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13. ABSTRACT (Maximum 200 words) Provides basic nuclear, biological, and chemical (NBC) contamination survivability information to facilitate test planning, conducting, and reporting, and to achieve standardized testing of mission-essential Army materiel. It describes typical facilities, equipment, and procedures used to contaminate small items of equipment, to decontaminate the items, to sample for contamination remaining on the items, to assess the resulting degradation/damage to the items, and to assess the item/operator/NBC protective gear compatibility. The TOP is to be used primarily for the testing of small items of equipment that are decontaminated by the individual soldier or by two-man or three-man teams operating portable and hand-held decontaminating devices. Such items include personal gear, small arms, radios, optical devices, small electrical generators, and small packages of materiel. The TOP was prepared in response to the requirements prescribed by Army Regulation (AR) 70-75.				
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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

Test Operations Procedure (TOP) 8-2-111
AD No.

24 April 1998

NUCLEAR, BIOLOGICAL, AND CHEMICAL (NBC) CONTAMINATION
SURVIVABILITY, SMALL ITEMS OF EQUIPMENT

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1. SCOPE.

1.1 Purpose.

Nuclear, biological, and chemical (NBC) contamination survivability is the capability of a system and its operators to withstand an NBC-contaminated environment, including decontamination, without losing the ability to accomplish the assigned mission. Characteristics of NBC contamination survivability are decontaminability, hardness, and compatibility. To survive NBC contamination, materiel must meet criteria for all three. This test operations procedure (TOP) provides standard test procedures and controls designed to demonstrate that small items of mission-essential equipment have met the provisions of Army Regulation (AR) 70-75^a as implemented by Quadripartite Standardization Agreement (QSTAG) 747, edition 1¹ (included as Appendix B of this TOP). NBC contamination survivability is to be monitored throughout the materiel acquisition cycle and is to be evaluated and assessed during development and operational testing. Neutron-induced gamma activity (NIGA) is not addressed in this TOP. Information on NIGA can be obtained from other sources.

1.2 Limitations.

a. This TOP implements the provisions of AR 70-75^{a*}. It is tailored to the contamination survivability testing of small items of equipment intended to be decontaminated by the individual soldier, using decontamination kits, or by two- or three-man decontamination teams operating hand-held, portable decontaminating devices.

b. Decontamination Equipment. Examples of such equipment are small arms, fixed and semi-fixed ammunition, boxed ammunition, personal gear, radios, tentage, night vision and similar optical devices, and boxes and pallets that may require unpacking after the package has been contaminated by NBC agents. NBC survivability testing of large items of equipment exteriors, such as tanks, vans, personnel carriers, and trucks, is described in TOP 8-2-510, NBC Contamination Survivability, Large Item Exteriors^b.

c. The NBC contamination survivability criteria and implementing procedures of this TOP are not related to the safety criteria of AR 385-61² and Department of the Army Pamphlet (DA PAM) 385-61³ or other local regulations governing handling, storage, and disposition of chemical-contaminated equipment.

d. Nuclear contamination survivability of equipment includes neutron-induced activity and activity resulting from radioactive dust and debris fallout, as specified in the NBC contamination

* Reference letters/numbers match those in Appendix D. The referenced documents apply to requirements of United States laws and regulations. Other nations should use their own laws and regulations.

survivability criteria (Reference 1). When determining a nuclear survivability negligible risk hazard, the total contribution from both sources must be considered. Induced radiation cannot be removed or reduced by present field decontamination materials and procedures; induced activity hazard testing requires different equipment, procedures, and safety considerations. Therefore, the procedures for nuclear decontamination in this TOP pertain only to removal of simulated nuclear fallout.

1.3 Method of Evaluation.

The following procedures should be used to evaluate the ability of the item tested to meet the criteria for decontaminability, hardness, and compatibility.

a. Decontaminability.

(1) Vapor Hazard. The effective average concentration of agent vapor desorbed over time is C_e (see Paragraph 4.1.6.2.d). The mission time provided by the user is t . Then $C_e t = k$, which should be compared with the appropriate value in Table 1 of Reference 1 (included in Appendix B of this TOP).

(2) Contact Hazard. The mass collected by the contact samplers should be adjusted for the average area of human contact with the item. This value should be compared with the appropriate value in Table 1 of Reference 1 (included in Appendix B of this TOP).

b. Hardness.

(1) Obtain the mission-essential performance characteristics from the material developer (i.e., voltage output, airflow, pressure, etc.).

(2) Measure these parameters on the as-received item.

(3) Perform the contamination/decontamination cycles. Measure the same parameters after each cycle.

(4) Compare pre- and post-contamination/decontamination measurements to obtain the percent degradation (if any).

c. Compatibility.

(1) Obtain the mission-essential soldier tasks from the user.

(2) Perform these tasks (timed) in the standard garment.

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(3) Perform these tasks (timed) in mission-oriented protective posture level 4 (MOPP4).

(4) Compare the times and effectiveness of the operator(s).

1.4 Definitions.

Unique terms are defined in Reference 1 (see Appendix B of this TOP).

2. FACILITIES AND INSTRUMENTATION.

Facilities, instrumentation, and safety procedures used for chemical/biological and nuclear survivability testing are strictly controlled. Principal regulations are cited below.

2.1 Facilities.

<u>Item</u>	<u>Requirement</u>
Chemical laboratory and chemical agent storage facility.	Constructed to ensure safe and secure storage, handling, analysis, and decontamination of chemical agents used for research, development, test, and evaluation (RDT&E) quantities of chemical agents. The chemical agent laboratory, instruments, and personnel assignments must meet all requirements of AR 50-6 ⁴ , AR 190-59 ⁵ , and the safety requirements of Reference 2 and Army Materiel Command Regulation (AMCR) 385-100 ⁶ .

<u>Item</u>	<u>Requirement</u>
Toxic-agent test facility.	Constructed to allow contamination, decontamination, and extended residual hazard sampling of small items of equipment deliberately contaminated with chemical agent in a temperature- and humidity-controlled environment. Must be equipped and certified for work with chemical agents. All exhaust air must be filtered; equipment, interior surfaces, tools, and waste must be easily decontaminated. No agent may be released to the environment. The facility must be designed to ensure safe and secure storage, transfer, handling, challenge, and disposal of chemical agents, decontaminating solutions, and solvents. The toxic agent test facility and personnel screening must meet all requirements of References 4 and 5 and the safety requirements of References 2, 3, and 6.
Fluorescent particle (FP) and biological assay laboratories.	Required to store and prepare test quantities of biological and residual nuclear contamination simulant materials, to charge disseminating devices, to prepare samplers, and to analyze all biological agent simulant and nuclear simulant (FP) materials.
Chambers for biological and residual nuclear simulant testing.	Equipped with an air intake and an exhaust system which exhausts through high efficiency particulate filters (capable of retaining 99.7 percent of particles 0.3 μm or greater in diameter) into an exhaust system. The chamber should have sufficient volume to allow free air circulation around the test item.
Personnel change room and shower facility.	To allow test participants to shower and change into clean test clothing before and after assay of samples, and to reduce cross-contamination and contamination of facilities and non-test personnel.

<u>Item</u>	<u>Requirement</u>
Environmental control system.	Test areas in laboratories and chambers must be equipped with environmental controls that allow air temperature and total air exchange rates to be controlled and maintained at prescribed levels throughout the testing period.
Instrumented test range or appropriate operational test facility.	To allow observation and measurement of degradation in performance of mission-essential equipment attributable to contamination/decontamination procedures.

