply reapplied.

5. Key measurements in the performance of the coatings are:

a. Amount of agent remaining on the surface as a free liquid (contact hazard).

b. Amount of agent absorbed into the coating.

c. Amount of agent transferred through the coating onto the sub-surfaces treated with the coating.

d. Amount of agent off-gassed from the coating.

e. Measurements are normally made as a function of droplet size and dry film thickness (DFT) using thickened soman (TGD) and thickened sulfur mustard (THD). In a typical experiment, a polyurethane (PU) painted test piece, such as a chemically hardened surface, is coated with a product and is contaminated with chemical agent to density of 10 g/m^2 in 2, 5 or 10 μl droplets. The agent is then allowed to dwell on the test surface for one hour at 20^0C. A sorbent material is then applied to the surface with a contact pressure of 20 g/cm^2 for 15 minutes. The sorbent material is then extracted with an appropriate solvent and the extracts analysed by GC to determine the amount of free liquid that remains on the surface of the coating. Having removed the free liquid contamination, the temporary coating is removed and analysed to determine the amount of agent absorbed into the coating (a sample of the coating can also be removed at this point to undertake conventional off-gassing experiments). Analysis of solvent extracts taken from the peeled test plate allows quantification of the amount of agent transferred to the subsurface.

CHAPTER 6
TEST PROCEDURES AND METHODOLOGY

0601. General

1. The goal of this chapter is to describe procedures and methods for the evaluation of defence systems including those that have CBRN defence functions. As a design guide, this chapter can be viewed as providing guidance for inclusion in test and evaluation activities. Operational testing should examine the system when operated by representative users in an environment as realistic as possible. The objective of the evaluation methodology is to determine if the defence system can be decontaminated after a CBRN incident and to estimate the residual hazard resulting from the residual contamination after decontamination. Initially, evaluation of the materials and sub-systems should be conducted in the laboratory, and then field experiments on the entire system. This "philosophy" can reduce the cost if, for example, the material is found not to be resistant to CBRN agents. Evaluation results of the entire system could be similarly unsatisfactory and further testing would not be necessary.

0602. Testing the Entire System

1. The best method to measure the residual hazard after decontamination is to contaminate and decontaminate the entire system, and then measure the residual hazard. This evaluation method of the entire system is achievable in specific test facilities. The system can be contaminated with real agents or simulants, and then decontaminated using the equipment and the decontamination solutions or the appropriate processes. The residual hazard is then measured using specific monitoring devices or laboratory equipment after sampling. It is envisaged that the sampling and laboratory analysis will be more costly than using monitoring devices. The complete system evaluation is more time consuming, and needs greater resources and bigger facilities. To alleviate this constraint, tests can be conducted on materials and parts of the system and the results can be used to estimate the residual hazard, which is important to guide the re-usability of the system after restoration and under what conditions.

0603. Testing Representative Parts

1. One other option is to evaluate parts or subcomponents representative of the system, and then to model the residual hazard for the entire system using the results obtained for the small parts.

2. If evaluation of the entire system is not easy and requires large facilities, representative parts of the system can be evaluated. For example, models representative of typical parts such as doors and specific zones including corners can be built on the same scale as the system but can be evaluated in smaller facilities and with lesser CBRN agent or simulant. After contamination and decontamination, the residual contamination can be measured using monitoring devices or laboratory

equipment. It could be advantageous to use specific and complex shapes to test representative parts of the entire system. These would be composed of corners, bolds, tubes, open and close pipes, grids, etc. One example is presented below.

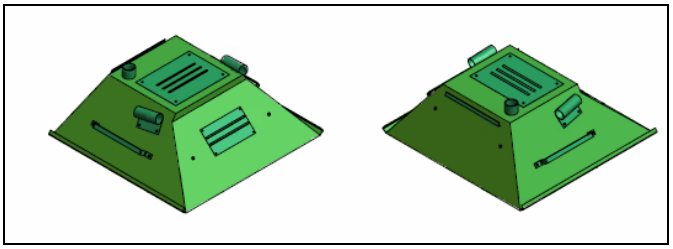


Figure 6-1. Representative Turret Parts of a System

3. The following NATO countries have facilities that can be used to evaluate system efficiency to resist CBRN contamination and the required decontamination procedures:

a. BEL - DLD has indoor test facilities for CBRN agents.

b. CAN - DRDC Suffield has indoor facilities for R&D in CB defence (BL-3 and Chemical Containment facilities) and for tests and training with chemical and some biological agents and CBR simulants. It also has outdoor facilities to conduct tests and training with chemical agents and CBR simulants. DRDC Ottawa has facilities for assessment of radiological decontamination.

c. DEU – WIS has indoor facilities for tests with chemical agents, biological simulants and radioactive particles and indoor facilities for conducting collective training with chemical substances.

d. FRA – CEB has field and indoor facilities for tests with radiological particles, indoor facilities for tests with C agents and field facility for B tests with simulants.

e. NDL – TNO has indoor test facilities for CBRN agents.

f. GBR – Defence Science and Technology Laboratories has indoor facilities for tests with chemical agents, biological simulants and radioactive particles and outdoor facilities to conduct those tests.

g. USA – U.S. Army ECBC, Aberdeen Proving Ground (Maryland, USA) has indoor laboratory facilities for C and B agents research and development, including surety walk-in hoods, environmental chambers and a BSL-3 facility. Large scale chambers for C and B agent testing on equipment up land vehicle size, and capable of supporting explosive dissemination of B and C agents.

h. USA – U.S. Army Chemical Defense Training Facility (CDTF, Missouri, USA) – indoor facilities for conducting training with chemical weapons.

i. USA - U.S. Army Dugway Proving Ground (Dugway, Utah) has indoor and outdoor testing facilities for both developmental and operational tests involving CBRN agents and simulants. The Life Science Test Facility is certified to test developmental equipment with aerosolized Biosafety Level 3 (BSL-3) agents, biological detectors, protective clothing and decontamination systems and their effects on materials.

j. SWE – Sweden has radiation testing facilities.

4. Modelling Residual Contamination. Considering the ratio of the specific parts and the residual contamination obtained from the painted plates and the representative parts of the system, the residual contamination on the outside of the system can be estimated. The residual contamination obtained using the modelling should give results close to those that would be obtained from the complete system.

0604. Materials Testing

1. Defence systems are composed of different materials, which cover a large part of the outside of the system. After contamination and decontamination, these materials could contain a significant amount of residual contamination even if the quantity of contamination in a single part of the system is low because they cover a large exterior part of the system. In the same way, the interior of the system should be considered and some materials that could be contaminated should be evaluated to know their decontaminability.

2. When considering the exterior of the defence system, the main materials are commonly steel, aluminium or composite covered with paint per STANAG 4360 (Land) or STANAG 4360 (Air). The decontamination must be tested with the decontamination solution and the decontamination process proposed when the defence system is designed. Other materials can be present on systems, for example polymeric and composite materials. At the moment, no standard exists for the evaluation of polymeric materials, but STANAG 4360 with the appropriate decontamination solution or process can be used instead.

0605. Agents and Simulants

1. **Agents**. Evaluations should be conducted with real CBRN agents as much as possible. The agents for evaluation must be chosen carefully with regards to the test objective. Agents commonly used for each threat include:

a. For C agents: sulfur mustard (HD), soman (GD) and VX.

b. For B agents: bacteria, viruses, and toxins.

c. R particulates or simulants used on the entire system or large part of it must be short half-life agents to avoid radioactive wastes. It is possible to use other radiological agents but only on painted plates of a few centimetres area. Many aspects of R contaminant behaviour can be modelled with non-active

substitutes of similar or identical chemical composition. Radioactive material should be used only when essential.

2. **Simulants**. Evaluations with real agents are expensive and cannot be conducted by industry for safety reasons and because the use of real agents are controlled. Some simulants can be used. Furthermore, it can be advantageous to first perform tests with simulants before using real agents. Despite much research, no simulant has been identified which can cover all functions of the real agent. Thus many simulants can be used and the selection of the best one should be done carefully regarding the aim of the evaluations. Simulants must have some characteristics, which make them adapted for the evaluations. Simulants must have similar physical and chemical properties as the agent.

a. Chemical Simulants. Compounds can be selected to simulate the chemical or physical properties of the agents. For example, a chemical simulant must not have all the same functions as the real agent, but just some chemical functions that make them suitable for testing and evaluation. To simulate the evaporation rate or vapour pressure, a physical simulant is chosen, whereas simulation of chemical reactions is done with chemical simulants. Selection of simulants is based on four aspects:

(1) Physical Properties. Physical properties are related to knowledge of the molecule (weight, density, viscosity) and to the behaviour of the change of state, particularly the melting and boiling points, surface tension, and the saturated vapour pressure in saturated conditions. These parameters are important when selecting a specific physical simulant.

(2) Chemical Properties. Chemical simulants must have some characteristics close to the real agent:

(a) Chemical functions: links P-S, C-Cl, and others.

(b) Intrinsic parameters of the compounds: explosivity, stability in air and temperature dependence.

(3) Reactivity. Some parameters describing the reactivity of the substance include kinetics of reaction, thermodynamic values, and others.

(4) Effects on humans and environment. Simulants must be safe for use in outdoor testing or in a non-restricted facility. A simulant must also be safe for use in non-specific laboratories, such as a university or industry, where contractors can perform their work. Cost of the simulant and the number of suppliers are among other aspects to take into consideration. Many simulants can be used and these are just examples. Malathion and parathion are well-known simulants for organophosphate nerve agents.

b. Biological Simulants. Real biological agents can be replaced by simulants to carry out tests in the laboratory or in the field. For these simulants, the physical properties such as diameter and viability, are important and must be close to the real agents. Additionally, they must also have a similar resistance to biological agents and decontamination processes like the real agents.

c. Radiological Simulants:

(1) The contamination resulting from a RDD could involve any of a variety of isotopes in a variety of chemical forms. Four isotopes are chosen for analysis of the resulting contamination after an energetic RDD based on the International Atomic Energy Agency's (IAEA) technical document "Categorization of radioactive sources". These four isotopes and chemical forms are: ^{137}Cs in the form of caesium chloride (CsCl), ^{90}Sr in the form of strontium titanate ($SrTiO_3$), ^{60}Co (metal) and americium/beryllium in an americium oxide mix with beryllium metal (AmO_2/Be). The isotope ^{192}Ir is also a concern for military and short term aerial denial.

(2) The contaminants listed above are relatively long-lived isotopes and, due to regulatory considerations and the generation of radioactive waste, the number and quantity of experiments that could be performed with the actual isotopes are extremely limited. A list of suggested surrogate isotopes is given in Table 6-1.

(3) These isotopes can generally be produced by neutron activation, but before activation one must ensure that isotopically pure chemicals are used to avoid the concurrent production of unwanted long-lived isotopes. The suppliers of the isotopes are aware of the problems associated with the activation of materials, thus consultation with them is advised when purchasing the material. The surrogates were chosen based on their ease of production, short half life, chemical composition and mechanical composition. Other isotopes that may be used include ^{99}Tc, ^{64}Cu, and ^{42}K.

Table 6-1. Suggested Surrogate Isotopes

Isotopes	Half Life (yr)	Chemical Forms	Surrogate Isotopes	Half Life (Days)	Chemical Forms
^{60}Co	5.2	Metal	^{192}Ir	74	Metal
^{137}Cs	30.1	CsCl	^{24}Na	0.63	NaI/NaCl
^{90}Sr, ^{82}Sr	28.5	SrTi03	$^{85}Sr/^{89}Sr$	65/50	$SrTiO_3$
^{241}Am/Be	433	Oxide	$^{141}Ce/^{143}Ce$	32/1.4	Oxide
Nuclear Fallout			^{140}La	40h	Nitrate, sand, carbonate

(4) The contaminants will normally be applied either as a liquid (water) solution or as a solid (powder). The contamination (liquid or solid) of the test plates should be optimized to reduce the amount of initial contamination required while still achieving the desired level of contamination (Table 6-4). This means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical and as low as reasonably achievable (ALARA). The desired level can be achieved by placing the material in a horizontal position and using high concentration of the contaminants or, if using liquid, recycling the liquid solution to continuously contaminate the material. If using a wet contamination the contaminated materials should be allowed to dry.

d. Nuclear Simulants. Nuclear explosions generate fission products as radioactive particles and black rain. It is important to simulate the physical forms of the contamination. Possible nuclear simulants for testing purposes include:

(1) Zinc Sulfide (ZnS) is nonradioactive;

(2) Contaminated silica with ^{140}La;

(3) Soluble ^{140}La nitrate or ^{24}Na acetate to simulate marine environment and rainout/washout; and

(4) Insoluble ^{140}La carbonates to simulate tartar or contaminated dried mud.

0606. Test Instrumentation

Table 6-2. Testing Parameters and Precision Range for Measurement

Domain	Parameter	Unit	Range
Measuring	Air temperature	°C	± 0,5
	Relative humidity (RH)	Percent	± 5
	Wind speed	m/s	5 %
Chemical tests	Sampling chemical vapour off-gassing: solid sorbent tubes, bubblers, miniature continuous air monitoring. Measuring agent concentration in samples (spectrophotometer, automated or hand-injected gas-liquid chromatograph,	Flow rate, L/min.	± 5%

Domain	Parameter	Unit	Range
	or equivalent)		
	Contamination density	g/m^2	± 5%
Biological tests instruments	Contamination density	Colony forming units CFU/mL of solution	± 10%
	Swab sampling of surface	Swab sampling in CFU/mL	± 10%
	Assay of biological simulants (microscopes, automatic colony counters)	CFU / sample	± 10%
Radiological tests instruments	Dissemination of particles (air sampler)	Activity per volume (Bq/m^3)	± 30%
	Surface average contamination (gamma detector)	Surface activity (Bq/m^2)	± 30%
	Localized residual contamination (hot spot) (alpha, beta or R-X detector)	Surface activity (Bq/m^2)	± 30%
	Unfixed contamination (swipe and particle counter)	Bq	± 30%
	Sampling airborne particles contamination		> 95 % sampling efficiency
	Counting particles	Number	± 5%
CBRN compatibility and hardness tests instruments	Measuring the differences in soldier tasks during operation of the test item while in (a) battledress uniform, and (b) CBRN protective clothing. Devices for time-and-motion measurements will be	Precision and accuracy requirements must be compatible with the test item and nature of the task being studied, but must allow the detection of 15 percent degradation in a	± 15%

Domain	Parameter	Unit	Range
	standard items, but test-specific devices may also be required.	specific task in five trials or less.	
	Measuring the test item mission essential performance characteristics before and after each of five nuclear, biological, or chemical contamination/ decontamination cycles.	Precision and accuracy requirements must be compatible with the nature of the test item and type of function, but must allow for the detection of 20 percent degradation in the mission essential performance characteristics after completion of the five contamination / decontamination cycles.	± 20%

0607. Test Planning

1. CBRN contamination survivability testing requires the handling and use of chemical agents, biological agent simulants and possibly radioactive materials. The guidelines described in this AEP have been safely followed by trained operators for many years. Throughout testing, primary emphasis must be on operator and test safety, but the importance of technical quality, completeness of test data, and conformance with specific test and operating procedures must also be emphasized. Each CBRN contamination survivability test plan must be reviewed individually for technical accuracy, conformance to regulations, safety procedures, and standing operating procedures (SOPs) applicable to the specific item and tests being conducted. In the case of radiological tests, personnel are exposed to radiations dosages despite wearing IPE. Therefore they must be equipped with personal dosimeters.