2.2 Instrumentation.

<u>Devices for Measuring</u>	<u>Measurement Accuracy</u>
Air temperature	$\pm 0.5^{\circ}\text{C}$
Relative humidity (RH)	± 5 percent
Wind speed	± 0.1 m/sec
Still color camera	Adequate to document typical test procedures, details of contamination techniques, and any discrepancies from planned procedures necessitated by operational conditions.
Television camera, motion picture camera, and/or recorder	Adequate to monitor the test chamber, and to document, and time test events and procedures.

2.2.1 Chemical Test Instrumentation.

<u>Devices for Measuring</u>	<u>Measurement Accuracy</u>
Sampling chemical agent vapor off-gassing from contaminated surfaces [bubblers, miniature automatic continuous air monitoring system (MINICAMS [®]), solid sorbent tubes, or equivalent] with sampling efficiency >95 percent.	Flow rate in L/min, ± 5 percent.
Contamination density and droplet size (Printflex [®] cards, Kromecoat [®] cards, filter papers, or equivalent).	Contamination density, in g/m^2 , ± 10 percent; droplet size diameter in mm, ± 10 percent.
Agent concentration in samples (spectrophotometer, automated or hand-injected gas-liquid chromatograph, or equivalent).	Agent/sample in mg, ± 8 percent. (In automated mode. Better precision is achievable at additional cost and time).
Measuring and counting spot size instrument (Hamamatsu Image Analyzer [™] , Quantimet [™] , or equivalent).	Droplet stain size in mm, ± 10 percent; droplet stain number by size, ± 10 percent.

<u>Devices for Measuring</u>	<u>Measurement Accuracy</u>
Chemical contact hazard samplers (silicone rubber samplers or equivalent). The silicone rubber that has been used is 1 mm thick, translucent, unfilled, poly (dimethylsiloxane) with a durometer reading of 60. ^c The silicone rubber should be rinsed with water, then dried for 24 hours at 85°C. Circular disks of this material, 3.64 cm in diameter (area of 25 cm ²) were used as samplers.	Agent extraction efficiency from sampler in µg/sample, ±10 percent.
Applying agent contamination to the test item.	Contamination density, in g/m ² , ±10 percent; droplet size, within range specified for the agent.
Safety monitoring for agent within a test chamber, hood, or toxic facility work area. MINICAMS [®] , real-time monitor (RTM), miniature infrared analyzer (MIRAN [®]), automatic continuous air monitoring system (ACAMS), or their equivalent, may be used in conjunction with a suitable agent containment device or temperature control box.	Near real-time. All instruments have differing sensitivities. The available instruments with the best sensitivity shall be used.
Rigid containers for holding test items for agent vapor desorption and sampling, must be constructed of nonabsorbing material such as stainless steel, glass, etc. Internal dimensions to be measured and reported.	Interior dimensions ±2 mm.

2.2.2 Biological Test Instrumentation.

<u>Devices for Measuring</u>	<u>Measurement Accuracy</u>
Applying biological agent simulant contamination to the test item (Collison atomizer or equivalent).	Air contamination of $1 \pm 0.5 \times 10^6$ colony forming units (CFU)/L of air.
Swab sampling of the test item (calcium alginate swabs, test tubes, and diluent).	Swab surface sampling efficiency in CFU/sample, ± 10 percent.
Assay of biological simulants (microscopes, automatic colony counters, etc.).	Number of CFU/sample, ± 10 percent.

2.2.3 Radiological Test Instrumentation.

<u>Devices for Measuring</u>	<u>Measurement Accuracy</u>
Dissemination of FP.	Air contamination of $1 \pm 0.5 \times 10^6$ particles/L of air.
Sampling FP surface contamination (Microtiter [®] plate-sealing tape, or equivalent).	>95 percent sampling efficiency.
Sampling airborne FP contamination (membrane filter samplers or equivalent).	>95 percent sampling efficiency.
Counting FP samples.	Number of FP particles/sample, ± 5 percent.

2.2.4 NBC Compatibility and Hardness Test Instrumentation.

<u>Devices for Measuring</u>	<u>Measurement Accuracy</u>
Measuring the differences in soldier tasks during operation of the test item while in (a) battledress uniform, and (b) NBC protective clothing. Devices for time-and-motion measurements will be standard items, but test-specific devices may also be required.	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 specific task in five exposures 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 characteristic after completion of the five contamination/decontamination cycles.

3. REQUIRED TEST CONDITIONS.

NBC contamination survivability testing requires the handling and use of chemical agents. Such testing is strictly controlled by Army Materiel Command (AMC) regulations. The procedures described in this TOP have been safely used by trained operators for many years. They are intended to provide general procedures only and should not be construed as regulatory in nature. Throughout testing, primary emphasis must be on operator and test safety, but the importance of technical quality, completeness of test data, and conformance with specified test and operating procedures must also be emphasized. Each NBC contamination survivability test plan must be reviewed for technical accuracy and conformance to regulations, safety procedures, and standing operating procedures (SOPs) applicable to the specific item and tests being conducted.

3.1 Pretest Preparation.

a. Review published test records, procedures, and the case files of tests of similar items to identify potential problem areas. Consult applicable safety and surety regulations to ensure compliance of all test procedures. Review all SOPs and procedures to be used for applicability, adequacy, and completeness.

b. Review the requirements documents, the operational mode summary/mission profile (OMS/MP), and failure definition/scoring criteria (FD/SC). Use the independent evaluation plan (IEP) or the independent assessment plan (IAP) to determine the overall test structure, the data required, criteria, and analysis to be used. List the mission-essential performance characteristics and the mission-essential soldier tasks specified by the materiel developer and the combat developer, respectively. These will be used to measure degradation in performance caused by NBC contamination and decontamination and by the need for the operator to wear the NBC protective ensemble. Identify the units of measurement and the accuracy and precision required for each parameter measured. Resolve all problems concerning measurable performance and degradation.

c. Review, coordinate with the assigned evaluator and assessor, and determine a realistic test item sample size. The sample size may be determined by test item availability, cost, or other factors and be less than optimum. If sample size is less than optimum, devise a testing scheme to optimize test item use and required data output.

d. Examine the test item design and the materials of construction. Compare them with the NBC survivability handbook^d material lists and perform an analysis based on previous test experience and technical information from the materials data base concerning their ability to survive exposure to contamination, decontaminants, and the decontamination process. Note any areas where agent could pool or seep, such as cracks, crevices, hinges, joints, countersunk screw heads, or other difficult to decontaminate features. Although very difficult to accomplish, 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 appears to make test failure probable, testing the suspect design or material should be performed early in the test cycle. Preliminary results can often be determined from a pilot study and analysis of the collected information. However, test success can only be confirmed by using chemical agents.

e. 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 an NBC environment.

3.2 Environmental Documentation.

An environmental assessment must be on file covering the storage, use, and disposal of the simulants, hazardous and contaminated materials, and agents used in NBC contamination survivability testing. The assessment must fully address the potential environmental impact of the specific survivability testing being planned. The detailed test plan (DTP) must cite the environmental assessment (EA) and/or a record of environmental consideration (REC) that cites the EA and the appropriate categorical exclusion. The REC must be approved before testing

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begins. If the planned survivability testing is not adequately addressed in an existing environmental assessment, an environmental assessment specifically addressing the survivability testing to be conducted must be prepared, as required by the National Environmental Policy Act (NEPA^e) and AR 200-2^f.