0608. Test Procedures

1. **Standard and National Methodologies**. Many decontaminants have damaging effects on material. Due to differences in decontamination policies and decontaminants used in the individual NATO/PfP countries (see Table A-2, Annex A), no common method of test sample decontamination can be established. Therefore, it makes sense to use national decontamination methods in order to record the relevant data for material damage caused by the specific decontaminants and to identify the efficiency of decontamination by determining the residual risk. Therefore, because of

the need to standardize operations, the decontamination methods and decontaminants of all NATO/PfP nations should be included in CBRN contamination survivability hardening considerations.

2. **Contamination Conditions**:

a. Chemical Testing. The surfaces of the item initially are uniformly contaminated to a contamination density of 10 g/m^2 with 5 - 70 mg droplets of thickened soman (TGD), VX, and thickened or unthickened sulfur mustard (HD). Contamination drop size: VX and HD: mass median diameter (MMD) 1.4 ±0.16 mm and thickened soman (TGD): MMD 3.5 ±1.5 mm. The purity of chemical agents used must be known and recorded as test data, and the quantity applied must be adjusted to achieve the required pure agent contamination density of 10 g/m^2. The actual contamination density depends upon the mission profile and where the materiel is used in the operational environment. A separate test must be performed for each chemical agent used, and the agents are listed below.

(1) Neat VX of purity greater than 85 percent. The agent may be dyed with approximately 0.5 percent (weight/volume) of a suitable dye.

(2) Neat GD of purity greater than 85 percent and thickened with 5 percent (weight/volume) of Rohm and Haas Acryloid K125 poly (methyl methacrylate), lot No. 3-6326. This should provide thickened agent with a viscosity of 2300 ±10% centistoke at 25 °C. Since complete solution of the polymer in GD is slow, mixing should continue until the measured viscosity is constant. The agent may be dyed with approximately 0.5 percent (weight/volume) of a suitable dye.

(3) Neat HD with a purity of greater than 85 percent. The agent may be dyed with approximately 0.5 percent (weight/volume) of a suitable dye.

b. Biological Testing. The contamination level for biological testing should be at least 10^7 CFU. For outside biological testing, the contamination density should be: 1±0.5 x 10^7 CFU/m^2. Biological simulant selected for this test can be a spore suspension of *Bacillus Atrophaeus,* also referred to as *Bacillus subtilis* var. niger (BG), which simulates the behaviour of *Bacillus anthracis* and is considered a best-case biological simulant. The exterior surfaces are uniformly contaminated with at least 1 x $l0^7$ CFU/m^2 of simulant biological agent 1-5 µm in size.

c. Radiological Testing. Contamination levels for radiological contamination will correspond to level agreed within STANAG 2473, which describes the radiological contamination level acceptable to NATO forces for different types of operational times (Table 6-3). Unprotected personnel in the downwind area can inadvertently inhale or ingest radiological material deposited on the surface of an item. Therefore, the level of contamination for the testing and evaluation of items for their contamination survivability capability will be based on the

contamination level values separated in three categories: high, medium and low level as seen in Table 6-4. Testing requires substantial safety precautions.

Table 6-3. Lowest Contamination Levels in STANAG 2473

Mission time	Levels of High-Toxicity alpha emitters Contamination (Bq/cm^2)	Levels for Beta and Low-toxicity alpha emitters (Bq/cm^2)
7 Days	5	50
3 months	0.5	5

Table 6-4. Initial Contamination Levels

	Alpha (Bq/cm^2)	Beta / Gamma (Bq/cm^2)
High	50	500
Medium	5	50
Low	1	10

d. Nuclear Testing: Contamination levels for nuclear contamination will be equivalent to between 100 and 300 MBq/m^2 for plates and between 10 to 300 MBq/m^2 for a vehicle. Radiological material selected for nuclear testing can be for a nuclear explosion where two-thirds of the activity could be induced activity resulting from the neutrons of the initial blast and they are not to be considered in the test. The other one-third of the activity (to be determined in the test) would result from radioactive debris remaining on the item after nuclear fallout contamination. The unprotected users of the item would arrive at H+2 hours and remain one meter from the item for a period of time based on the item mission profile, not to exceed 12 hours.

3. **Test Procedures for Chemical Contamination**:

a. Two test items should be used in testing, one for evaluation of residual vapour hazards and one for evaluation of contact and transfer hazards. When testing some high cost and complex items with chemical agents, test item availability and/or economies may dictate the use of one test item for both residual vapour and residual contact hazards. The procedures that follow assume that at least two test items are available.

b. Contaminate a test item either over its entire area or over the specific areas pre-selected for contamination. Apply agent with a microsyringe or spray apparatus that has been calibrated and approved for the chemical agent being disseminated. Thickened agent should be applied as uniformly as possible, with droplets having an MMD of 3.5 ±1.5 mm, until a contamination density of

10 g/m^2 has been achieved. Agents HD and VX should be applied as droplets of 1.4 ± 0.16 mm to a density of 10 g/m^2. A density of 10 g/m^2 is equal to 100 mg of agent in a 100 cm^2 area. Laboratory-prepared standard droplet cards may be used by the operator as a Visual aid in applying the proper amount of agent. Droplet cards should match the approximate size and shape of the sample area. Alternatively, if the agent has visible dye, digital photography with appropriate marked rulers may be placed alongside the test item.

c. Immediately after chemical agent contamination, remove the droplet size and contamination density samplers. Place the contamination density samplers in a jar with the appropriate type and quantity of solvent, seal tightly, label, and analyze for agent. Place drop-size sampling cards in a carrying tray and, depending on the type of card and agent used, either process immediately or hold for a predetermined time to allow stain sizes to stabilize. Process the contaminated cards for stain size measurement according to local SOP. An ALARA process must be carried out for individual trials.

d. On trials using thickened agent, drop-size samplers should remain attached to the test item throughout agent application. On VX trials, since a contamination density of 10 g/m^2 essentially coats the test item with a monolayer of agent, drop-size samplers should be removed after a single pass of the disseminator or applicator if droplet size is to be verified. When an agent dispenser is used that has been calibrated and standardized to deliver a reproducible droplet size and agent quantity, verification of the droplet spectra can often be calculated without actual counting and sizing procedures. The type of dispenser used and the data verifying the reproducibility of the dispenser (quantity dispensed and droplet size) shall become a part of the test documentation.

4. **Test Procedures for Biological Contamination**:

a. For biological simulant, calibrate a nebuliser (collision generator or equivalent) to disperse BG spores containing particles in the 1 to 5 micrometer size range, using pre-calculated operating time, air pressure, and slurry concentration. Contaminate the air inside the chamber to a level of approximately $1x10^6$ CFU/L of air by aerosolizing the slurry for approximately four minutes. The exact BG slurry count, disseminator air pressure, the duration of generator operation, and the number of BG spores/L of chamber air needed to meet the test item target contamination density level of $1x10^7$ CFU/m^2 will be determined by the project biologist. Use current SOPs and report the information as required laboratory data.

b. Immediately after completion of biological air chamber contamination, sample the chamber air for BG concentration using all glass impingers without pre-impingers. Allow one hour for fallout contamination on the surfaces of the test item. Air wash the chamber for one hour to reduce chamber air contamination. The one hour air wash will also serve as the one hour weathering time.

5. **Test Procedures for Radiological Contamination**:

a. Select, describe, and photograph representative areas of the test item for fluorescent particles (FP) simulant sampling, which is an alternative to actual radiological material. Each of the areas should also be subdivided, so as to contain a set of three smaller areas, each containing a minimum of 4 cm^2. Identify at least three such sets.

b. Before the start of a trial, use a 4 cm^2 patch of microlitre-plate sealing tape and sample the first area in each set. This patch sample will be used to measure pre-test background contamination.

c. Contaminate the air inside the chamber to a level of approximately 1 x 10^6 FP/L of air by aerosolizing dry FP using a laboratory FP dissemination apparatus. The desired contamination level on exterior surfaces is 2.5 x 10^5 particle/cm^2. The exact weight of dry FP material and the length of time the disseminator is operated to meet that value will be determined by the senior operator and reported as required data.

d. Immediately after completion of FP aerosol dissemination, sample the chamber air for FP concentration at two locations, one on each end of the chamber. Sample for 30 to 60 seconds, using two 6 L/min membrane filters oriented face-downward. Immediately after contamination, remove the contamination density samplers, the agent disseminator, and other support equipment. Decontaminate the agent disseminator being careful not to disturb or allow decontaminant on the sampling areas at this time. Syringes may be flushed and stored for reuse if appropriate safety procedures are followed. Allow one hour for fallout contamination of the test item. Air wash the chamber for one hour to reduce chamber air contamination.

e. After the one-hour air wash and before decontamination of the test item, use a second 4 cm^2 patch of microlitre tape and sample the second area from each set of three to measure the surface FP contamination density.

f. Photograph each sampling area to show level and uniformity of contamination. On tests where the entire surface of the test item was contaminated, photograph, through the hood opening, flat areas selected to demonstrate conformance with droplet size and contamination density requirements.

6. **Decontamination of Test Item**:

a. The contaminated test item shall be allowed to weather (remain on surface) for one hour after contamination is completed. For nuclear fallout contamination, the one-hour air wash of chamber will substitute for the one-hour weathering

time. Start decontamination immediately after sampling the test item for contamination level.

b. For removal of nuclear fallout and debris, the method recommended is brushing any loose material from the surface of the item and then washing the item with hot, soapy water, applied with a soft bristle brush. Some items of equipment have item-specific decontamination procedures intended to replace those outlined in the field manual. These specific procedures should be followed when supplied as part of the test documentation package such as a manual.

c. Start decontamination with areas contaminated first, and finish with the areas contaminated last. The decontamination process must last no longer than 75 minutes, including decontaminant-residence time but excluding agent-monitoring time.

d. Decontamination should be performed as if the entire surface of the test item were contaminated. The contaminated areas selected for sampling should receive no more or no less attention, time, or effort than uncontaminated areas. If this is perceived as a problem, two crews may be used: one for sampling and one for decontamination. Appropriate time should be spent working on sections having acute angles and hard-to-work areas. Since FP can be re-aerosolized easily, any contaminated chamber surfaces should be avoided or may be vacuumed immediately after the initial contamination sampling has been completed.

e. Obtain visual documentation of the decontamination procedures for inclusion in the report.

7. **Residual Hazard Determination**:

a. Residual Chemical Hazards:

(1) One of the test items allocated for CBRN contamination survivability testing could be used to estimate residual vapour hazards after the contamination/decontamination cycle. Residual vapour hazards are required only after contamination with GD or HD. Because of the low volatility of VX, residual vapour hazards need to be determined if specific in the test documentation or if the pre-test evaluation indicates that vapour sampling is advisable. One approach to estimate residual vapour hazard is as follows:

(a) When determining residual vapour hazard, place the decontaminated item in a sampling box, temperature-controlled box, or other enclosure that is of appropriate size to fit the item. For reproducible results, the box should have interior surfaces made of stainless steel or other material that is non-sorptive for agent. The box should generally “fit” the item with

unobstructed free airflow around the item, but without excessive free air space that will allow "pockets" of agent vapour to remain for long periods of time. The box should be ducted and baffled, and appropriate air diffusing devices should be placed on the intake and exhaust ports to help replacement air to flow as evenly as possible over all contaminated surfaces (laminar flow). The box should be vented to allow it to be initially flushed, on command, with clean outside air (approximately one air exchange per minute for four minutes), and constructed to provide air (agent vapour) sampling ports. The interior of the box should be sampled for residual agent vapour before being used. Exact box shape and dimensions must be calculated when the size and shape of the test item and hence the volume of the sampling box, are known.

(b) Calculate the number and flow rate of samplers required to achieve reliable airflow over the test item. Ensure that a minimum of two vapour samples are obtained for any time interval. Three samples are desirable. If cumulative samplers (bubblers or solid sorbent tubes) are used, an exact vapour sampling sequence must be specific in the detailed test plan for the 12-hour period, providing sufficient sampling time to give confidence that the lower detection level of the chemical analysis procedure is not a limiting factor. On small volume boxes, the samplers alone may give sufficient volume. On larger boxes, some venting may be required along with the sampling to achieve sufficient volume.

(c) After placing the test item in the vapour sampling box, verify that the box is airtight and that all equipment is working properly. Flush the box and associated air and sampling lines with clean air long enough to allow at least four air changes to rid the box of any agent or volatile contaminants.

(d) Start aspirating the vapour samplers, and use samplers appropriate to the measurement required.

b. Residual Biological Hazard. When the test item surface is dry following decontamination, swab sample the third 25 cm^2 area in each set to determine the residual contamination remaining on the test item. For porous materials such as ropes, tarpaulins, harness, cable, etc., extract the item with saline solution, which should then be filtered, cultured, and counted. When swab sampling data are available, calculate the contamination reduction values for each material/location sampled. If the contamination reduction values do not meet the CBRN contamination survivability criteria, decontaminate the item again and sample for residual contamination. Repeat the decontamination and residual contamination sampling a second time if required to meet the contamination-reduction criteria.

c. Residual Radiological Hazard. After decontamination and when the test item surface is dry, sample the third area from each sample set to determine the residual contamination remaining on the test item. If the contamination

reduction values do not meet the CBRN contamination survivability criteria, decontaminate the item again and sample for residual contamination. Repeat the decontamination and residual contamination sampling a second time, if required, to meet the contamination reduction criteria. Record the time and procedure used for each additional decontamination and sampling cycle.

d. Residual Contact Hazard:

(1) One of the test items allocated for CBRN survivability testing will be used to estimate residual contact hazard.

(2) Contact sampling periods should be as specified in the DTP. These samples must be taken during the 12-hour period following decontamination. Generally, contact sampling periods will correspond to vapour hazard sampling periods (though not necessarily for the entire vapour sampling time), with the initial sample being taken during the 4-minute clean air wash, of the vapour sampling schedule. Conduct duplicate sampling.

(3) Sample the locations on the equipment where direct contact with the operator's skin, or hands, or prolonged contact with other body parts is expected. The test plan may also specify other locations to be selected.

(4) Prepare contact samplers [a thin disk of silicone rubber (one mm thick) or other suitable material] with a nominal size of 25 cm^2. The contact sampler should be backed by aluminium foil to prevent contamination of the weight, and then by a material such as sponge rubber to force contact with all surface irregularities. Place the assembled sampler on the selected area using a pressure of approximately 65 g/cm^2 for ten seconds. Additional contact samplers can be sequentially placed on the same area, for selected intervals of time up to a total of 60 seconds, in multiples of five seconds. These sequential contact sampling times should relate to the use concept of the item (how long a human might be expected to lean on, touch, or hold onto a sampled area). A slight rocking motion may be required to apply sampling force more uniformly to surfaces that are slightly curved. Immediately remove the sheet of silicone rubber. Place the sheet in a sample jar with the appropriate type and quantity of solvent, seal the jar and transport it to the chemical laboratory for analysis.

(5) Sampling and analysis should use test instruments and methods that give precise and accurate values for the primary data parameters. Most military chemical alarms, detectors, detector papers, and kits provide only qualitative "yes/no" answers. Data from such sources should be used to complement data obtained from more precise test instruments.

(6) If coupons or swatches of item material are used for testing, treat each one as if it were the test item. Contaminate, decontaminate, and sample each

one individually for contamination density, residual vapour, and contact hazard.

8. **Hardness Determination**:

a. After completion of all decontamination and sampling procedures, inspect all surfaces of the item for visible evidence of degradation caused by the agents, decontaminants, and decontamination procedures. Describe any degradation, and document it with photographs. Operate the test item according to the appropriate test item manual. Measure and record the mission essential performance characteristics identified by the combat developer. Measure each characteristic at least twice. Interview operators and record all evidence of operational degradation. The mission essential performance data collected must be compatible and comparable with the pre-test values collected for the test.

b. The required five contamination/decontamination cycles may be conducted with any one or a combination of the three chemical agents, or the five total cycles may be conducted with chemical agents, biological simulant, radiological particles/simulant, nuclear fallout simulant, or any combination of these. If a hardness determination cannot be made on testing the initial item, additional test items must be used so that no more than five contamination/decontamination cycles are performed on any one test item. Select the sequence and the type of contamination/decontamination procedures required for the five cycles of the hardness determination after evaluation of the test item's identifiable vulnerabilities and questionable materials of construction.

c. Hardness data collection should be performed after each contamination/decontamination cycle and 30 days after the first contamination. Although there can be some flexibility from a testing program to another program, hardness data must be sufficiently accurate and precise to define any degradation over a 30-day period.

d. The International Standards Organization (ISO) and the American Society for Testing and Materials (ASTM) provide test procedures for determining hardness of materials. Consult those test procedures when developing hardness testing methods.

CHAPTER 7
ACCEPTANCE CRITERIA AND PROTOCOLS

0701. Hardness

1. Materiel developed to perform mission-essential functions shall be hardened to ensure that no more than 20 percent degradation over a 30-day period in selected quantifiable mission-essential performance characteristics is caused by five exposures to CBRN contaminants and industrial chemicals, decontaminants, and decontaminating procedures encountered in the field.

2. The "five exposures" requirement in the hardness criterion refers to a *cumulative total* of contamination/decontamination cycles using one or more contaminants and associated decontamination processes. Normally, the five exposures should be conducted on a *single* system or item of equipment to determine the hardness criterion.

0702. Decontaminability

1. The exterior and interior surfaces of materiel developed to perform mission-essential functions shall be designed such that CBRN contamination remaining on, or desorbed or reaerosolized from the surface following decontamination shall not result in more than a negligible risk (as defined in Table 7-2) to unprotected personnel working inside, on, or one meter from the item.

2. Materiel developed to perform mission-essential functions shall be designed such that, when exposed to a neutron fluence from a nuclear detonation that results in a total dose of 3,000 cGy to the crew of the equipment, the neutron activation in the item will result in no more than a negligible risk (as defined in Table 7-2) to unprotected personnel arriving at H+2 and remaining inside, on, or one meter from the item for a period of time based on the mission profile, not to exceed 12 hours.

3. Applicable values for acceptable risk for chemical agent contamination (absorbed and desorbed) are presented in Table 7-1. The values are extracted from STANAG 4360.

4. The values for negligible risk for CBRN contamination (Table 7-2) applies to all materiel designed to perform mission essential functions.

Table 7-1. Acceptable Risk Values for Chemical Agent Contamination

Agent	Absorbed Quantity [µg/cm^2]	Desorbed quantity in 15 min [µg/cm^2]
HD	≤ 60	≤ 10
GD	≤ 12	≤ 1
VX	≤ 12	≤ 1

5. For TICs listed under STANAG 2909 the degradation of mission-essential

functions is the important factor. The toxic hazard after decontamination is negligible in comparison to chemical agents, but the values given in Table 7-2 can be used to determine decontamination effectiveness.

6. For chemical agents, the respective contamination densities are provided in Chapter 6. For biological agents and radioactive contaminants, the initial contamination levels for interiors are a factor of 10 lower to account for the protection provided by the enclosure. Toxins are treated as chemical agents and pass/fail criteria are not necessary because toxins are destroyed by the decontaminants.

7. Interior surface contamination will be limited to the exposed areas that could reasonably be expected to result from a successful surprise attack on the materiel item postured in its most vulnerable configuration, and to those exposed surfaces normally susceptible to agent transfer from a contaminated crew.

Table 7-2. Negligible Risk Values for CBRN Contamination(a)

		Vapour/Aerosol (mg-min/m^3)	**Liquid [b] (mg/70-kg man)**
CHEMICAL	VX	0.25 (0.02 for visual acuity) [c]	1.4
	GD	2.5 (0.5 for visual acuity) [c]	30
	HD	50	180 (0.01 mg/cm^2) [d]
BIOLOGICAL[e]	Bacteria (including spores) and viruses	< 1 CFU/Plaque-forming unit (PFU)	

RADIOLOGICAL[f]		**Levels of High-Toxicity alpha emitters Contamination (Bq/cm^2)**	**Levels for Beta and Low-toxicity alpha emitters (Bq/cm^2)**
	Mission Time 7 days	5	50
	Mission Time 3 months	0.5	5

NUCLEAR[g]		**(maximum of 12 hour exposure)**
	Contaminants	0.1 cGy
	Induced Activity	0.1 cGy

[a]Values are for purposes of CBRN contamination survivability design acceptance and are not to be miss-interpreted as Negligible Risk Values for chemical agents as defined in AC/225 (Panel VII) D/100.

[b] Applies to skin dose, not absorption through the eyes

[c] Applies to pilots.

[d] Since the effect of HD is localised, it is not appropriate to consider a threshold dose of liquid HD as applying to the entire 70-kg man. It is preferable the use of mass/body surface area (mg/cm^2) units to describe the dose for which negligible effects are observed. The location and surface area must be specified, such as palm of hands or the arms, since mild incapacitation depends on where the contamination exists and the extent of body surface involved.

[e] Since extremely minute quantities of some biological agents can cause incapacitation, equipment must be designed to allow no residual contamination with bacteria (including spores) and viruses after decontamination (< 1 CFU/PFU per m^2).

[f] STANAG 2473 describes the radiological contamination level acceptable to NATO forces for different types of operational times. These contamination levels serve as guidance for commanders in the field for the level of action required when operating in a contaminated environment. The levels in Table 7-2 are the lowest level that some action is required due to the contamination.

[g]It is necessary to differentiate between radiological and nuclear, because there are orders of magnitude between the estimated activities and the tolerable risks

for personnel.

8. For radioactive contamination, the contamination levels in Table 7-3 are generally higher compared to levels required for Clearance decontamination release limits. Recommendations for the initial level of contamination for the testing and evaluation of contamination survivability are based on the values separated into three categories (high, medium, low). These levels are related to both fixed and non-fixed contaminants. Fixed contaminants are considered adhered to the surface and cannot be removed by swiping the surface. The contamination can be considered fixed after two to three decontamination cycles. Non-fixed contamination is contamination that is considered removable and can be detected using swipe.

Table 7-3. Initial Contamination Levels

	Alpha (Bq/cm^2)	**Beta / Gamma (Bq/cm^2)**
High	50	500
Medium	5	50
Low	1	10

Note: The Medium Category equates to radiation exposure State Category 1A of "up to 7 days maximum" contamination limits detailed in STANAG 2473.

9. Decontamination begins 60 minutes after contamination using standard field decontaminants or simulants, equipment and procedures; and the decontamination process, excluding monitoring, should last no longer than 75 minutes which is a typical time for decontaminating items using present decontamination procedures.

10. Surface temperature is 30º C and exterior wind speed is no greater than 1 m/s (3.6 km/h) for chemical contamination/decontamination tests. Although surface temperatures of equipment in the field will frequently exceed 30º C, this temperature is optimum for assessing decontaminability because it allows sufficient contamination to remain after the one-hour sorption/weathering process. This surface temperature causes sufficient offgassing of residual agent after decontamination to adequately evaluate the decontaminability process. Requiring low airspeeds (less than 3.6 km/h) results in greater chemical agent concentrations over time.

11. For fallout after nuclear bursts, a contamination as high as 185 GBq/m^2 has to be taken into account. Knowing that decontamination to a level as low as reasonable achievable would be desirable, a decontaminability standard of 25 cGy dose per mission period is in line with guidance in STANAG 2083. This amount of fallout contamination would result in a dose rate of approximately five (5) cGy/h at one (1) m distance from a typical large armoured vehicle. Using 75 cGy as a negligible risk dose (rd) which could come from exposure over a mission profile period (maximum of 12 hours) where two-thirds are from operational exposure, such as direct radiation

from initial effects (or from fallout on the ground), and one-third from equipment contamination.

12. For the evaluation of the decontaminability of a system or vehicle after nuclear testing, non-radioactive substances with similar physical and chemical properties to nuclear fallout should be used. The total mission dose is not an appropriate criterion, because it is not directly measurable on the material and depends on a lot of different, unpredictable parameters. It is preferable to measure the dose rate in cGy/h, (or mSv/h2)[1] at 1 m distance from the system, which allows a direct statement about decontaminability and an estimation of the mission dose. The system or vehicle must not exceed a dose rate of 0.1 cGy/h (1 mSv/h) as a limit for residual contamination after thorough decontamination procedure. The gamma dose rate at 1 m distance from the contaminated item should only be used to estimate the dose individuals will obtain during decontamination procedure.

Table 7-4. Contamination Control Guidance for Up to 7-day Missions.

Radiation Exposure State (RES)	Contamination level below which RES for a 7-day mission will not be exceeded (Bq/cm²)	
	Equipment and protective clothing	
	High-toxicity alpha emitters	Beta and low-toxicity alpha emitters
Category 1 A 0.05 - 0.5 cGy 0.5 – 5mSv	5	50
Category 1B 0.5 - 5 cGy 5 – 50 mSv	50	500
Category 1C 5 - 10 cGy 50 – 100 mSv	100	1000
Category 1D 10 - 25 c Gy 100 – 250 mSv	250	2500

[1] Radiation measurements either centisievert (cSv) or millisievert (mSv) is preferred in all cases. However, due to the fact that the military may only have the capability to measure centigray (cGy) or milligray (mGy), the values are still presented in units of cGy for convenience. For whole body gamma irradiation, 10 mGy = 1cGy = 1 cSv = 10 mSv.

Category 1E 25 - 75 cGy 250 – 750 mSv	750	7500

13. A neutron induced activity dose of 0.1 cGy per mission (maximum of 12-hour exposure) is attainable for all items if reasonable attention is given to problem materials such as manganese.

14. For low level radiation (LLR) scenarios, STANAG 2473 has to be applied to evaluate decontamination. This STANAG gives mission doses and contamination limits (in Bq/cm²) for 7-day and 3-month missions in five exposure categories. Table 7-4 shows the categories for a 7-day mission.

15. It is important to stress that all decontaminability requirements pertain to deliberate decontamination actions by use of formal decontamination stations and procedures.

0703. Compatibility

1. The design of materiel developed to perform mission-essential functions shall take into consideration the combination of equipment and personnel in anticipated CBRN protection. The combination of equipment and CBRN protection shall permit performance of mission-essential operations, communications, maintenance, resupply, and decontamination tasks by trained and acclimatized troops over a typical mission profile in a contaminated environment not to exceed 12 hours:

a. In meteorological conditions of areas of intended use.

b. With no degradation, excluding heat stress, of crew performance of mission-essential tasks greater than 15 percent below levels specified for these tasks when accomplished in a non-CBRN environment.

0704. Analytical Procedure

1. The requirements to use during analytical procedures for test data are depicted in Figures 7-1, 7-2, and 7-3, as they apply to acceptance criteria and protocols.

2. **Decontaminability:**

a. Figure 7-1 illustrates that a contaminated item must be capable of being decontaminated to a negligible risk level within one hour of task initiation to allow the user to perform human essential tasks and functions. The decontaminants and decontamination procedures must be available in the field for the complete decontamination effort. The term “negligible risk value” refers to a level of contamination at which there is negligible risk to unprotected personnel working inside, on, or one meter from the item. For small items the decontamination time allowed is ½ hour. The operative parameter is the

mission essential time since the equation used in the evaluation is ct = k, c = the measured desorption concentration, and t = the mission time.

b. For a shorter mission time (in which the unprotected user is exposed), the permissible desorption concentration may be higher than that of another mission where the exposure time is greatly increased. In some instances the standard decontamination methods must be altered to enable achievement of acceptance standards. This altering is acceptable and encouraged but attention must be paid to ensure the modified procedures are documented for implementation upon fielding of the item.