3.3 Test Controls and Limitations.

Controls and limitations applicable to a specific subtest are presented in Paragraph 4 as part of the procedure to which they apply.

a. A quality-control plan should be prepared for each test program to ensure that variables are controlled and that appropriate records are kept throughout the duration of testing. Test variables include purity and stability of agents 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.

b. Unless receipt inspection was accomplished as part of a subtest completed before NBC contamination survivability testing, the test item should be inspected in accordance with (IAW) TOP 8-2-500⁷. Inspection data, certificates of compliance, or similar documentation should be reviewed to ensure that exterior surfaces, finishes, and packaging meet specifications. Generally, the item should be tested in "as-received" condition, matching its condition when issued to troops in the theater of operations as far as possible. NBC contamination survivability testing may be required periodically throughout the equipment life cycle if the effect of normal wear is a major factor in survivability.

c. Available robotics and automatic devices should be used whenever possible in test chamber operations to minimize the risk of exposure of test personnel to chemical agents.

d. At all times, testing must be conducted IAW approved test documentation, such as technical manuals, field manuals, equipment operating instructions, SOPs, the approved test planning directive, the IEP/IAP, and the DTP. Deviations from test documentation will be put in writing and approved by the appropriate authority.

4. TEST PROCEDURES.

4.1 Chemical Contamination Survivability.

4.1.1 Objectives.

- a. Decontaminability. Determine chemical agent vapor and percutaneous hazards, including eye effects, associated with troop use of equipment that has been contaminated with chemical agent and then decontaminated using standard and/or item-specific chemical decontamination techniques.
- b. Hardness. Determine the degree of performance degradation in mission-essential functions of Army materiel after chemical agent contamination and decontamination by standard and/or item-specific procedures.
- c. Compatibility. Determine the degree of degradation in mission-essential soldier tasks as a result of operating a piece of equipment in MOPP4. See Paragraph 4.4 for details.

4.1.2 Criteria/Conditions.

4.1.2.1 Criteria.

- a. Mission-essential equipment shall be hardened to ensure that exposure to five contamination/decontamination cycles does not degrade the operational performance of the equipment more than 20 percent (or that specified by the combat developer) measured over a 30-day period. The five-cycle requirement refers to a cumulative total of five exposures to one or more contaminants (nuclear, biological, or chemical) and the associated decontamination processes.
- b. At most, residual contamination levels for mission-essential equipment must constitute a negligible risk to unprotected users of the equipment after chemical agent contamination and decontamination. In the determination of chemical agent survivability, the following NBC contamination survivability test conditions (Paragraph 4.1.2.2) apply.

4.1.2.2 Conditions.

a. General Conditions.

- (1) The surfaces of the item initially are uniformly contaminated to a contamination density of 10 g/m² with 5- to 7-mg droplets of thickened soman (TGD), or 1- to 2-mg droplets of unthickened distilled mustard (HD) or VX. The purity of chemical agents used must be known

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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 .

(2) Decontamination begins 1 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 30°C and exterior wind speed is no greater than 1 m/sec.

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

b. Detailed Conditions. Detailed conditions for chemical agent contamination survivability testing are given below.

(1) Chamber temperature and relative humidity (RH): $30 \pm 5^\circ\text{C}$ and RH of 40 ± 10 percent or as specified in the IEP or IAP.

(2) Chamber/hood air circulation over the test item: $<1 \text{ m/sec}$.

(3) Chamber/hood pressure: atmospheric pressure.

(4) Exterior agent contamination density: $10 \pm 1 \text{ g/m}^2$.

(5) Contamination drop size: (a) VX and HD: mass median diameter (MMD) $1.4 \pm 0.16 \text{ mm}$ and (b) TGD: MMD $3.5 \pm 1.5 \text{ mm}$.

(6) Time from sample collection to analysis: <7 days.

(7) Time from first test item hardness contamination to last hardness data collection: 30 days.

4.1.3 Controls and Limitations.

The controls and limitations for chemical agent contamination survivability testing are:

a. Test Item:

(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 where the user will have direct contact.

(3) Before each trial, inspect and sample (vapor and contact) the surfaces of each test item for background contamination.

b. Sampler (Vapor and Contact) and Analysis Control Data. These will include:

(1) Nonoperated sampler control (a sampler taken into the room surrounding the test chamber/hood but not aspirated).

(2) Operated sampler control (a sampler taken into the room surrounding the test chamber/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 need not be at equal concentration intervals; rather, they should be spaced closer together near the low concentration end of the calibration curve.

c. For operator safety and to ensure that only clean air is released to the environment, the test chamber or fume hood to be used must be approved for chemical agent testing. The procedures, controls, and SOPs in effect at the time of approval will be followed at all times.

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

a. Test chamber/hood: temperature -- °C, RH -- percent, and air speed -- m/sec.

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

c. Results of each post-decontamination vapor and contact sample collected during the 12-hour sampling period -- µg/sample (should be equivalent to 10 g/m²).

d. Internal dimensions of the vapor sampling containers.

- e. Results of the sampling and analysis controls and standards.
- f. Sample history with elapsed time to analysis -- days.
- g. Contamination, weathering, decontamination, and sampling time -- minutes.
- h. Names and titles of principal test participants.
- i. Description of the decontamination solutions (i.e., formulation, active ingredients, and age), methods, equipment, and item-specific procedures used.
- j. Description of the test item surface condition (pretest), including construction material, paint type, paint thickness (number of coats), paint condition, and surface cleanliness (mud, grease, and other), with photographs.
- k. Test item pretest (baseline) and posttest mission-essential functional performance data, recorded to the highest level of accuracy and precision commensurate with the parameter being measured. The frequency of posttest mission-essential functional performance data collection may vary, depending on the outcome of a pretest hardness evaluation of the test item. Without strong support from the pretest hardness evaluation, a hardness test evaluating mission-essential functional performance should be 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 the pretest values.
- l. 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.
- m. A system safety risk assessment of test findings IAW guidance addressed in Military Standard (MIL-STD)-882B^g (see also TOP 1-1-060^h).
- n. The measured stain size on the surface caused by the drops, if safety procedures permit and if this information is desired.
- o. A description of the use concept requiring the contact sampling times specified [Paragraph 4.1.5.7.b(3)].

4.1.5 Methods and Procedures. The use of the actual test item is the most reliable and realistic method for assessing all aspects of the item's decontaminability. However, it is not always feasible and/or cost effective to use the actual item to determine decontaminability. An alternate method is to use small sections, swatches of materials, or components from the item and then contaminate, decontaminate, and sample them individually in a chemical fume hood or small

chamber. Proper scaling techniques must be applied if the whole item is not contaminated. The data requirements, scaled-down test methods, and data analysis for the actual small item and the swatch or component testing are essentially the same and may be the only source of data. Actual item testing is the preferred method and should be used when feasible and cost effective. The test methods and procedures that follow are for the actual small item of equipment; the concept can be adapted to swatch or component testing.

4.1.5.1 Agents. A separate test must be performed for each chemical agent used. Agents to be used are listed below:

- a. Neat VX with purity greater than 85 percent. The agent may be dyed with approximately 0.5 percent (weight/volume) of a suitable dye.
- b. Neat soman (GD) with 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 cSt at 25°Cⁱ. Batch-to-batch variability in viscosity can be greater than 10 percent. Complete solution of the polymer in GD is slow; therefore, 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.
- c. Neat HD with purity greater than 85 percent. The agent may be dyed with approximately 0.5 percent (weight/volume) of a suitable dye.

4.1.5.2 Receipt Inspection and Functional Performance.

a. Before testing, inspect the test items for damage and completeness of assembly. Damage, missing components, and other discrepancies should 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.

b. A key factor in chemical contamination survivability testing is the determination of degradation in equipment functional performance caused by the contamination/decontamination process. Before testing, ensure that pretest 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 should be 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 at least twice 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.

c. "Mockups" may be used on some tests in lieu of expensive or non-expendable test items. The mockups may be specially fabricated to simulate the test item or may be the actual test item with expensive optical, electronic, or other internal components removed. The mockups should be furnished and/or approved by the materiel developer. Carefully analyze and document the similarities and differences between the mockup and the test item it simulates.