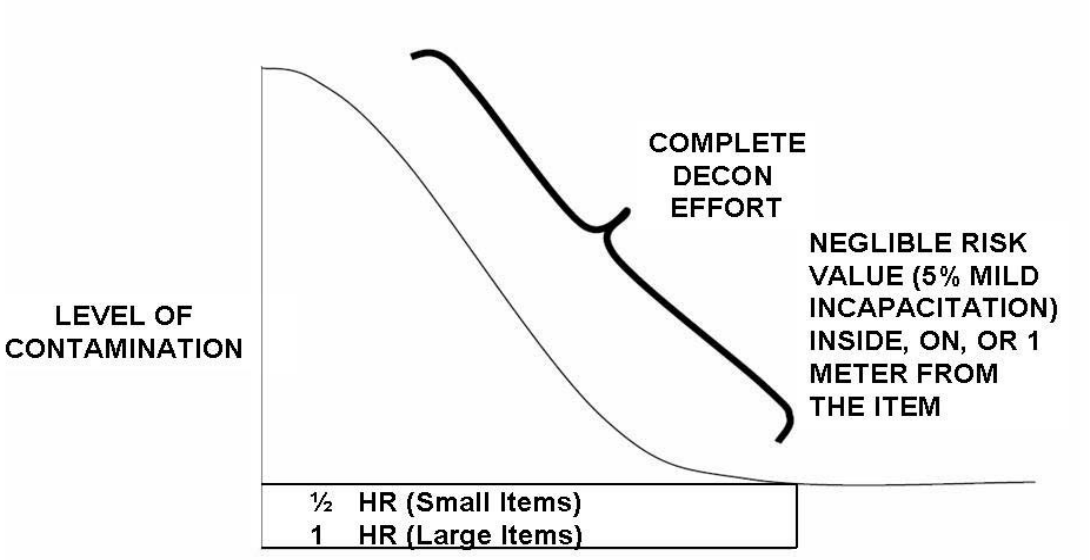


Figure 7-1. Decontaminability

3. **Hardness:**

a. The hardness requirement is shown graphically in Figure 7-2. Mission essential (or critical) equipment are hardened to ensure that degradation over a 30-day period, after five exposures to CBRN agents and decontaminants, are no more than 20 percent (or other value designated by the combat developer based on approved rationale) in selected quantifiable essential characteristics of RAM standards.

b. For an item to meet the acceptable standard, the mission essential performance characteristics must be compared with pre- and post-exposures degradation. As an example, if voltage output were a mission essential characteristic for a power source, the output would be measured before

exposure and all subsequent measurements made after each exposure, and then compared to the baseline. These parameters must be measured after 30 days to properly address the hardness criterion.

4. **Compatibility:**

a. The compatibility criterion is depicted in Figure 7-3. This requirement is analyzed by measuring mission essential task executions done by a soldier while wearing the standard protective IPE uniform and then while in each higher level of protection, up to the dress state 4 level. The results of timed exercises in which mission tasks are performed are compared to address this aspect of CBRN contamination survivability.

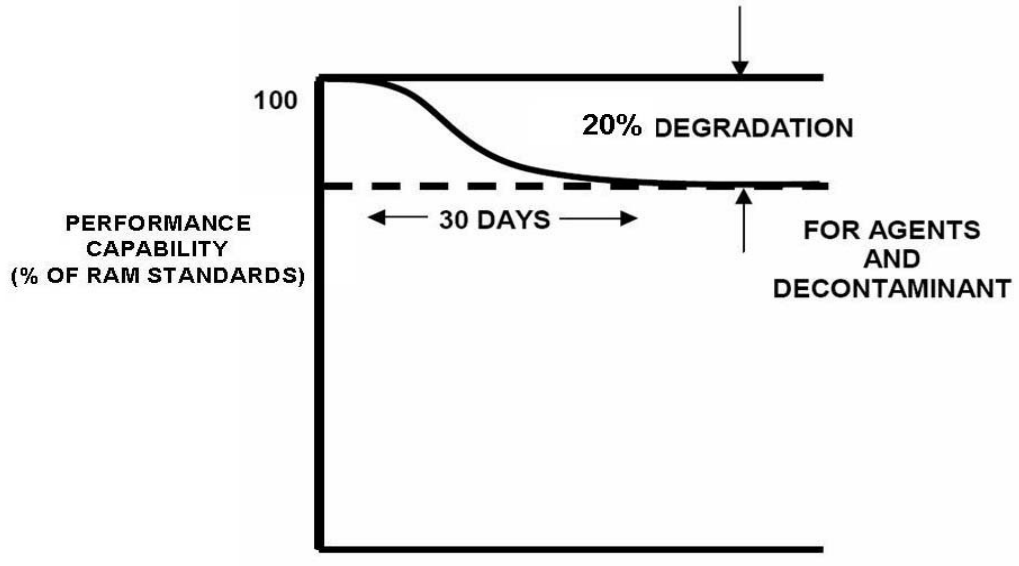


Figure 7-2. Hardness

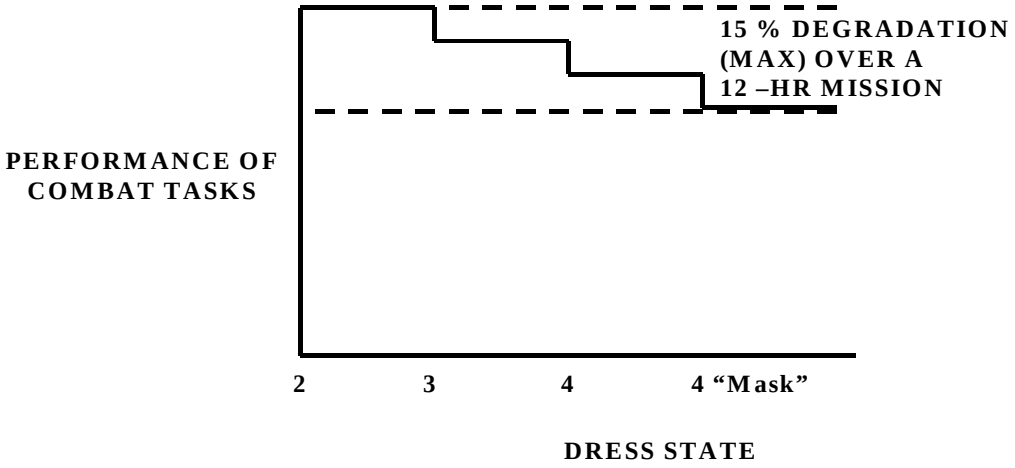
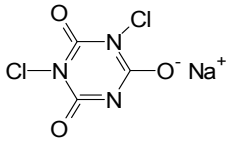
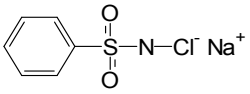


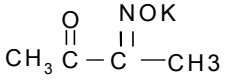
Figure 7-3. Compatibility

b. The design of mission-essential equipment and materiel must take into consideration the combination of equipment and existing or anticipated CBRN protection. The combination of equipment and CBRN protection must permit performance of mission essential operations, communication, maintenance, resupply, and decontamination tasks by trained and acclimatized troops for a typical 12-hour mission profile in a contaminated environment. This must be done with no degradation of crew performance greater than 15 percent below levels specified for tasks accomplished in a non-CBRN environment. For instance, the compatibility criterion measures if a soldier wearing gloves can perform dexterity tasks involving pushing buttons or using their hands and fingers. Or, it determines if a soldier wearing hood and mask can read labels or see clearly and how much degradation is caused due to the protective clothing when a human and system interact in a 12-hour mission.

ANNEX A – CBRN DECONTAMINANTS

Table A-1. Decontaminants Sorted by Chemical Category

Category	Active Component	Structure	Commercial Decontaminant
Chlorine-based	Sodium hypochlorite (common bleach) Calcium hypochlorite (chlorinated lime or bleaching powder)	$NaOCl$ / $Ca(OCl)_2$ (active ions: OCl^-)	- Super Tropical Bleach (STB) - High Test Hypochlorite (HTH) - Activated Solution of Hypochlorite (ASH) - Self Limiting Activated Solution of Hypochlorite (SLASH) - C8 emulsion (Kärcher, Germany
Chlorine-donor	*Sodium N,N*-dichloroisocyanurate (NaDCC, Fichlor)		- BX24 (Cristanini S.p.A., Rivoli Veronese, Italy) - CB emulsion (OWR, Elztal-Rittersbach, Germany) - CASCAD®/SDF (Allen-Vanguard, Canada)
Chlorine-donor	Chloramine-B/T		- M258, M258A1 and M280 Skin Decontaminants (Tradeways Ltd)
Peroxide	Hydrogen peroxide	H_2O_2	- EasyDECON (Intelagard, USA) - MDF 200 (Modec, USA)

Category	Active Component	Structure	Commercial Decontaminant
			- Decon Green (ECBC, USA; not yet commercial available)
Peroxide	Peracetic acid	$CH_3CO(OOH)$	- Wofasteril - BDS2000 (Kärcher, Germany), Q200 Quadrimex, France
Peroxide	Potassium peroxymonosulfate	$KHSO_5$	- Oxone (Dupont) - L-Gel (LLNL, USA), not yet commercially available
Alkaline hydrolysis	Alkoxides (strong base in organic solvent)	$R\text{-}O^-$	- DS-2 - GDS2000 (Kärcher, Germany) - GD-5/6 (OWR, Germany)
Oxime	2,3-butanedione monooximate		- RSDL® (E-Z-EM Inc., USA)
Reactive gas	Ethylene oxide	C_2H_4O	
Reactive gas	Chlorine dioxide	ClO_2	
Reactive gas	Vapourized hydrogen peroxide (VHP)	H_2O_2	
Reactive gas	Modified vapourized hydrogen peroxide (mVHP)	H_2O_2 and NH_3	- mVHP (STERIS, USA)
Reactive gas	Paraformaldehyde	$H\text{-}[CH_2O]_n\text{-}OH$	

Category	Active Component	Structure	Commercial Decontaminant
Reactive gas	Ozone	O_3	
Reactive gas	Methyl bromide	CH_3Br	
Metal oxide particles	Aluminum, sodium	AlO	M100 SDS (Guild Associates Inc., USA)
Metal oxide particles	'Nanoactive' titanium dioxide and magnesium oxide	TiO_2, MgO	FAST-ACT (NanoScale Materials Inc., USA)
Enzymes	For example: Organophosphorous Hydrolase (OPH) and Organophosphorous Acid Anhydrolase (OPAA)		DEFENZ (Genencor, USA) All-Clear (Kidde Firefighting, USA)

Table A-2. CBRN Decontaminants Currently Used by Military Forces in NATO and PfP Countries

Country	Decontaminant in Use
Belgium	TDE 202, GDS 2000, RSDL®, DS-2, Calcium Hypochlorite, Sodium Hypochlorite
Canada	Sodium Hypochlorite, CASCAD®, RSDL®
Czech Republic	Desprach (Bentonite), Neodekont [abrasives, anionic surfactants, supplementary Manox (alcohol), Hydrogen Peroxide, Chlorohexidine Gluconate], OR3 (Alcohol, Amines, Alkoxides), Decon Emulsion (10% Calcium Hypochlorite in water, solvents, emulsifiers), ODS5 (surfactants, Monoethanol Amine, Butyl Alcohol), 2% Calcium Hypochlorite in water.
France	Q2000 (Peracetic Acid)), SDCMF2 (calcium hypochlorite), Fullers earth, water under pressure.
Germany	German Emulsion, Calcium Hypochlorite, RSDL®, BDS2000, GDS2000, RDS2000.
The Netherlands	RSDL®, GDS2000, CB emulsion and GD-5.
Norway	DS-2, NBC-SANATOR, Fuller's earth, caustic soda, chloride of lime, universal mixture (aqueous solution of 10% caustic soda and 10% chloride of lime), chloramine-T, isopropanol and non-synthetic soap.
Spain	BX 24, RM-21, RM-31, RM-54, RM 55, Sodium Hypochlorite.
Sweden	High pressure hot water, water and soap, GD2000, DS2 (with limitations), CASCAD (limited use), Virkon S, RSDL® (PS105), Dutch Powder (PS104), Chloride of Lime.
United Kingdom	Fuller's Earth, CAD (Sodium dichloroisocyanurate), TDE 202, BX 24, soapy water, 5% Calcium Hypochlorite.
United States of America	Decon Foam (DF) 200, Super Tropical Bleach, EasyDecon, calcium hypochlorite (HTH), hot soapy water, Soap and detergents, RSDL®, M295 and M291 decon kits, M100 SDS sorbent powder.
Latvia	Calcium Hypochlorite, Alkylaryl Sulfonates, Lysoformin 2000.
Hungary	TDE 202, RM 21, RM 35, Calcium Hypochlorite, GDS 2000.

ANNEX B - CHEMICAL AND BIOLOGICAL CONTAMINATION SURVIVABILITY OF AIR FORCE SPECIFIC MATERIAL (AIR FORCE ANNEX)

B1. General

1. The goal of this Air Annex to AEP-7 is to provide guidance to the Air Force to enhance their ability to accomplish their missions in a CBR-contaminated environment by application of CBR contamination survivability factors on Air Force specific material. This Air Annex to AEP-7 is aimed at identifying the necessary CB hardening on Air Force specific material and design features. The basis of the main document for material selection and design criteria is still valid. This standard may apply to any other military aviation asset.

2. These guidelines are provided to ensure the capability of an aircraft (A/C) system to withstand a CB-contaminated environment, including decontamination, without losing the ability to accomplish the assigned missions. This includes also all flight safety requirements. Flight- and mission-essential material groups exposed to the effects of CB incidents and involved in operation activities are also areas of consideration because they give rise to cross-contamination and residual hazard to personnel after decontamination.

3. This Annex deals only with special requirements for A/C as they are the most vital elements of Air Force specific material. General findings and requirements in this Annex need careful consideration during the development of non-flying equipment.

4. Methodology for hardness and decontaminability tests for material selection during the development phase and for product assurance purposes will be provided. Redundancy and resupply of items cannot be the reason for ignoring hardening measures because these items may also become contaminated. Materiel developers can contribute considerably to alleviating the operational and logistical burden caused by contamination. CB contamination survivability requirements must be taken into account in the initial phases of development.

5. The prospects of a successful retrospective hardening of material that have already been introduced into the forces are poor. Likewise, it is not feasible to harden equipment retrospectively by changing its design.

B2. Chemical and Biological Hardening Strategy

1. In order to achieve effective and complete CB survivability of Air Force specific material, it is necessary to proceed in accordance with the following objectives:

   a. Guidelines for hardening measures must be applied to all mission-essential equipment of NATO Air Forces being used for air base or off-base operations.

b. Hardening guidelines have to be provided in detail to Army aviation and Navy aviation forces.

c. CB survivability factors have to be applied to material from the start of the conception phase. In flight- and mission-essential material groups which are exposed to BC agents can not be hardened, other measures like covering, use of CBRN-filters, etc. have to be developed/implemented.

d. Performance levels of materials for CB contamination survivability must be subjected to periodical review to take into account advances in material technology, improved equipment design and decontaminants technology.

e. During research and development of Air Force specific material, developer activities must be monitored to determine whether material meets the hardening requirements.

f. A/C construction companies have to carry out hardness and decontaminability tests within the boundaries of national restrictions in order to certify CB survivability of processed materials. Appropriate simulants are made available for quality assurance testing (see Para 5.1.4).

g. The appropriate project authority in conjunction with the A/C design authority is required to establish programmes for quality acceptance and inspections which are to include CB contamination requirements.

B3. Parts of A/C Structure Requiring Chemical Hardening

1. The items, requirements, and considerations in this chapter were evaluated and developed by using three typical existing A/C types (fast jet A/C, transport A/C and helicopters) widely employed throughout NATO. Each A/C type was evaluated with regard to mission, system specific considerations, construction of the A/C, sequence of operations for A/C inspections, cross servicing, loading and unloading processes and properties of the materials/coatings. The detailed design of the A/C must be considered already on the drawing board, including its systems and subsystems, bay layouts and functional characteristics. From this a baseline hardening standard can be identified and agreed with the customer, against which the requirements can be compared.