4.1.5.3 Test Preparation.

a. Examine each test item and select the areas to be contaminated with agent. The number of areas selected should be 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 listed in Field Manual (FM) 3-5⁸. Include any item-specific procedures provided by the combat developer.

b. Review the intended use of the item in the field and identify areas most likely to contribute to a vapor 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 and 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, as specified in Reference 8 or the item-specific technical manual.

(1) Test Items with Generally 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-cm² areas representative of areas that would be contaminated in a chemical attack. Prepare a line drawing or photograph showing these areas and the sites within each area that are to be sampled for contamination density and droplet size.

(2) 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 "case-by-case" basis. Select the largest area feasible (up to 100 cm²) 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 modification. Any unique hazard-related aspect of the specific item to be tested must take precedence over standard procedures.

c. Before agent tests begin, rehearsals should be held to familiarize test crews with the functioning of the test items, test procedures, and data requirements. Crews should be allowed to practice, using simulants, until agent dispensing and decontamination become reproducible and routine. The test item to be used during the actual test should not be used for rehearsals.

d. Place the test item in the test chamber or fume hood and set the environmental control system for the temperature, RH, and wind speed or air exchange rate specified for the test. Condition the test item until it has equilibrated at $30\pm5^{\circ}\text{C}$ (for at least 1 hour). Temperature, RH, and air exchange rate should be recorded continuously throughout the test.

e. Before agent contamination, background swab and vapor samples should be taken from or near areas designated for contamination testing. The sampling and analysis must be tailored to detect materials that could interfere with the chemical analysis for the agent being used.

f. 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 IAW the OMS/MP.

4.1.5.4 Hood/Test Chamber Operation.

a. The procedures, controls, and SOPs in effect at the time the chamber or fume hood was approved for chemical agent testing will be followed at all times.

b. The hood/test chamber exhaust system should be activated any time an agent is present. It should be operated at the maximum rate consistent with maintaining the required environmental conditions within the test chamber or fume hood.

4.1.5.5 Contamination and Residual Hazard Determinations. Two test items should be used in testing, one for evaluation of residual vapor 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 economics may dictate the use of one test item for residual vapor and residual contact hazards. The procedures that follow assume that two test items are available.

a. Contaminate a test item either over its entire area or over the specific areas 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/m². (A density of 10 g/m² is equal to 100 mg of agent in a 100 cm² 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.

b. 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.

c. Immediately after 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.

d. On trials with thickened agent, drop-size samplers should remain attached to the test item throughout agent application. On VX trials, a contamination density of 10 g/m² essentially coats the test item with a monolayer of agent; therefore, 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.

4.1.5.6 Decontamination of the Test Item. The contaminated test item shall be allowed to weather for 1 hour after contamination is completed.

a. 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.

b. Only standard decontamination methods, procedures, and decontaminants should be used. For most pieces of equipment, these are described in Reference 8. Some items of equipment have item-specific decontamination procedures intended to replace those outlined in the FM. These item-specific procedures should be followed when supplied as part of the test documentation package (i.e., the operator's 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.

e. Obtain visual documentation of the decontamination procedures to enhance the report. Video is recommended.

4.1.5.7 Residual Hazard Determination.

a. **Residual Vapor Hazards.** One of the test items allocated for NBC contamination survivability testing will be used to estimate residual vapor hazards after the contamination/decontamination cycle. **NOTE:** Because of the low volatility of VX, residual vapor hazards need to be determined only if specified in the IEP/IAP, the test directive, or other test documentation, or if the pretest evaluation indicates that vapor sampling is advisable.

(1) When determining residual vapor hazard (whether using the actual test item, a full-scale mockup, actual test item components, or swatches of test item materials), place the decontaminated item in a sampling box, temperature-controlled box, or other enclosure of appropriate size to fit the item. For reproducible results, the box should have certain characteristics or features. It should have interior surfaces made of stainless steel or other material that is nonsorptive 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 vapor 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. 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 4 minutes), and constructed to provide air (agent vapor) sampling ports. The interior of the box should be sampled for residual agent vapor 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.

(2) Calculate the number and flow rate of samplers required to achieve reliable airflow over the test item. Ensure that a minimum of two vapor samples are obtained for any time interval. (Three samples are desirable). If cumulative samplers (bubblers or solid sorbent tubes) are used, an exact vapor sampling sequence must be specified in the DTP 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.

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

(4) Start aspirating the vapor samplers. Use samplers appropriate to the measurement required.

b. Residual Contact Hazard. One of the test items allocated for NBC survivability testing will be used to estimate residual contact hazard.

(1) Contact sampling periods will 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 vapor hazard sampling periods (though not necessarily for the entire vapor sampling time), with the initial sample being taken during the 4-minute clean air wash of the vapor sampling schedule. Conduct duplicate sampling.

(2) Locations on the equipment where direct contact with the operator's skin or hands or prolonged contact with other body parts is expected shall be sampled. The DTP may specify other locations to be selected.

(3) Prepare contact samplers [a thin disk of silicone rubber (1 mm thick) or other suitable material] with a nominal size of 25 cm². The contact sampler should be backed by aluminum 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/cm² for 10 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 5 seconds. These sequential contact sampling times should relate to the use concept of the item (e.g., how long a human might be expected to lean on, touch, hold, etc., the area sampled). 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.

c. Sampling and Analysis. 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.

d. Coupons/Swatches. 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 vapor, and contact hazard.

4.1.5.8 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 pretest values collected in Paragraph 4.1.5.2.b.

b. The required five contamination/decontamination cycles may be conducted with any one or a combination of the three chemical agents, or all five cycles may be conducted with chemical agents, biological 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 (Paragraph 3.1.d).

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 program to program, hardness data must be sufficiently accurate and precise to define any degradation over a 30-day period.

4.1.6 Data Reduction, Presentation, and Evaluation.

4.1.6.1 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 and present "mockup" receipt inspection data, noting differences between the mockup and the test item.

c. Assemble data pertaining to surface materials and their finishes in a form that can be presented to compare pre- and posttest hardness functional performance data.

4.1.6.2 Decontaminability. Chemical decontaminability will be determined by comparing posttest residual agent with established criteria for each agent (Paragraph 4.1.2.1). The item will be considered chemical agent decontaminable if residual vapor and contact hazard agent are reduced to levels at or below established decontamination criteria.

a. 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 (Paragraphs 4.1.5.3.a and b).

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 specified 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 and compare it with the approved NBC contamination survivability criteria in Table 1 of Appendix B [see also Paragraph 1.3.a(2)]. Consider the test item MP, probability of contact, type of contact, contact time, type of agent, and contact hazard sampler-to-skin correlation factors (bare skin, clothed, and contact pressure). The factors to be considered will vary significantly for every type of item tested. The procedures for assessing operator exposure to contact hazard must be tailored to each test item and mission scenario.

d. Tabulate the average concentration of agent vapor recovered from each test item sampling location (component, if used) identified by time. Consider the test item mission, probable mission scenario(s), and operator location and estimate the effective average concentration (C_e); that is, the fraction of the average concentration that is likely to be presented to and be inhaled by the operator [Paragraph 1.3.a(1)]. Compare the results with the approved NBC contamination survivability criteria for military materiel (Table 1 of Appendix B).

(1) No simple procedure exists for determining vapor hazard to the test item operator(s). The credible dosage received is a function of agent desorption from the decontaminated test item, worst-case or other selected scenarios that have almost unlimited variables, and the established "no effects" criteria.

(2) One approach to determine if agent vapor dosages from a test item are likely to exceed the established criteria has been presented¹. This approach hypothesizes exposure scenarios on a case-by-case basis, depending on the test item and its expected use in the field.

e. If an item fails the decontaminability criterion, attempt to identify the material composition responsible for the failure.