2. Items involved in operational turn-round (OTR) and other inspections.

3. This list summarizes relevant A/C-inspections and maintenance activities, but does not imply any specific sequences or A/C type and is not exhaustive:

Table B1. Relevant A/C-Inspections and Maintenance Activities

Item	Special Consideration
(a) External intercom connector	Protective cover required but easily opened whilst wearing IPE by use of a

	universal flap/door opening tool
(b) Areas dealing with ground safety - Auxiliary air door braces - Control indicators and maintenance data panels - Cables and umbilicals - Wheel chocks - Rotor tie down - Ground lock devices and blanks (covers)	Prevent or minimize contact or transfer hazard; consider use of disposable overgloves.
(c) Compartments for SLAR, IR-, image and video cameras	One-way ventilation sealing recommended, protective cover required but easily opened whilst wearing IPE by use of a universal flap/door opening tool; consider use of disposable gloves
(d) Zones requiring operational decontamination (1) Entry, exit and loading areas - Cockpit - Gasket and - Sealing compound - Frame - Bullet-proof windscreen - Canopy - Cargo loading doors/ramps for supplies, troops and casualties (2) Weapon system areas - External weapon stations (underwing/bottom fuselage/stub wing) - Bombs - Rockets - Missiles - Dispensors - Torpedoes - Guns/canons - Internal weapon stations - Bomb bays - Guns/canon compartments - Sonobuoy - Dunking sonar	Follow guidelines in document AC/225 (Panel VII/ASP) D/28 - Special sealing compounds - Agent resistant canopy material - Agent resistant seals - Access handles either protected or easily decontaminated - Agent resistant seals to prevent any ingress of liquid agent and contaminated dust - Access handles either protected or easily decontaminated - Ramps and load floors easily decontaminated - Weapon pylons, including connectors and electrical/pyrotechnical/explosive release mechanism constructed to be easily accessible, to be operable whilst wearing IPE and non-hazardous to the operator - Effective agent resistant seals - Easily accessible, operable whilst wearing IPE and non-hazardous to the

- Other stations - Chaff compartment - Flare boxes - ECM pods - Sonobuoy compartment - Recce pods	operator - Effective agent resistant seals - Easily accessible, operable whilst wearing IPE and non-hazardous to the operator
(3) Refuelling and POL apertures / ports and replenishment	
- POL, including exterior fuel tanks - In-flight refuelling probe - Hydraulic fluids - Other fluids - Liquid oxygen - Drinking water - Other gases	- Agent resistant seals - Easily accessible, operable whilst wearing IPE and non-hazardous to the operator - Replenishment points to be protected by a cover preventing agent ingress - Closed line replenishment
(4) Inspection areas - Flaps, doors and other openings including panels and gauges	
(5) Engine - Air intake/first stage compressor/inlet guide vanes - Propeller - Helicopter rotor/blades/lag dumpers - Drive train - Auxiliary power unit - Ram air intakes and cold air units - Oil / air coolers	- Effective agent resistant seals - Easily accessible, operable whilst wearing IPE and non-hazardous to the operator. - Installation of splash deflectors on landing gear to avoid pickup of contamination - Secondary air intake route for taxiing - Selection of agent resistant materials
(6) Airborne refuelling dispensers	- Agent resistant seals - Easily decontaminated, operable whilst wearing IPE, non-hazardous to the operator - Agent resistant seals and materials

Table B2. Other A/C Equipment
(Avionics, Electronics, Hydraulics, Pneumatics and Others)

(a) Avionics - Aviation equipment	- Electronically inert special agent resistant coating

- Electronic compartments/parts - Ground reprogramming and data input/output ports	- Encapsulation of electronic devices - Protection against contamination - Use of agent resistant materials
(b) Cooling systems	- Cooling and cockpit air supply must be chemically filtered
(c) Hydraulic and lubrication systems	- "Closed"-system/leak free - Agent resistant seals
(d) Fuel systems	- Avoid fuel contamination of structure to reduce incidences of agent pick up.
(e) Pneumatics	- Chemical hardening/resistance of material against agents and decontaminants.

B4. Materials Used on and in the A/C Structure

1. The following table summarizes typical materials used in the construction of existing NATO A/C but it is not exhaustive.

Table B3. Typical Materials Used in the Construction of Existing NATO A/C

A/C Component/Part	Type of Material

(a) Paint systems/surface coatings	- Wash primer
	- Primer
	- Finish
	  - Alkyd resin paint
	  - Acrylic paint
	  - Polyurethane paint
	  - Epoxy paint

(b) Tyres of undercarriage wheels	- Blend of natural rubber and styrene-butadiene rubber, butyl rubber

(c) Cockpit windows/canopies	- Bullet-proof glass
	- Polymethyl methacrylate
	- Polycarbonate
	- Coating:
	  - Polysiloxanes
	  - Polyfluoro siloxanes
	  - Silicon dioxide

(d) Gaskets for flaps, hatches, doors and cockpit canopy	- Various types of elastomers, fluorinated rubbers
(e) Sealed joints	- Silicone or other sealants
(f) Radome	- Composites and ceramics coated with antistatic paints.
(g) Tapes on front edge of A/C wings and fins and leading edges of rotor blades	- Teflon tape, A/C fabrics.
(h) Antennae	- Composites with anti-static paint.

(i) Structural material	- Titanium, magnesium, aluminum, stainless steel and other alloys and composites (thermoset and thermo-plastics) with chemical and decontamination resistance.
(j) Electronic parts	- Coatings
(k) Cockpit interior	- Cloth, leather, fabrics and various synthetic materials.
(l) Cargo bay and load ramps	- Metal alloys, various synthetics and fabrics.
(m) Optronics	- Germanium, gallium arsenide, optical glass, coatings, adhesives and seals.

B5. Testing Methodology to Certify Chemical and Biological Contamination Survivability of Air Forces Specific Material

1. **Preconditions for Comparable Test Results:**

a. Test Sample Specifications.

(1) The shape and size of test samples are primarily dictated by material-specific requirements of the individual test methods, particularly in the case of hardness testing. Thus, test sample measurements are integral parts of the test instructions. Emphasis must be placed on the fact that for achievement of comparable test results, it is required that the sample history, such as the way of preparation and the manufacturing process, corresponds to that of the actual fielded material. The selection of test samples for decontaminability tests must be based upon the mission-specific use of materials. This additionally affects the method of contamination, decontamination (see 5.1.2), and the determination of residual hazard. Shape, size and preparation of test samples are incorporated into agreed NATO documents, like STANAG 4360 - SPECIFICATIONS FOR PAINTS AND PAINT SYSTEMS RESISTANT TO CHEMICAL AGENTS AND DECONTAMINANTS FOR THE PROTECTION OF AEROSPACE EQUIPMENT). As long as similar documents do not exist for other classes of material like plastics, elastomers, adhesives and sealants, guidance must be taken from the above-mentioned STANAG.

(2) As a general guideline, concern must be taken to ensure as much similarity as possible among material characteristics of the manufactured item and those of the test samples. For some types of material, especially polymers, it may also be necessary to condition samples by accelerated or natural ageing.

(3) Whenever this Air Annex to AEP-7 does not specify the testing procedure explicitly, testing criteria could be taken from AC/225(LG/7) D102, biological attachment.

b. Initial Levels of Contamination:

(1) In order to develop air force equipment with an adequate hardness platform and exhibiting actual ranges of residual risk, contamination levels on test samples must be mission-related. Exterior surfaces are initially uniformly and separately contaminated with:

- 2 g/m^2 of thickened GD (normal coverage)

- 10 g/m^2 of thickened GD (exceptional coverage) as worst case

- 10 g/m^2 of thickened HD (exceptional coverage)

- 2 g/m^2 of unthickened VX (normal coverage) at same droplet size as GD

- 10 g/m^2 of unthickened VX (exceptional coverage) as worst case

- 10 g/m^2 of unthickened HD (normal coverage)

- 10 g/m^2 of unthickened GD (exceptional coverage)

- 10^5 spores/m^2 of biological simulants 1-5 µm in size

(2) Distribution:

- Unthickened agents: 1 µl droplets

- Thickened agents with 10% Parlon S300, or 4% K125 (Röhm & Haas), 2 g/m^2 likewise in approximately < 20 droplets of 2-5 mm in diameter.

(3) The degree of contamination of interior surfaces must be determined by experimentation.

(4) It is important that the area of liquid contact is controlled, or at least recorded to be able to compare data and to make predictions for cases with different coverage or spreading. The application of far higher contamination levels on test samples may be desired to achieve a sharper segregation among different candidate materials. Other means of contamination, such as by chemical agent vapour or aerosol or co-condensation, are possible and may have to be considered.

(5) Contact times of contamination on the test samples may range from 1 to 48 hours or more. Other test conditions such as temperature or humidity have to be specified, and must correspond to the envisaged use of the material in a mission.

c. Methods of decontamination:

(1) Many decontaminants have damaging effects on material. Due to differences in decontamination policies and decontaminants used in the individual NATO countries, no common method of test sample decontamination can be established. It makes sense to use national decontamination methods in order to record the relevant data for material damage caused by the specific decontaminants and to identify the efficiency of decontamination by determining the residual risk. Nevertheless, because of the need to standardize operations, the decontamination methods of all NATO nations must be included in CB hardening considerations.

(2) "Soft" decontaminants must be incorporated to allow a broad variety of candidate materials.

(3) During hardness testing, the exposure to CB agents will not be terminated by chemical elimination, but by physical removal of the test substance by use of solvents, e.g. isopropanol, and a rinse with water.

d. Use of simulants:

(1) If available, simulants must be used instead of chemical agents. This would enable industrial developers of plastics, elastomers etc., to qualify new materials with regard to hardness and decontaminability criteria. Moreover, simulants may allow easy and rapid product assurance tests without the restrictions associated with using CB agents.

(2) Unfortunately, simulants generally are not applicable to more than one combination of material and CB agent, unless the respective test results would be corrected individually using proper conversion method (e.g. correlation coefficients, formulae or procedures). This considerably limits the present usefulness of simulant testing. More research work is required before the general use of simulants can be used to support decision making.

e. Residual risk. Acceptable levels of residual risk can vary depending on the type of equipment, location of contamination, and the tactical use of the equipment. The basic levels or values are in STANAG 4360.

2. **Developmental test methods**

a. Hardness Criteria and Tests. The allowable criteria are defined by the technical function of the material. The degradation is usually expressed as a percentage of property change. The allowable percentage may differ with each group or even type of material. An "accumulative hardness test" may consist of three or more contamination and/or decontamination cycles conducted within five days to simulate typical air force missions. However, certain critical items may require a higher number of contamination/decontamination cycles.

(1) Test on Plastics and Fibre Composites. Plastics and fibre composites are mostly used for structural components of an A/C. Therefore, it has to be assured by specific test procedures that these materials are not undesirably affected in their properties by CB agents and decontaminants. During all phases of CB agent exposure and following the application time of decontaminants on materials, visual signs of material damage like swelling, discolouration, dissolving, clouding of the surface or the absence of such effects are recorded.

(2) Chemical Agent Absorption/Permeability Test. The ability of permeable materials to absorb chemical compounds is a quality parameter, which may be determined as follows: The test specimen is contaminated with a liquid agent according to paragraph B5.1.b for a given time. Thereafter, unabsorbed chemical agents are removed and the quantity of absorbed agent is determined either by mass balance or, after solvent extraction or vapour desorption from the test sample by gas chromatography (GC) or thin layer chromatography (TLC). Various national test procedures are available. There is an urgent need for standardisation of absorption tests, because of large differences in national testing procedures.

(3) Material Testing. The degree of degradation of material properties caused by CB agents is determined by different material testing procedures. To perform these tests, the test samples are contaminated according to paragraph B5.1.b. After removal of agent according to paragraph B5.1.c or of the decontaminant surplus from the sample surface, the mechanical and/or functional tests are performed. Parts that are challenged dynamically shall be tested by imposing an oscillating load to the specimen. The following test procedures are available:

(a) Stress cracking test

DIN 29 971

(b) Tensile strength, Elongation at break, Modulus of elasticity

ISO 37-94

DIN 53 504-94

ASTM D 638-02

(c) Durometer hardness

ISO 868-85

DIN EN ISO 179-1

ASTM D2240-02

(d) Impact strength

DIN EN ISO 179-1/-2

ASTM D 256-02

(e) Bending strength

DIN EN ISO 178-02

DIN 53 452-04/77

(f) Weight and dimension change

ISO 175-99

ASTM D 543-95

(g) IR and RADAR characteristics

Test similar to STANAG 2338

(h) Test for surface hardness

DIN EN ISO 6507-1/-2

(4) Transparencies. Transparencies are normally affected by chemical agents and organic solvents used in decontaminants. Such effects include swelling, hazing, crazing or changes in optical properties. Evaluation test for transparencies include the following methods:

(a) Visual observation

(b) Chemical agent absorption

Procedure according to national test methods (See paragraph B5.2.a(2))

(c) Weight and dimension changes

ISO 175-99

ASTM D 543-95

(d) Light transmission and haze

ASTM D 1003-00

FTM 406/3022

MIL P 8184-02/89

(e) Stress cracking

ISO 6252-92

DIN EN ISO 179-1

(f) Impact strength

DIN EN ISO 179-1/-2

ASTM D 256-02

(g) Durometer hardness

ISO 868-85

ASTM D 2240-02

ASTM D 785-98

(h) Bending strength

DIN EN ISO 178-02

(i) Infrared transmission test

BS EN 1836-97

(j) Glass transition temperature

ISO 6721-1

ASTM D 3418-99

(5) Paints and coatings. Paints and coatings are used to protect material, like composites or metals, from meteorological influences, corrosion, aggressive chemicals or other pollutants. The following test methods for paints and coatings are available:

(a) Visual observation

STANAG 4360

ASTM D 660

ASTM D 661

ASTM D 714

ASTM D 1729

(b) Absorption of chemical agents, penetration

STANAG 4360

ASTM D 471

(c) Brightness

ISO 4628/1-82

DIN 53230-04/83

(d) Erichsen cupping test

ISO 1520-99

(e) Cross cut adhesion test

ISO 2409-92

DIN EN ISO 2409-94

BS 3900

(f) Conductance test

MTL-W-81 381 A

(g) Wettability

Measurement of surface tension

Rame-Heart goniometer method

(h) IR and Radar characteristics

STANAG 2338

(i) Film hardness test

ASTM D 3363

(6) Adhesives and sealants. All known adhesives and sealants absorb chemical agents to a certain extent. This alters the mechanical properties of the adhesives and sealants. The following evaluation tests are applicable:

(a) Visual observation

(b) Peel resistance

ISO 36-99

DIN 53530-02/81

ASTM D 1876-01

ASTM C 794-01

(c) Tensile strength

DIN EN ISO 26922-93

ASTM D 624-00

(d) Tear resistance

DIN EN ISA 1465-95

ASTM D 624-00

(e) Wedge test

DIN 65 448-01/88

ASTM D 3762-98

(f) Swelling test

Weight and dimension change

(7) Elastomers. Elastomers used in aircraft construction, including tyres and hydraulic hoses, can be exposed to both liquid and vaporous CB agents. Chemical agents and organic solvents are easily absorbed by elastomers, thereby increasing their volume and adversely affecting their mechanical properties. The following test procedures are available:

(a) Visual observation

(b) Chemical agent adsorption/penetration

(See paragraph B5.2.a(2))

(c) Weight and dimension changes, resistance to liquids, vapours and gases

ISO 1817-99

DIN 53 521-11/87

ASTM D 471 –98

(d) Tensile strength, elongation at break, modulus of elasticity

ISO 37-94

DIN 53 504-94

ASTM D 412a-98

(e) Durometer hardness (Shore A/D)

ISO 868-85

DIN 53 505-00

ASTM D 2204-02

(f) Tear resistance

ISO 34-1-94

DIN 53 507-03/83

DIN 53 515-90

ASTM D 624-00

(g) Resistance to flex cracking and crack propagation

ISO 132-99

DIN 53 522-01/79

(h) Compression set test

ISO 815-91

(8) Metals / Alloys. Metals and alloys are agent- and solvent-proof. They are only subject to corrosive effects, if their coating is insufficient or not present. Applicable test methods are the following:

(a) Visual observation

(b) Weight change

(c) Corrosivity

(i) Coated surfaces: DIN 50 928/4-09 85

(ii) Uncoated surfaces: DIN 50 930/4-93

(9) Miscellaneous A/C parts. (Electronics, fibre-optics).

(a) Impedance test

(b) Conductivity test

b. Decontaminability Tests. The aim of decontaminability is to facilitate decontamination efforts, thereby reducing the residual hazard. Since the principal benefit of decontamination is to allow personnel to reduce their level of protection, decontaminability criteria must be related to the physiological response of unprotected personnel to CB agents. More precisely defined, criteria for decontaminability are related to toxicity data. For instance, agent concentration dosage levels corresponding to acceptable incapacitation of unprotected personnel. Both vapour and contact hazard have to be considered. There is an urgent need to correlate decontaminability test data of material with physiological effects to allow evaluation of these data in the context of residual risk under operational conditions.

(1) Desorption Test Method. To determine decontaminability of a non-metallic material, the quantity of agent desorbing from the test sample following decontamination is measured as a function of time, while keeping the air flow rate and temperature constant. Contamination level and contact time refer to paragraph B5.1.b. The subsequent decontamination procedure of the test sample is carried out according to national test requirements. The aim is to use standardized contamination and decontamination procedures in the future. For the evaluation of the analytical data, obtained by desorption measurements, agreed criteria are to be defined, which are correlated with the negligible risk under circumstances similar to mission-essential conditions. There are two main methods:

(a) Desorption Via Gas Phase. The test method to measure the agent desorbing from the sample is similar to that used in various laboratories termed “liquid droplet test method for permeation test”. The test sample is fixed in a test cell to allow a dried and filtered air stream to take the desorbing vapours to a sampling unit, e.g. bubbler or Tenax tube. The air is drawn over the surface of the test sample at specified air speed on the sample surface, volumetric flow rate, temperature and desorption rate as a function of time. Thereafter, the sampled air is analyzed by standard analytical methods.

(b) Desorption by Contact. A piece of adsorbent – such as silica gel or silicant foil – with a defined area is attached to the surface of the decontaminated test sample with defined pressure and contact time and at a defined temperature. Thereafter, the absorbent is extracted with a solvent and the extracted chemical agent analyzed as above. Special consideration must be given to decontaminability testing of design features by using specific test methods. For the elaboration of such test methods, orientation may be taken from various national real-scale decontamination techniques.

3. **Chemical and Biological Compatibility considerations**. The ability of a system to be operated, maintained, and resupplied by personnel wearing the full CBRN protective ensemble is termed “compatibility”. A piece of air force equipment which is hardened against CB agents and decontaminants must be effectively operable in a CB contaminated environment. Thus, there is an obligation during the development phase to consider the design of the equipment and its usage by personnel wearing IPE. The ideal measurement of compatibility is the performance degradation of crew members undertaking mission-essential tasks in a CB contaminated environment. Influencing parameters include the time wearing IPE and environmental conditions such as temperature, humidity and the time of day. Because of possible incomplete decontamination, additional protective measures and procedures may be required. Such measures and procedures must also meet compatibility requirements.

4. **Product assurance test (verification methods)**. For material selection, a great variety of test methods are available (see paragraph B5.2). To verify product assurance, only a few of these test procedures are essential. The following selection is proposed:

a. Plastics/composites

Stress cracking test DIN 29 971

b. Transparencies

Light transmission and haze ASTM D 1003-00

Impact strength DIN EN ISO 179

c. Paints and coatings

Visual observations STANAG 4360

Erichsen cupping test ISO 1520-99

d. Adhesives and sealants

Tensile strength DIN EN 26922-93

Peel resistance ISO 36-99

e. Elastomers

Tensile strength ISO 37-94

f. Metals/Alloys

Corrosivity test DIN 50 928/4-09/85

DIN 50 930/4-93

B6. Databases for Chemical and Biological Contamination Survivability of Materials

1. The following factors must be taken into consideration:

a. Databases are essential for storage and referencing of the collective knowledge of and use by the participating nations.

b. Access to databases for all NATO nations is desirable.

c. Procedures must be established to standardize the input/output of data and data interrogation.

d. National agencies could be identified and promulgated as focal points for collection, collation and transfer of data.

ANNEX C - THE NINE FAMILIES APPROACH

C1. The Nine Families Approach

1. TICs pose a challenge to decontamination, and therefore during the development of new decontaminants and/or systems it is important to ensure that the corresponding capabilities are in place. In order to allow both industry and the Armed Services to reduce testing of new decontaminants and decontamination systems to a justifiable degree, the voluminous list of TICs has been short listed to include only relevant representatives of the whole ensemble. The two lists below contain substances of relevance to NATO troops and have been used to develop the nine families approach.

2. **ITF-40 List**. The "ITF-40" (International Task Force[3]-40) list uses a matrix where chemical substances are awarded scores with respect to the consequences of an incident involving the respective substance and the probability of such an incident to happen. The list below shows individual scores added up to a total; the higher this total is, the higher the substance is ranked.

Table C-1. Consequences of an Incident Involving the Respective Substance

Hazard	Impact	Hazard Score
Catastrophic	Loss of ability to accomplish the mission or mission failure	13-16
Critical	Significantly (severely) degraded mission capability or unit readiness	8-12
Marginal	Degraded mission capability or unit readiness	4-7
Negligible	Little or no adverse impact on mission capability	0-3

Table C-2. Probability of Such an Incident to Happen

Probability	Description	Probability Score
Frequent	Occurs very often, continuously experienced	10-12
Likely	Occurs several times	7-9
Occasional	Occurs sporadically	4-6
Seldom	Remotely possible; could occur at some time	1-3
Unlikely	Can assume will not occur, but not impossible	<1

[3] http://chppm-www.apgea.army.mil/desp/pages/jeswg/4QFY01/itf-40-2US.ppt

3. **CSG List**. Table C-1 shows the “CSG list” of TICs that pose a considerable hazard to NATO troops by Challenge Subgroup to JCG-CBRN. This list is more oriented towards classical military threats.

4. **Synopsis**. The 9-families-approach presented by HMSG joins those two lists and ranks the substances according to the challenge they pose to the decontamination process. For instance, gases due to their volatility do not pose a challenge for decontamination and hence are eliminated from the HMSG-list. The remaining substances are put in families according to the property actually imposing the main threat. For instance, wherever the main threat of an acid is its acidity, it is represented by sulphuric acid in the HMSG list. To complete the listing approach, a single chemical from each family is chosen to act as a representative for the whole group during the evaluation of a new decontaminant or decontamination process.

Table C-3. Assignment of ITF-40/CSG TICs to the HMSG Nine Families

TIC	Principal Hazard	MP (ºC)	BP (ºC)	Vap. Press (mm Hg)	ITF-40	CSG-List	In HMSG "9 Families-Approach" Represented by	Rationale
Nitroglycerine (Desensitized)	Instability	13.5	256	0.00026	X		Acrylonitrile	Toxic org. solvent, similar decon approach
Nitroglycerine	Instability	2.8	125		X		Acrylonitrile	Toxic org. solvent, similar decon approach
Parathion (in Compressed Gas Mixtures)	Toxicity	6	375	$3.78X10^{-5}$ @20C	X		Parathion	
Benzene	Toxicity	5.5	80	95.2 @25C	X		Acrylonitrile	Toxic org. solvent, similar decon approach
Methane	Flammability	-182.5	-164		X		none	1
Ethane	Flammability	-183.3	-88.6		X		none	1
Ethylene	Flammability	-169.2	-103.7		X		none	1
Acetylene	Flammability	-80.8	-84.0		X		none	1

TIC	Principal Hazard	MP (ºC)	BP (ºC)	Vap. Press (mm Hg)	ITF-40	CSG-List	In HMSG "9 Families-Approach" Represented by	Rationale
Methylamine (Anhydrous)	Flammability	-93.5	-6.3	2249.6 @20C	X		none	1
Hydrogen Cyanide	Flammability, Toxicity	-13.4	25.6	620@20C	X		none	1
Propane (Liquefied)	Flammability	-189.7	-42.1		X		none	1
Chloroethylene (Vinyl Chloride)	Flammability	-153.8	-13.4	2500 @20C	X		none	1
Carbon Disulphide	Flammability Explosive	-111.6	46.5	297.4 @20C	X		Carbon Disulphide	
Ethylene Oxide	Flammability Explosive	-112.5	10.4	2937 @20C	X	X	none	1
Isobutene	Flammability	-140	-6.9	2016.9 @21.1C	X		none	1
Trimethylamine (Anhydrous)	Flammability	-117.2	2.87	1448 @21.1C	X		none	1
Methyl Oxirane (Propylene Oxide)	Flammability Explosive	-112	34.23	445@20C	X		Carbon Disulfide	
Butane (pure)	Flammability	-138.4	-0.6	17	X		none	1
But-1-ene	Flammability	-185.4	-6.3	2016.9 @21.1C	X		none	1
Buta-1,3-diene	Flammability	-108.9	-4.41	1869.6 @21.1C	X		none	1

TIC	Principal Hazard	MP (ºC)	BP (ºC)	Vap. Press (mm Hg)	ITF-40	CSG-List	In HMSG "9 Families-Approach" Represented by	Rationale
Acrylonitrile	Toxicity	-83.55	77.3	86.25 @20C	X	X	Acrylonitrile	
Phenol (Solutions)	Toxicity	(40.85)	(181.8)	(0.357 @20C)	X		Phenol (Solutions)	
Propene (Pure)	Flammability	-185.3	-47.4		X		none	1
2-Methylpropene (Isobutylene)	Flammability	-186 to -106	-7 to 3	3450 @38C	X		none	1
Dimethylamine (Anhydrous)	Flammability	-92.2	7.4	1500 @25C	X		None	1
Dimethylamine (Solution)	Flammability	-37@40%	54@40%	215 (40%)	X		Dimethylamine (Solution)	
Sodium Cyanide	Toxicity	563.7	1496		X		Sodium Cyanide	
Potassium Cyanide	Toxicity	634.5			X		Sodium Cyanide	
Carbon Monoxide	Flammability, Toxicity	-199	-191.5		X		none	1
Hydrogen	Flammability	-259.1	-252.9		X		none	1
Hydrogen Chloride (Anhydrous)	Toxicity	-115	-85.1	31333 @25C	X	X	Sulphuric Acid / none	1
Hydrochloric Acid	Toxicity	-46.2 @31.2%	108.6@ 20%	100 @20C	X	X	Sulphuric Acid	2

TIC	Principal Hazard	MP (ºC)	BP (ºC)	Vap. Press (mm Hg)	ITF-40	CSG-List	In HMSG "9 Families-Approach" Represented by	Rationale
Hydrogen Fluoride (Anhydrous)	Toxicity	-83.55	19.52	803 @21.1C	X	X	Hydrogen Fluoride	3
Sulphuric Acid	Toxicity	10	290	<0.3 @25C	X	X	Sulphuric Acid	2
Sulphuric Acid (Fuming >30% free SO_3)	Toxicity	32	100	47.8@20C	X	X	Sulphuric Acid	2
Nitric Acid (>40%)	Toxicity	-41.6	83	<0.76 @20C	X	X	Sulphuric Acid	2
Phosphorus Trichloride	Toxicity	-112	76	100 @21C	X	X	Sulphuric Acid	2
Hydrogen Sulphide	Flammability	-86	-60	1900 @20C	X	X	none	1
Phosphoryl Trichloride (Phosphorus Oxychloride)	Toxicity	1.25	106	27.9	X		Phosphoryl Trichloride (Phosphorus Oxychloride)	
Ammonia	Explosion. Toxicity	-47,74	-33,33			X	none	1
Bromine	Caustic, Toxicity	-7,2	58,8	58 mbar @ 7°C 220 mbar@ RT;		X	none	1

TIC	Principal Hazard	MP (ºC)	BP (ºC)	Vap. Press (mm Hg)	ITF-40	CSG-List	In HMSG "9 Families-Approach" Represented by	Rationale
Chlorine	Caustic, Toxicity	-101,5	-34,04			**X**	none	1
Formaldehyde	Caustic, Toxicity	-92	-19,1			**X**	none	1
Phosgene	Toxicity	-127,9	8			**X**	none	1

1) Volatile, no challenge for decontamination.

2) Whilst there might be implied a toxic hazard, only the acidity of aqueous solutions presents the challenge for decontamination.

3) Whilst the acidity/corrosivity is one hazard, HF poses additional risks due to its long-lasting aggressiveness in human and animal tissue.

5. The above selection process gives the following nine chemicals, which covers the decontamination challenges of both CSG- and ITF-40's list members:

- Acrylonitrile
- Carbon Disulphide
- Dimethylamine (solution)
- Hydrogen Fluoride
- Parathion
- Phenol (solution)
- Phosphoryl Trichloride
- Sodium Cyanide and
- Sulphuric Acid

6. If a decontaminant or decontamination system proves efficient against these nine chemicals, it can reasonably be considered efficient against the complete list unless there is a specific incompatibility between the decontaminant and another member of the family other than the selected representative. In that case, an additional test must be performed involving that family member and the decontaminant formulation or procedure under examination.