4.1.6.2 Hardness.

a. Summarize and tabulate all post-trial mission-essential performance data, identified by test cycle number, agent, and decontaminant.

b. Compare the mission-essential performance data for each contamination/decontamination cycle with the receipt inspection performance data. Use the mission-essential performance data and operator interview data to determine whether more than 20 percent degradation in item performance has occurred (Paragraph 1.3.b). Highlight and discuss significant results.

4.2. Biological Contamination Survivability.

4.2.1 Objectives.

a. Decontaminability. Determine hazards associated with troop use of equipment that has been contaminated with biological material (simulant spores) and then decontaminated using standard and/or item-specific biological decontamination techniques.

b. Hardness. Determine degradation in mission-essential performance characteristics of military materiel after biological agent contamination and then decontamination using standard and/or item-specific techniques.

4.2.2 Criteria/Conditions.

4.2.2.1 Criteria.

a. Mission-essential equipment shall be hardened to ensure that exposure to five NBC contamination/decontamination cycles does not degrade the mission-essential task performance of the equipment more than 20 percent or that specified by the combat developer measured over a 30-day period. The five-cycle requirement refers to a cumulative total of five exposures of one test item to one or more contaminants (nuclear, biological, or chemical) and the associated decontamination processes.

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b. After decontamination, residual contamination levels for mission-essential equipment must constitute a negligible risk at most to unprotected users of the equipment. In the determination of biological simulant survivability, the following NBC contamination survivability test conditions apply (Appendix B).

4.2.2.2 Conditions.

a. General Conditions.

(1) The exterior surfaces are uniformly contaminated with 1×10^7 CFU/m² of biological agent simulant 1 to 5 μ m in size.

(2) Decontamination begins 1 hour after contamination, using standard field and/or item-specific decontaminants, equipment, and procedures. The decontamination process lasts no longer than 75 minutes. The item surface temperature is 30°C and the wind speed (air movement) is no greater than 1 m/sec.

(3) Hazard levels will be calculated assuming an exposure time based on the mission profile (MP), as specified by the combat developer, not to exceed 12 hours.

b. Detailed Conditions. Detailed conditions for simulant biological agent simulant/contamination survivability testing are given below.

(1) Chamber temperature and RH: $30 \pm 5^\circ\text{C}$ and ambient RH.

(2) Chamber air circulation over the test item: <1 m/sec.

(3) Sealed chamber/hood.

(4) Exterior simulant contamination density: $1 \pm 0.5 \times 10^7$ CFU/m².

(5) Simulant particle size: 1 to 5 μ m.

4.2.3 Controls and Limitations. The controls and limitations for biological agent simulant contamination survivability testing are:

a. Test Item:

(1) Paint type, specifications, and application must comply with military standards for the test item. If the item requires repainting, all old paint must be removed before applying new paint.

(2) Surface areas selected for sampling must be representative of the surface materials, texture, paint, and areas where the user will have direct contact.

b. Sample and Analysis Controls: (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.

c. Decontamination Control.

(1) Use standard decontaminating solutions, or solutions designated by the developer.

(2) Contamination weathering time before start of decontamination: 1 hour \pm 2 minutes after completion of contamination. The decontamination process should last no longer than 75 minutes.

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

4.2.4 Data Required. Report the following data in the units indicated.

- a. Chamber temperature -- °C, RH -- percent, and calculated wind speed -- m/sec.
- b. Agent simulant *Bacillus subtilis* var. *niger* (BG): name and control number, diluent used, viscosity, percent solids, date harvested and/or reconstituted, date used, and CFU per mL.
- c. Disseminator used, quantity of BG suspension disseminated -- mL, air pressure -- psi, and dissemination time -- seconds.
- d. Photographs and written description of each area sampled.
- e. Simulant contamination level of the chamber air immediately after dissemination, expressed in CFU/L of air.
- f. Simulant contamination levels for each sample location area before and after decontamination, expressed in CFU/cm².
- g. Results of sampling and analysis controls, expressed in CFU/control.
- h. Sample history with elapsed time to analysis -- hours.
- i. Elapsed time to complete test item contamination (fallout), weathering (chamber air-wash) time, decontamination time, and time of each sample -- minutes.

j. Description of decontaminating solution (i.e., formulation, active ingredients, and age), equipment, and procedures used, including item-specific procedures.

k. Description of test item surface condition (pretest and posttest), materials of construction, paint type, and surface cleanliness (mud, grease, decontamination materials, and other). Photographs of joints, crevices, textures, or other areas that may leak or prove difficult to decontaminate.

l. Receipt inspection results and pretest (baseline) and posttest mission-essential functional performance data used to determine test item hardness (degradation).

m. The names and titles of the principal test participants.

n. A system safety risk assessment of test findings IAW guidance addressed in Reference g (see also Reference h).

4.2.5 Methods and Procedures.

4.2.5.1 Biological Agent Simulant. The biological simulant selected for this TOP is a spore suspension of BG. Experience has shown it simulates the behavior of anthrax and is a worst case simulant for other biological agents.

4.2.5.2 Receipt Inspection and Functional Performance. Perform a receipt inspection and a pretest mission-essential functional performance test as described in Paragraph 4.1.5.2, if not previously performed as part of another test phase.

4.2.5.3 Pretest Preparation.

a. Before each trial, inspect and sample the surface of the test item for residual decontaminant and for other foreign substances that could interfere with sample analysis.

b. Perform an analysis of the item as discussed in Paragraph 4.1.5.3. Select the materials of construction, surface textures, and surface locations to be sampled. Identify three 25-cm² sampling areas from each material/location to be sampled. Duplicate areas are desirable for each material/location. Document any material or surface selected that requires sampling areas to be less than 25 cm². Describe and sketch or photograph each area selected for sampling. If any parts of the test item have been excluded from biological survivability testing by the combat developer, identify such parts.

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

d. Before the start of simulant tests, rehearsals may be required to familiarize test crews with all test procedures and data requirements. Allow crews to practice until simulant dispensing and decontamination become reproducible and routine. During rehearsals, do not use the test item to be used during hardness and decontaminability tests.

e. BG is a common microorganism 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 allergic reaction to the organism, conduct all testing 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 was approved for biological simulant testing will be followed at all times.

f. Templates cut to match the test item's shape and sampling areas and covers for the test chamber floor and test instruments may be useful in reducing levels of unwanted contamination and secondary aerosols.

4.2.5.4 Contamination and Contamination Density Sampling.

a. To contaminate the test item to the specified level, calibrate a nebulizer/generator (Collision generator) to disperse BG containing particles in the 1- to 5- μ m size range, using precalculated time, pressure, and slurry concentration.

b. Place the test item in the test chamber and equilibrate at $30\pm 5^{\circ}\text{C}$ until the item reaches a stable temperature (at least 24 hours). Environmental conditions specified for the test chamber will be maintained and recorded throughout the test.

c. Before the start of a trial, swab sample the first 25-cm² area in each set. This swab sample will be used to measure pretest residual background contamination.

d. Contaminate the air inside the chamber to a level of approximately 1×10^6 CFU/L of air, by aerosolizing a slurry of BG spores using a nebulizer/ generator for approximately 4 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 level of 1×10^7 CFU/m² will be determined by the project biologist. Use current SOPs and report the information as required laboratory data.

e. Immediately after completion of chamber air contamination, sample the chamber air for BG concentration, using all-glass impingers without preimpingers. Allow 1 hour for fallout contamination of the test item. Air-wash the chamber for 1 hour to reduce chamber air contamination.

f. Immediately after the air-wash, swab sample the second 25-cm² area in each set to determine the test item contamination level.

4.2.5.5 Decontamination of the Test Item.

a. The 1-hour chamber air-wash time will serve as the 1-hour weathering time. Start decontamination immediately after sampling the test item for contamination level.

b. Use only standard decontamination methods, procedures, and decontaminants. Decontamination procedures for specific items are described in Reference 8. Some items of equipment will have item-specific decontamination procedures intended to supplement those in Reference 8. Follow these item-specific procedures when supplied as part of the test documentation package.

c. Chlorine-containing compounds such as supertropical bleach, calcium hypochlorite, or sodium hypochlorite are the decontaminating solutions of choice for biological agents. However, chemical agent decontaminating solution number 2 (DS-2) is effective against biological agents and may be specified in the test documentation as the decontaminating solution for some biological testing. The decontamination process should last no longer than 75 minutes, including decontaminant residence time.

d. Perform decontamination as if the entire surface of the test item were uniformly contaminated. Contaminated sampling areas should receive no more or no less attention, time, or effort than areas that will not be sampled. Appropriate time should be spent on sections having acute angles and hard-to-work areas and on joints and cracks that might allow contaminants or decontaminants to reach interior surfaces.

e. Record all decontamination procedures, equipment, tools, and time used in the decontamination process.

4.2.5.6 Residual Hazards Sampling After Biological Contamination/Decontamination. When the test item surface is dry following decontamination, swab sample the third 25-cm² 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 NBC 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.

4.2.5.7 Hardness Determination.

a. If the review of the probable modes of failure of the test item (Paragraph 3.1.c) indicated that biological decontamination could affect operational performance significantly, the hardness determination should include one or more contamination/decontamination cycles with biological agent simulant. After decontamination is complete and the final set of swab samples has been taken, inspect exterior surfaces for evidence of corrosion caused by the decontamination process.

b. Measure and record all mission-essential performance characteristics. Measure each characteristic at least twice, depending on the inherent difficulty in reproducing a specific value, and compare with pretest values. Interview equipment operators and record any indications of operational degradation attributable to the contamination/decontamination cycle. Measurement of hardness degradation should be for five cycles, scheduled over a 30-day period.

4.2.6 Data Reduction, Presentation, and Evaluation.

a. Describe each sampling area and give the location, material of construction, surface geometry, and surface texture. Cite the decontaminant, decontamination procedures, any materiel developer's item-specific procedures, and decontamination time.

b. Summarize and present the chamber conditions during the test period. Record the batch or lot number of the simulant used, its viscosity and age, and the aerosol disseminator operating data. Identify and explain any deviations from target values.

c. For each material/location sampled, summarize and describe the swab sample control, chamber air contamination level, test item contamination level, and post-decontamination residual sampling level, including additional residual sampling values obtained after second and third decontamination repeats.

d. Calculate the biological spore decontamination reduction ratio achieved by the decontamination process (the item challenge contamination level divided by the residual contamination level) for each material/location sampled. Present the spore reduction ratio and the raw challenge and hazard data. Compare the calculated decontamination ratio values with the NBC contamination survivability criterion for biological spores. The item will be considered decontaminable for biological agent if the contamination is reduced to levels at or below the established criterion. If alternative methods of decontamination appear likely to improve decontamination effectiveness, recommend them for consideration.

4.3 Nuclear Contamination Survivability.

4.3.1 Objectives.

a. Decontaminability. Determine hazards associated with troop use of equipment that has been contaminated with radioactive debris and then decontaminated using standard and/or item-specific decontamination techniques.

b. Hardness. Determine performance degradation in mission-essential functions of military materiel after radioactive contamination and then decontamination using standard and/or item-specific techniques.

4.3.2 Criteria/Conditions.

4.3.2.1 Criteria

a. Mission-essential equipment shall be hardened to ensure that exposure to five contamination/decontamination cycles does not degrade the operational performance of the equipment more than 20 percent, or that specified by the combat developer, measured over a 30-day period. The five-cycle requirement refers to a cumulative total of five exposures to one or more contaminants (nuclear, biological, or chemical) and the associated decontamination processes.

b. Following decontamination of the test item to remove nuclear fallout debris, the residual radiation activity on/in the test item will result in no more than negligible risk to unprotected users of the item. In the determination of nuclear fallout survivability, the following NBC contamination survivability test conditions (Paragraph 4.3.2.2.) apply (Appendix B).

4.3.2.2 Conditions.

a. General Conditions.

(1) One-half of the activity could be induced activity resulting from the initial blast effects and nontest item-related sources and would not be measured in this test. The other half of the activity (which would be determined in this test) would result from radioactive debris remaining on the item after nuclear fallout decontamination.

(2) The unprotected users of the item would arrive at H+2 hours and remain 1 meter from the item for a period of time based on the item MP, not to exceed 12 hours.

(3) Decontamination begins 1 hour after contamination, using standard field and/or item-specific decontaminants, equipment, and procedures. The decontamination process lasts no longer than 75 minutes. The item surface temperature is 30°C and the wind speed (air

movement) is no greater than 1 m/sec.

b. Detailed Conditions. The detailed conditions for simulant nuclear fallout contamination survivability testing are given below:

(1) Chamber temperature and RH: $30 \pm 5^\circ\text{C}$ and ambient RH.

(2) Chamber air circulation over the test item: <1 m/sec.

(3) Sealed chamber.

(4) Nuclear fallout simulant: FP.

(5) Fallout simulant particle size: 1 to 5 μm .

(6) Target simulant contamination density: $2.5 \pm 0.5 \times 10^5$ particles/cm².

(7) Sampling and counting controls: test item background control, laboratory control, and sample particle counting control.

(8) Surface areas selected for sampling must be representative of the surface materials, texture, paint, and the areas where the user will have contact with the item.

(9) Contamination weathering time before start of decontamination: 1 hour ± 2 minutes after completion of contamination. The decontamination process should last no longer than 75 minutes.

4.3.3 Controls and Limitations.

a. Paint type, specifications, and application must comply with 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.

b. Before each trial, inspect and sample the surface of the test item for prior test residue and other foreign substances that could interfere with sampling and analysis.

c. Use qualified and trained operators, standard equipment, and standard procedures (the same type of equipment and procedures that troops would use in the field with that test item).

4.3.4 Data Required. Report the following data in the units indicated:

a. Simulant FP data: FP lot or control number, color, particle count/gram, and particle size

range -- μm .

b. FP disseminator used: air pressure -- psi, dissemination time -- seconds, and quantity of FP disseminated -- grams.

c. Test chamber: temperature -- $^{\circ}\text{C}$, RH -- percent, and calculated airflow -- m/sec.

d. Photograph and written description of each area sampled.

e. FP contamination level of the chamber air immediately after dissemination, expressed in particles/L of air.

f. FP contamination level for each sample location before and after decontamination, expressed in particles/ cm^2 .

g. Results of sampling and counting controls.

h. Time to complete test item contamination (fallout), weathering (chamber air-wash) time, decontamination time, and time of each sample -- minutes.

i. Description of decontamination equipment, procedures, and solutions used, including item-specific procedures.

j. Description of test item surface condition (pretest and posttest), materials of construction, paint type, texture, surface cleanliness (mud, grease, decontamination materials, and other), and any experimental treatments or test environments to which the item has been subjected. Photographs of joints, crevices, textures, or other areas that may leak or be difficult to decontaminate.

k. Receipt inspection results and pretest (baseline) and posttest mission-essential functional performance data used to determine test item hardness (degradation).

l. The names and titles of the principal test participants.

m. A system safety risk assessment of test findings IAW Reference g (see also Reference h).

4.3.5 Methods and Procedures.

4.3.5.1 Nuclear Fallout Simulant. The nuclear fallout simulant to be used is FP in the 1- to 5- μm size range. Before start of testing, the FP to be used should be tested for fluorescent color.