ANNEX D – TEST PROCEDURES

D1. General Recommendations

1. Before test begins, it is necessary to review the following documents: the requirements capability document, the operational mode summary/mission profile (OMS/MP), the failure definition/scoring criteria (FD/SC) and the independent evaluation plan (IEP), and independent assessment plan (IAP) to determine the overall test structure and safety considerations, data required, criteria, and analysis to be used. List the mission essential performance characteristics and the mission essential soldier tasks specific to the equipment developer and the combat developer respectively. These will be used to measure degradation in performance caused by CBRN contamination and decontamination and by the need for the operator to wear the CBRN protective equipment. Identify the units of measurement and the accuracy and precision required for each parameter measured. Resolve all problems concerning measurable performance and degradation.

2. The assigned evaluator and assessor must coordinate with the tester and determine a realistic test item sample size. The sample size may be determined by test item availability, cost, or other factors and may be less than optimum. The shape and size of test samples are primarily dictated by material-specific requirements of the individual test methods, particularly in the case of hardness testing. If the sample size is less than optimum, devise a testing scheme to optimize test item utilization and required data output.

3. Examine the test item design and the materials of construction. Conduct research on current materials database to determine if tests have been done with novel decontaminants and perform an analysis based on previous test experience and technical information. This provides information concerning the materials ability to survive exposure to contamination, decontaminants, and the decontamination process. Note any areas where an agent could collect or seep, such as cracks, crevices, hinges, joints, countersunk screw heads or other features that may be difficult to decontaminate. Ensure that any identifiable vulnerabilities or questionable design or materials are adequately tested. If the steps above reveal any aspects of design or identify material that appear to have a probable test failure, then testing of the suspected design or material can be performed early in the test cycle. Preliminary results can often be determined from a pilot study and analysis of the collected information. However, a test success can only be confirmed by using chemical agents, biological simulants and radiological material or simulants.

4. Select and identify areas of the test item to be contaminated, decontaminated, and sampled for residual contamination. Identify areas that must be handled or touched by the operators. Ensure that the areas selected are typical and representative of the total test item surface and materials of construction and that they are areas likely to be contaminated and present an operator risk in a CBRN environment.

5. Test variables include purity and stability of contaminants used, purity and stability of decontaminants and decontamination solutions, calibration and maintenance of instrumentation and disseminators, accuracy and precision of the laboratory analysis, and quality and uniformity of all test samples.

6. Available robotics and automatic devices are used whenever possible in test chamber operations to minimize the risk of exposure of test personnel to contaminants.

7. Testing must be conducted in accordance with approved test documentation, such as technical manuals, field manuals, equipment operating instructions, SOPs, and the approved DTP or other testing planning documents. Deviations from test documentation will be recorded in writing and approved by the appropriate authority.

D2. Decontamination Conditions

1. Sealed chamber/hood.

2. Decontamination begins one hour after contamination, using standard field and/or item-specific decontaminants, equipment, and procedures. The decontamination process, excluding monitoring, lasts no longer than 75 minutes.

3. The item surface temperature is 20° C, and if the test is conducted outside, the exterior wind speed is no greater than 1 m/s.

4. Hazard levels will be computed assuming an exposure time based on the mission profile for the item as specified by the combat developer, not to exceed 12 hours.

5. The chamber temperature is no higher than 20° C, and RH range between 60% except specific conditions.

6. The chamber/hood air circulation over the test item: <1 m/s

7. Chamber/hood pressure: atmospheric pressure.

8. Time from radiological sample collection to analysis: <7 days.

9. Time from first test item hardness contamination to last hardness data collection: 30 days.

D3. Test Items Conditions

1. Paint type, specifications, and application must comply with the military standards for the item. If the item requires repainting, all old paint must be removed to ensure a standard thickness and application of paint.

2. Surface areas selected for sampling must be representative of the surface materials, texture, paint, and areas in which the user will have direct contact with.

3. Before each trial, inspect and sample for background data, the surfaces of each test item.

D4. Sampler Conditions

1. Non-operated sampler control (a sampler taken into the room surrounding the test chamber and hood but not aspirated).

2. Operated sampler control (a sampler taken into the room surrounding the test chamber and hood and aspirated, but not exposed to agent).

3. Standard analytical controls (standard samples of known concentration, interspersed among the unknown samples, generally at a ratio of one control for each 10 unknown samples). The chemical analysis procedure shall be conducted using an appropriate number of standards, blanks, and analytical controls whose current concentrations are the same as when prepared, to ensure the reliability of the analytical procedure and to document the precision obtained with each batch of test samples. The standards do not need to be at equal concentration intervals; rather, they are spaced closer together near the low concentration end of the calibration curve.

4. Sample and analysis controls must include: (1) laboratory control, (2) swab control (unused swab), (3) swab of a non-contaminated surface in the field, (4) diluent control, (5) plate control, and (6) a maximum of 18 hours between sample collection and analysis.

D5. Test Data Required

1. Report the following data in the units indicated below. Record the data in the smallest increments that the instrumentation/procedure is designed to achieve and can be easily read.

a. Chemical Testing:

(1) Test chamber/hood: temperature -°C, RH - percent, and airspeed - m/s.

(2) Agent: name and control number, purity - percent, viscosity after adding thickener - centistokes (if thickened), quantity and identity of dye and thickener (if thickened or dyed) - g/L, age since thickened (if thickened), quantity of agent dispensed - grams, agent contamination density - g/m2, and drop size - mg.

(3) The measured stain size on the surface caused by the drops, if safety procedures permit, if required.

b. Biological Testing:

(1) Test chamber/hood: temperature - °C, RH - percent, and airspeed - m/s.

(2) Agent simulant: Name and control number, diluent used, viscosity, percent solids, date harvested and/or reconstituted, date used, and CFU per ml.

(3) Disseminator used, quantity of simulant suspension disseminated - ml, air pressure – kilopascal (kPa), and dissemination time - seconds.

c. Radiological and Nuclear Testing:

(1) Radionuclide

(2) Chemical and physical forms, dispersion mode.

(3) Particles size.

(4) Average surface contamination.

(5) Fluctuation of the contamination on the surface (non homogeneity measurement), hot spot.

(6) Fraction of unfixed contamination.

(7) Re-suspension.

(8) Surface state, clean, dirty, dry, wet.

(9) Treatments after contamination: dried.

(10) Fluorescent particles (FP) contamination level for each sample location before and after decontamination, expressed in Bq/cm^2.

(11) Results of each post-decontamination vapour and contact sample collected during the 12-hour sampling period in g/sample.

(12) Internal dimensions of the vapour sampling containers.

(13) Results of the sampling and analysis controls and standards.

(14) Sample history with elapsed time to analysis in days.

(15) Contamination, weathering, decontamination, and sampling time - minutes.

(16) Names and titles of principal test participants.

(17) Description of the decontamination solutions (examples: formulations, active ingredients, and age), methods, equipment, and item-specific procedures used.

(18) Description of the test item surface condition (pre-test), including construction material, paint type, paint thickness (number of coats), paint condition, and surface cleanliness (mud, grease, and other) with photographs.

(19) Test item pre-test (baseline) and post-test mission essential functional performance data, recorded to the highest level of accuracy and precision that is commensurate with the parameter being measured. The frequency of post-test mission essential functional performance data collection may vary, depending on the outcome of a pre-test hardness evaluation of the test item. Without strong support from the pre-test hardness evaluation, a hardness test evaluating mission essential functional performance is performed after each contamination/decontamination cycle and 30 days after the first contamination. The mission essential functional performance data collected must be comparable in values and accuracy with pre-test values.

(20) Descriptions and photographs of test item cracks, crevices, and other features that may allow contaminants or decontaminants to penetrate below the surface and may be difficult to decontaminate.

(21) A System safety risk assessment of test findings in accordance with national guidance as required.

(22) A description of the use concept requiring the specific contact sampling times.

D6. Receipt Inspection and Functional Performance

1. Prior to testing, inspect the test items for damage and completeness of assembly. Damage, missing components, and other discrepancies must be documented. Inspect the surface of the items for foreign materials not normally present. If required, clean gently by brushing, vacuuming, or washing. Record the item's surface condition, finish, and any physical deviations from normal.

2. A key factor in contamination survivability testing is the determination of degradation in equipment functional performance caused by the

contamination/decontamination process. Prior to testing, ensure that pre-test functional performance data for the test item have been obtained for all mission essential functional performance characteristics. Based on the probable modes of failure, functional performance characteristics are classified as either functional performance attributes (go, no-go) or functional performance variables measurable over a continuous range of values. Operate the test item according to the operator's manual. Measure and record mission essential functional performance characteristics identified by the combat developer. Measure each parameter two or more times and record to the smallest significant units of measure. Do not proceed with testing if any mission essential functional performance characteristic falls outside developer specifications.

D7. Test Preparation

1. Examine each test item and select the areas to be contaminated with agent. The number of areas selected are supported by statistical analysis to provide quality data. Before each trial, inspect and sample the surfaces of the test item. All residual decontaminant and other foreign substances that could interfere with sample analysis must be removed before testing. Identify the category of materiel to which the test item belongs, and select appropriate decontamination procedures for the specific item or similar items in accordance with national procedures. Include any item-specific procedures provided by the combat developer. Review the intended use of the item in the field and identify areas most likely to contribute to a vapour or contact hazard when the equipment is used by unprotected operators. Identify areas that might allow contaminants or decontaminants to penetrate below the surface. Selection of the number, location, and shape of the areas to be tested will depend primarily on the OMS/MP. Other considerations include test item size, geometry, materials of construction, paint, surface texture, and presence of joints or crevices. Photograph or sketch and describe each area selected for sampling. Do not place identifying marks on the areas to be sampled. The size and location of the areas to be contaminated and sampled must be considered in terms of the specific test item and selected to ensure representation of the areas of most probable operator hazard. Use qualified and trained operators, standard equipment (the same type of equipment that would be used by troops for that test item), and standard decontamination procedures.

2. Test Items with Uniform Shapes. Examples of such items are ammunition boxes and containers, crates, kits in their containers, and items tested in their shipping containers. With such items, the entire test item does not need to be contaminated. Identify a minimum of three 100-cm^2 areas representative of areas that would be contaminated in a chemical incident. Prepare a line drawing or photograph showing these areas and the sites within each area that are to be sampled for contamination.

3. Test Items with Irregular or Unusual Shapes. Examples of such items are radios and antennas, portable generators, automatic weapons and small arms, and

electro-optical equipment. For such items, the areas to be contaminated and sampled must be selected on a “one-by-case” basis. Select the largest area feasible (up to 100 cm^2) for each component or material sampled. Test item shape and use may dictate that the entire item be contaminated with a decision required only as to what areas are to be sampled for contact hazard. Often, the test preparation procedures for regularly shaped items can be followed with minor modifications. Any unique hazard-related aspect of the specific item to be tested must take precedence over standard procedures.

4. Prior to initiation of agent tests, rehearsals are conducted to familiarize test crews with the functioning of the test items, test procedures and data requirements. Crews are allowed to practice using simulants until agent dispensing and decontamination become reproducible and routine. The test item to be used on the actual test should not be used on rehearsals.

5. Simulant BG is a common micro-organism living in most soils and is safe to handle and use as a simulant test organism without wearing protective equipment. However, to control laboratory background contamination and preclude any possibility of operators developing an allergy reaction to the organism, a testing is conducted with BG inside a test chamber approved for the testing of biological simulants. The procedures, controls, and SOPs in effect at the time the chamber is approved for biological simulant testing will be followed at all times.

6. Calibrate a dry FP-disseminating apparatus to disperse FP in the 1 to-5 µm size range. Determine a pre-calculated time, air pressure, and FP quantity to contaminate the test item to the target level.

7. Place the test item into the test chamber or fume hood and set the environmental control system for the temperature, RH, and wind speed or air exchange rate specific for the test. Condition the test item until it has equilibrated at a temperature of 20° C (for at least 1 hour). Temperature, RH, and air exchange rate must be recorded continuously throughout the test.

8. Before agent contamination, contact and vapour samples must be taken from or near the areas designated for contamination testing. This sampling and analysis must be tailored to detect materials of the test item and test equipment such as contact sampler that could interfere with the chemical analysis for the agent being used.

9. Place appropriate sampling cards on or adjacent to the test item when droplet sizing and contamination density assessment are required. Place the cards in an area that will be representative of the surface that will be contaminated in accordance with (IAW) the OMS/MP.

D8. Data Reduction, Presentation and Evaluation

1. **Receipt Inspection:**

   a. Assemble and collate all data on item damage, missing components, surface condition, other discrepancies, and test item history. Summarize and present results in tabular form, emphasizing deviations from developer specifications and any surface cleaning or maintenance performed.

   b. Assemble data pertaining to surface materials and their finishes in a form that can be presented to compare with pre- and post-test hardness functional performance data.

2. **Decontaminability:**

   a. Chemical decontaminability will be determined by comparing post-test residual agent with established criteria for each agent. The item will be considered chemical agent decontaminable if residual vapour and contact hazard agent is reduced to levels at or below established decontamination criteria given in Table 7-2, Section 0702. Describe each sampling area, including the location, material of construction, surface geometry, and surface texture. Cite the agent, contamination procedure, decontaminant, and the decontaminating procedures used, including item-specific procedures and time expended on each procedure. Obtain video coverage of the decontamination operation, if possible. Describe the statistical analysis used to define the number of areas to be tested to provide quality data.

   b. Summarize and present the hood/chamber conditions during the test period. Present the agent physical properties, agent contamination density, and the drop size for each item or sampling area. Identify deviations from specific values.

   c. Tabulate the quantity of agent recovered from each agent contact sampler, identified by the location and the time at which the sample was taken. Determine the agent contact hazard level for each test item.

3. **Conditions:**

   a. Meteorological conditions during testing must match those of areas of intended use. Paired comparison must be planned, thus eliminating meteorological conditions as a source of variation in comparing test item performance with and without the wearing of CBRN protective clothing.

   b. CBRN compatibility tests must be based on a test of design that considers all variables, such as the level of operator CBRN training, degree of acclimatization, familiarity and experience with the equipment, and test environmental variables.

c. All operators of the equipment will be properly trained and certified to operate the test equipment.

d. Use soldier operator, maintainer, tester, and evaluator (SOMTE), or equivalent, personnel on CBRN compatibility tests to the maximum extent possible.

e. Any crews who have been dressed in the full CBRN protective equipment for more than 75 minutes must be given an overnight rest period before participating in another test. Due to the debilitating effects of wearing the full CBRN protective equipment, this time limit is set to establish a standard to ensure that participating individuals are not over extended and are in fact, physically and psychologically ready to participate in another trial.