4.3.5.2 Receipt Inspection and Functional Performance. Perform receipt inspection and a pretest mission-essential functional performance test as described in Paragraph 4.1.5.2.b, if not previously performed as part of another test phase.

4.3.5.3 Test Preparation.

a. Perform an analysis of the item as discussed in Paragraph 4.1.5.3 to help identify areas to be sampled. Select typical materials of construction, surface textures, and locations of greatest operator hazard. Identify three 4-cm² sampling areas from each material/location to be sampled. Duplicate areas for each material/location are desirable. Make special note of any material or surface selected that requires the sampling areas to be less than 4-cm². If any parts of the test item have been excluded from, or specified for, item-specific decontamination, identify such parts.

b. Calibrate a dry FP-disseminating apparatus to disperse FP particles in the 1- to 5- μ m size range. Determine a precalculated time, air pressure, and FP quantity to contaminate the test item to the target level.

c. Before FP tests begin, rehearsals may be required to familiarize test crews with all test procedures and data requirements. Allow crews to practice until the operation of dispensing equipment, decontamination procedures, and sampling become reproducible and routine. Do not use the test item to be used during hardness and decontaminability tests for rehearsals; do not disseminate the FP.

d. To reduce FP contamination of instruments and equipment, templates and protective covers may be useful. Do not use plastic sheeting or other materials capable of carrying a high static charge in the chamber because the static charge can influence FP behavior; Velostat[®] or equivalent sheeting can be used.

4.3.5.4 Test Chamber Operation.

a. The procedures, controls, and SOPs in effect at the time the chamber or fume hood was approved for FP testing will be followed at all times.

b. Place the test item in the test chamber and equilibrate for 24 hours or until it reaches a stable temperature of 30 \pm 5°C. Environmental conditions specified for the test chamber will be maintained and recorded throughout the test.

4.3.5.5 Contamination and Sampling.

- a. Select, describe, and photograph representative areas of the test item for FP sampling. Each of these 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 Microtiter[®] plate-sealing tape and sample the first area in each set. This patch sample will be used to measure pretest (background) contamination.
- c. Contaminate the air inside the chamber to a level of approximately 1×10^6 FP particles/L of air by aerosolizing dry FP, using a laboratory FP dissemination apparatus. The desired contamination level on exterior surfaces is 2.5×10^5 particles/ 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. Allow 1 hour for fallout contamination of the test item. Air-wash the chamber for 1 hour to reduce chamber air contamination.
- e. After the 1-hour air-wash and before decontamination of the test item, use a second 4-cm^2 patch of Microtiter[®] tape and sample the second area from each set of three to measure the surface FP contamination density.

4.3.5.6 Decontamination of the Test Item. The 1-hour chamber air-wash will substitute for the 1-hour weathering time. Start decontamination immediately after sampling the test item for FP contamination level.

- a. Use only standard decontamination methods, procedures, and decontaminants. Decontamination procedures for specific items are described in Reference 8. 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 will have item-specific decontamination procedures intended to supplement those in Reference 8. These should be followed when supplied as part of the test documentation package.
- b. Determine the time allowed for the decontamination of each test item, and remain within the time established. The decontamination process should last no longer than 75 minutes, excluding agent monitoring time.

c. FP can be reaerosolized easily; therefore, any contaminated chamber surfaces should be avoided or vacuumed immediately after the initial contamination sampling has been completed.

d. Decontaminate the entire surface of the test item. Sampling areas should receive no more or no less attention, time, or effort than areas not designated for sampling. Spend appropriate time working on angles and hard-to-work areas. Make detailed records of any area that falls into this category.

4.3.5.7 Post-decontamination Sampling.

a. After decontamination and when the test item surface is dry, use a patch of Microtiter[®] tape to sample the third area from each sample set to determine the residual contamination remaining on the test item. Calculate the contamination reduction values. If the contamination reduction values do not meet the NBC 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 procedures used for each additional decontamination and sampling cycle.

b. After each contamination/decontamination cycle, inspect all exterior surfaces of the test item for evidence of deterioration or buildup of deposits or sludge that could affect test item performance. Give special attention to any area that might allow contaminants or decontaminants to penetrate below the surface.

4.3.6 Hardness Determination.

a. If the review of the probable modes for failure of the test item (Paragraph 3.1.d) indicates that nuclear decontamination could affect operational performance significantly, the hardness test should include one or more contamination/decontamination cycles with nuclear simulant FP.

b. After decontamination and the final Microtiter[®] tape samples have been taken, inspect external surfaces for evidence of degradation caused by the decontamination process. Operate the test item according to the operator's manual, and measure and record all mission-essential functional performance data. Measure each characteristic at least twice, depending on the inherent difficulty in reproducing a specific value, and compare the measurements with pretest values. Interview test item operators and record any indications of operational degradation attributable to the five contamination/decontamination cycles. Schedule hardness testing over a 30-day period.

4.3.7 Data Reduction, Presentation, and Evaluation.

- a. Describe each sampling area and give the location, material of construction, surface geometry, and surface texture. Cite the decontaminant and the decontaminating procedures used, including references to field manuals and/or item-specific decontamination procedures.
- b. Summarize and present the chamber conditions during the test period, including air movement, temperatures, and RH. Compare the contamination densities achieved with the target values. Present FP contamination density and the residual contamination remaining for each sampling area. Identify and explain any deviations from established criteria.
- c. Calculate the FP decontamination reduction ratio achieved by the decontamination process (the item challenge contamination level divided by the residual contamination level) for each location sampled. Compare the calculated decontamination ratio values with the NBC contamination survivability criterion for nuclear debris.
- d. Data reduction and presentation for hardness are the same as those in Paragraph 4.1.6.3.

4.4 NBC Compatibility.

4.4.1 Objective. Determine if mission-essential equipment can be operated, maintained, and resupplied by troops wearing the full NBC protective ensemble (MOPP4).

4.4.2 Criterion/Conditions.

4.4.2.1 Criterion. Excluding heat stress, degradation of troop performance of mission-essential tasks will be no greater than 15 percent below levels specified for these tasks when accomplished in a non-NBC environment.

4.4.2.2 Controls and Limitations.

- a. Meteorological conditions during testing must match those of areas of intended use. Paired comparisons should be planned, thus eliminating meteorological conditions as a source of variation in comparing test item performance with and without the wearing of NBC protective clothing.
- b. NBC compatibility tests should be based on a test design that considers all variables, such as the level of operator NBC 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) personnel on NBC compatibility tests to the maximum extent possible.
- e. Any crews who have been in MOPP4 clothing for more the 75 minutes should be given an overnight rest period before participating in another trial.

4.4.3 Data Required.

- a. A listing of mission-essential tasks identified by the combat developer for the equipment undergoing NBC compatibility testing. Include all pretest task performance estimates for the mission-essential tasks.
- b. Soldier tasks/equipment performance measurements made with operators wearing standard battledress and NBC protective clothing.
- c. Temperature, wind speed, RH, 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 occurring during compatibility tests.
- g. Descriptions and photographs of all clothing and protective ensembles, including pretest and posttest inspection information of the protective ensemble.

4.4.4 Methods and Procedures.

4.4.4.1 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 specified for the equipment.

4.4.4.2 Test Site Operations. Configure the decontamination test site to match the deliberate decontamination site described in Reference 8. Although the simulants used in decontamination tests are generally common industrial chemicals of low toxicity and negligible environmental impact, many decontaminants are highly reactive compounds or may contain hazardous components and must be recovered for disposal IAW hazardous waste guidelines.

4.4.4.3 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 personnel, and the sequence of tasks to be measured. Clearly specify the exact measurements to be taken, the sequence in which they are to be taken, and the instruments or measuring devices. Maximum 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 NBC protective gear trials to be conducted 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.