4. **Data Required**

a. A listing of mission essential tasks identified by the combat developer for the equipment undergoing CBRN compatibility testing. Include all pre-test task performance estimates for the mission essential tasks.

b. Soldier tasks/equipment performance measurements made with operators wearing standard battledress and CBRN protective clothing.

c. Temperature, wind speed, relative humidity, light conditions, cloud cover, and heat-stress level recorded throughout all testing.

d. A training record, military occupation specialty (MOS) qualification score, experience, medical or physical profile, and anthropomorphic data for each operator-participant.

e. Copies of operator, supervisor, and umpire questionnaires.

f. A test incident report to document out-of-tolerance performance, breakdown, or other anomalous performance recurring during compatibility test.

g. Descriptions and photographs of all clothing and protective equipment, including pre-test and post-test inspection information on the protective equipment.

5. **Methods and Procedures**

a. Equipment Operation. Equipment to be tested will be operated and maintained in strict compliance with operating manuals, instructions, and SOPs. In performing maintenance tasks, use only tools and repair procedures specific for the equipment.

b. Test Site Operations. This test sequence can be properly executed without the use of agents, simulants or decontaminating agents.

6. **Test Planning and Preparation**

a. Prepare a list of the test item's mission essential tasks as identified by the combat developer. The list should include the method of measuring the task and whether the task is to be classified as an attribute (go or no-go) or a variable, measurable over a continuous range of values.

b. Use qualified and trained operators, standard equipment (the same type equipment that would be used by troops for that test item), and standard procedures.

c. Prepare a test scenario specifying functions and operations to be evaluated during a typical mission profile. Include which test items will be used, the number of SOMTE, and the sequence of tasks to be measured. Clearly specify the exact measurement to be taken, the sequence in which it is to be taken, and the instrument or measuring device. Use of videotapes should be considered. Clearly explain the role of umpires or field observers. The scenario must ensure that all functions or tasks identified as essential are executed and evaluated.

d. Request a minimum of two SOMTE test crews to allow battledress trials and CBRN protective equipment trials to be run simultaneously, partially eliminating environmental conditions and heat-stress levels as variables. Perform a sufficient number of rehearsals to ensure that equipment familiarization and crew differences are not factors in the compatibility determination.

7. **Test Conduct**

a. Perform the scenario once in battledress and another time in CBRN protective equipment, with both crews operating simultaneously. Switch crews and repeat. Replicate this sequence until the decision point specific in the statistical design has been reached. To avoid bias on the final trial, do not inform SOMTE of the number of replicates to be run.

b. Complete any questionnaires used at the completion of each pair of trials. Whenever possible, review videotapes to ensure that the test is meeting objectives.

c. Degradation of crew performance caused by heat stress while wearing CBRN protective equipment will be observed and recorded, but degradation caused by heat stress will be excluded from the equipment compatibility estimate. To

help avoid heat stress, schedule the trails at times and seasons when heat stress will be at a minimum. National safety regulations will prevail.

8. **Data Reduction, Presentation and Evaluation**

a. Tabulate performance data for each task completed in battledress and in CBRN protective equipment and present as paired comparisons.

b. If questionnaires are used, tabulate and summarize questionnaire data, highlighting any operational difficulties attributed to the wearing of CBRN protective equipment by crew members or observers. Contrast questionnaire data for the two sets of trials and interpret results.

c. Summarize and present meteorological data and heat-stress meter data.

LEXICON

PART 1 - ABBREVIATIONS AND ACRONYMS

The lexicon contains abbreviations and acronyms relevant to AEP-7 and is not meant to be exhaustive. The definitive and more comprehensive list of abbreviations and acronyms is in AAP-15.

Abbreviation/Acronym - Meaning/Definition

ABS - copolymer acrylonitrile butadiene/styrene

A/C - aircraft

AEP - Allied Engineering Publication

ALARA - as low as reasonably achievable

ASTM - American Society for Testing and Materials

BG - bacillus subtilis

C - Celsius

C agent - chemical agent

CARC - chemical agent resistant coating

CB - chemical and biological

CFU - colony forming units

cGy - centigray

cm - centimetre

CBRN - chemical, biological, radiological, and nuclear

CFU – colony forming unit

DTP - Detailed Test Plan

EMP - electro magnetic pulse

FP - fluorescent particles

G - grams

GBq - giga-becquerel

GD - soman agent

GRP – glass-reinforced plastic

GUP - polyester/glass fiber

Gy - gray

h - hour

HD - unthickened mustard agent

IAP - independent assessment plan

IAW - in accordance with

IEP - Independent Evaluation Plan

IPE – Individual Protection Equipment

ISO - International Standards Organization

kg - kilogram

km - kilometre

l - litre

LLR - low level radiation

m - meter

m/s - meters per second

m - micrometer

mg - milligram

mm - millimetre

MMD - mass median diameter

MOS - military occupation specialty

MOPP - mission oriented protective posture

MP - mission profile

NATO - North Atlantic Treaty Organization

NBCCS – nuclear, biological, and chemical contamination survivability

OMS - operational mode summary

PA 6 - nylon 6

PC - polycarbonate

PFU - plaque-forming unit

PS - polystyrene

PVC - polyvinylchloride

RAM - reliability, availability, and maintainability

RDD - radiation dispersal device

RH - relative humidity

SOMTE - soldier operator, maintainer, tester, and evaluator

SOP - standing operating procedure

STANAG - standardization agreement

STB - super tropical bleach

TGD - thickened soman agent

TIBs - toxic industrial biologicals

TICs - toxic industrial chemicals

TIMs - toxic industrial materials

TPX - methyl pentene polymer

TREE - transient radiation effects on electronics

VHP - vaporized hydrogen peroxide

VX - name of nerve agent

LEXICON

PART 2 – TERMS AND DEFINITIONS

Note: AAP-21, NATO Glossary of CBRN Terms and Definitions, serves as the NATO source document for CBRN defence terms and definitions. Other terms, which have a more general military significance, are included in AAP-6, the NATO Glossary of Terms and Definitions. The following is a list of terms and definitions necessary for AEP-7 clarity. Terms that are listed in AAP-21 and/or AAP-6 are identified by the addition of the respective AAP number at the end of the definition.

Absorbed contamination - molecules of contamination which diffuse into the structure of the material and which are difficult to extract by decontaminating agents (See Figure A-1).

Adsorbed contamination - molecules of contamination that enter the pore structure of the material, or ionic nuclear contamination that is bound to reactive surface molecules. These types of contamination can be reached if decontaminating agents also enter the pores of the material. (See Figure A-1).

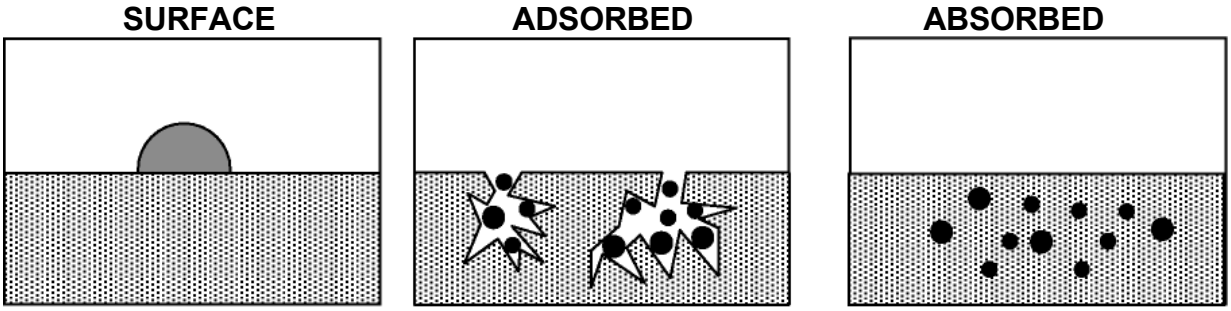


Figure A-1. Generic Types of Contamination

Bacteria - small single-celled micro-organisms, some of which are dependent upon the host cells while others may survive independently in adverse conditions.

Biological agent - a micro-organism which causes disease in man, plants, or animals or causes the deterioration of materiel.

CBRN – this term in the document title generically refers to chemical, biological, radiological and nuclear contamination.

CBRN survivability (Chemical, Biological, Radiological, and Nuclear) - the capability of a system to avoid, withstand, or operate during and/or after exposure to a CBRN environment (and decontamination process) without losing the ability to accomplish the assigned mission. Note: CBRN survivability is concerned with contamination that includes fallout and initial nuclear weapon effects.

CBRN environment – environment conditions found in an area resulting from chemical, biological, radiological contamination, or nuclear attacks or release other than attack (AAP-21).

Chemical agent - a chemical substance which is intended for use in military operations to kill, seriously injure, or incapacitate personnel through its physiological effects. The term excludes riot control agents, herbicides and substances generating smoke and flame. (AAP-6)

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.

Chemical, biological, radiological and nuclear environment - conditions found in an area resulting from immediate or persisting effects of chemical, biological, radiological or nuclear attacks or release other than attack.

Chemical, biological or residual radiation hardening - the design or modification of equipment, structures or materiel to preserve functionality following exposure to chemical, biological or residual radiation hazards by reducing the retention or adsorption of contaminants, increasing their susceptibility to decontamination or allowing their continued employment by personnel wearing the IPE.

Clearance decontamination - decontamination of equipment and/or personnel on temporary or permanent removal from an operation to a standard sufficient to allow unrestricted transportation, maintenance, employment and disposal.

Compatibility - the suitability of products, processes or services for use together under specific conditions to fulfil relevant requirements without causing unacceptable interactions. Related terms: commonality; common user item; force interoperability; interchangeability; interoperability; military interoperability; standardization. [ISO-IEC] 04 Oct 2000

Compatibility (CBRN) - ability of a system to be operated, maintained, and resupplied by personnel wearing the full individual protective equipment in climates for which the system is designed and for the time period specified in the system requirements.

Contamination survivability (CBRN) - capability of a system and its crew to withstand a CBRN contaminated environment, including decontamination, without losing the ability to accomplish the assigned mission. Note: The three main principles of CBRN contamination survivability are hardness, decontaminability and compatibility.

Decontaminability (CBRN) – the ability of a system to be rapidly and effectively decontaminated using standard CBRN decontaminants and procedures available in the field to the point that any remaining contaminant poses no casualty-producing hazard to unprotected personnel exposed for the duration of the mission.

Decontamination (CBRN) - The process of making any person, object, or area safe by absorbing, destroying, neutralizing, making harmless, or removing chemical or biological agents or removing radioactive material clinging to or around it (AAP-6).

Defence critical system – a defence critical system is a mission critical system (preferred term).

Hardness – the capability of materiel or system to withstand the damaging effects of CBRN contamination and any decontaminants and procedures required to decontaminate it.

Immediate decontamination - decontamination carried out by individuals upon becoming contaminated, to save life and minimize casualties. This may include decontamination of some personal clothing and/or equipment.

Industrial radiological sources (IRS) - any source of ionizing radiation in solid, liquid, aerosolised or gaseous form which may be used, or stored for use for industrial, medical, military (other than nuclear weapons), commercial or research purposes. Note: IRR can be further classified as being radiological sources from: medical, industrial, research, military application, commercial products, and nuclear material associated to reactors (Power, Naval, Research, and waste products and fuel cycle).

Mission critical systems - a system whose operational effectiveness and operational suitability are essential to successful mission completion or to aggregate residual combat capability. If this system fails, the mission likely will not be completed. Such a system can be an auxiliary or supporting system, as well as a primary mission system. (Note: this definition is the same for mission-essential equipment).

Mission-essential functions - minimum operational tasks that a system is required to perform in order to accomplish its mission profile.

Mission profile - a time-phased description of the operational events and environments an item experiences from beginning to end of a specific mission. Note: It identifies the tasks, events, duration, operating conditions and environment of the system for each phase of a mission. A mission profile is based on a typical scenario for the item/system.

Mycotoxin - any toxin produced by fungi.

Non-sensitive equipment (CBRN) - mission essential equipment which will continue to function effectively after being exposed to a standard decontaminant or decontamination process without special handling, covering or disassembly.

Nuclear environment - an environment created by initial nuclear weapon effects (air blast, thermal radiation, initial nuclear radiation, and electromagnetic pulse).

Nuclear survivability - the capability of a system to withstand exposure to a nuclear environment without suffering loss of its ability to accomplish its designated mission. Nuclear survivability may be accomplished by hardening, timely re-supply, redundancy, mitigation techniques (to include operational techniques), or a combination thereof.

Nuclear hardening - design features of an equipment, material, or system that allows it to resist temporary or permanent malfunction or degradation of performance after exposure to initial nuclear weapons effects (AAP-21).

Operational decontamination - Decontamination carried out by an individual and/or a unit, restricted to specific parts of operationally essential equipment, materiel and/or working areas, in order to minimize contact and transfer hazards and to sustain operations. This may include decontamination of the individual beyond the scope of Immediate Decontamination, as well as decontamination of mission-essential spares and limited terrain decontamination.

Persistency - in chemical or biological warfare, the characteristic of an agent pertains to the duration of its effectiveness in the environment. This varies greatly between agents and is conditioned by agent composition and the influences of weather and terrain (See AAP-21).

Radiation dispersal device – an improvised assembly other than nuclear explosive device specifically designed to employ radioactive material by disseminating it to cause damage, fear or injury by the radioactive decay of the material.

Sensitive equipment (CBRN) - mission essential equipment that requires special handling in order to remain functional when being exposed to a decontaminant or decontamination process. Note: AEP-58 refers to small individual equipment such as masks, helmets, electronics, optics, computers, and the interior of equipment and inside platforms as sensitive equipment.

Surface contamination - particles, or liquid which remains on the surface of materiel and which can be decontaminated by physical removal as well as chemical neutralization. See Figure A-1.

Thorough decontamination - decontamination carried out by a unit, with or without external support, to reduce contamination on personnel, equipment, materiel and/or working areas, to permit the partial or total removal of individual protective equipment and to maintain operations with minimum degradation. This may include terrain decontamination beyond the scope of Operational Decontamination.

Toxic industrial chemical (TIC) - any toxic compound in solid, liquid, aerosolised or gaseous form which may be used or stored for use for industrial, commercial, medical, military or domestic purposes. Note: To classify as a TIC facility, the chemical has to have LCt_{50} of less than 100,000 mg.min/m^3 in mammals and the production has to be greater than 30 tonnes/year at one facility. TICs could include pesticides, solvents, petrochemicals and radiological materials such as medical and diagnostic isotopes.

Toxic industrial biological (TIB) - any infectious material in solid, liquid, aerosolised or gaseous form which may be used, or stored for use for industrial, commercial, medical, military or domestic purposes.

Toxic industrial material (TIM) - a generic term for toxic or radioactive substances in solid, liquid, aerosolized 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 chemical, toxic industrial biological or Toxic Industrial Radiological. *Related term: toxic industrial hazard*

Toxin - the poisonous product of a living organism and may also be synthesized.

Virus – 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.

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