4.4.4.4 Test Conduct.

- a. Perform the scenario once in battledress and another time in NBC protective clothing, with both crews operating simultaneously. Switch crews and repeat. Repeat this sequence until the decision point specified in the statistical design has been reached. To avoid bias on the final trial, do not inform SOMTE personnel of the number of replicates to be conducted.
- 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 NBC protective clothing 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 trials at times and seasons when heat stress will be at a minimum. The factors outlined in Technical Bulletin - Medical (MED) 507⁹, together with the use of a stress meter, should serve as guides in identifying and controlling heat stress whenever meteorological conditions and level of exertion indicate that a potential heat-stress problem exists.

4.4.5 Data Reduction, Presentation, and Evaluation.

- a. Tabulate performance data for each task completed in battledress and in NBC protective clothing; present as paired comparisons.
- b. If questionnaires are used, tabulate and summarize questionnaire data from crew members or observers), highlighting any operational difficulties attributed to the wearing of NBC protective clothing. Contrast questionnaire data for the two sets of trials and interpret results (see also Paragraph 1.3.c).
- c. Summarize and present meteorological data and heat-stress meter data.
- d. Identify data gaps and discuss instances where data were inconclusive.

5. DATA REQUIRED.

Separate data sets are required for the three test procedures, Chemical Contamination Survivability, Biological Contamination Survivability, and Nuclear Contamination Survivability.

5.1 Chemical Contamination Survivability.

Requirements are specified in paragraphs 4.1.4a through 4.1.4o.

5.2 Biological Contamination Survivability.

Requirements are specified in paragraphs 4.2.4a through 4.2.4m.

5.3 Nuclear Contamination Survivability.

Requirements are specified in paragraphs 4.3.4a through 4.3.4l.

6. PRESENTATION OF DATA.

6.1 Chemical Contamination Survivability.

6.1.1 Decontaminability data should include a description of the as received test item or "mock-up", identifying any damage and specific conditions of the surface to be exposed to agents. Receipt inspection photographs are important. Differences between the mock-up and test item are described. Levels of contamination agent and decontaminant should be presented for each test, along with residual levels. Video of the decontamination process should be made and reviewed to identify any unique techniques or cautions. Compile a tabulation of results (residual contamination) along with the Approved NBC contamination survivability criteria (Table 1,

Appendix B). Prepare a narrative analysis of the decontamination procedure and a separate analysis of effects, considering test item mission, operator position, and possible remedial measures to counter hazardous conditions where present. Refer to paragraph 4.1.6 for further detail on processing of data.

6.1.2 Hardness data will be presented in a format to show direct comparison of pre-exposure and post-exposure mission essential performance of the test item. Refer to paragraph 4.1.6.2 for further detail on presenting hardness data.

6.2 Biological Contamination Survivability.

6.2.1 Decontaminability data should include a description of the as received test item or "mock-up", identifying any damage and specific conditions of the surface to be exposed to biological spores. Receipt inspection photographs are important. Differences between the mock-up and test item are described. For each agent used, identify the contamination density (spores per square meter), area to which applied, surface material, texture and temperature, and chamber temperature, humidity and wind conditions. Also tabulate decontamination solutions, equipment, procedures, and decontamination time. Video of the decontamination process should be made and reviewed to identify any unique techniques or cautions. Compile a tabulation of results (residual contamination) along with the Approved NBC contamination survivability criteria of 500 spores/square meter. Refer to paragraph 4.2.6 for further detail on presenting biological test results.

6.2.2 Hardness data will be presented in a format to show direct comparison of pre-exposure and post-exposure mission essential performance of the test item. Reports on hardness will contain comparisons of specific performance parameters for each of 5 decontamination procedures over a 30-day period.

6.3 Nuclear Contamination Survivability.

6.3.1 Decontaminability data should include a description of the as received test item or "mock-up", identifying any damage and specific conditions of the surface to be exposed to nuclear fallout simulant. Receipt inspection photographs are required of exterior materials, construction, paint, cleanliness, joints and crevices. Record the contamination level on exterior surfaces (as close to 2.5×10^5 particles/cm² as possible). Also tabulate decontamination solutions, equipment, procedures, and decontamination time. Video of the decontamination process should be made and reviewed to identify any unique techniques or cautions. Compile a tabulation of results (residual contamination) along with the approved NBC contamination survivability criteria of 25cGy rad/mission. Refer to paragraph 4.3.7 for further detail on presenting nuclear test results.

6.3.2 Hardness data will be presented in a format to show direct comparison of pre-exposure and post-exposure mission essential performance of the test item. Reports on hardness will contain comparisons of specific performance parameters for each of 5 decontamination procedures over a 30-day period.

6.4 NBC Compatibility.

6.4.1 Present crew performance data (time to perform function) in tabular form comparing regular battledress and MOPP IV clothing.

6.4.2 Summarize questionnaire data in narrative form highlighting crew difficulties.

6.4.3 Tabulate meteorological and heat-stress meter data.

6.4.4 Identify data gaps and discuss instances where data is inconclusive.

APPENDIX A. CHECKLIST.

SAMPLE CHECKLIST FOR SMALL ITEMS OF EQUIPMENT

Item No. Event or Procedure	Clarifying Information	Date Completed
1. Test directive received		_____
2. Test director assigned	Name: _____	_____
	Telephone: _____	_____
	E-mail: _____	_____
3. Cost estimate prepared	\$ _____ M/hr _____	_____
4. Project funded	Full _____ Partial \$ _____	_____
	Additional funds \$ _____	_____
5. Test plan started		_____
6. Test literature review completed		_____
7. Mission-essential tasks identified		_____
8. Test item examined	Problem areas identified	_____
	Sampling areas identified	_____
9. Test plan completed		_____
10. Test plan approved		_____
11. Test items received	Complete _____ Partial _____	_____
12. Special materials ordered		_____
13. Special equipment ordered		_____

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Item No. Event or Procedure	Clarifying Information	Date Completed
14. All materials on hand		_____
15. All equipment on hand		_____
16. Environmental impact assessment on file		_____
17. Test safety approved	Name: _____	_____
18. Receipt inspection completed		_____
19. Item technical manuals, operating instructions, etc., on hand		_____
20. Test item baseline mission-essential performance data completed		_____
21. Contamination devices calibrated		_____
22. Decontamination procedures ready		_____
Item-specific procedures included		_____
23. SOMTE and/or other trained personnel available		_____
24. Test chamber(s)/hood(s) approved		_____
25. Test team trained and ready		_____
26. First decontaminability test performed		_____

Agent: _____
Contamination density: _____
Decontamination: _____
Visual inspection: _____
Safe for next test: _____
All data calculated and assembled: _____
Other: _____

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Item No. Event or Procedure	Clarifying Information	Date Completed
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27. Second decontaminability test performed

Agent: _____
Contamination density: _____
Decontamination: _____ Visual inspection: _____
Safe for next test: _____
All data calculated and assembled: _____
Other: _____

28. Third decontaminability test performed

Agent: _____
Contamination density: _____
Decontamination: _____ Visual inspection: _____
Safe for next test: _____
All data calculated and assembled: _____
Other: _____

29. Fourth decontaminability test performed

Agent: _____
Contamination density: _____
Decontamination: _____ Visual inspection: _____
Safe for next test: _____
All data calculated and assembled: _____
Other: _____

30. Fifth decontaminability test performed

Agent: _____
Contamination density: _____
Decontamination: _____ Visual inspection: _____
Safe for next test: _____
All data calculated and assembled: _____
Other: _____

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Item		Date
No. Event or Procedure	Clarifying Information	Completed
31. Operator background information on file		_____
32. All test items operating and maintenance performed		_____
33. Troop training/pilot test		_____
34. First compatibility test performed		_____
	Meteorological conditions satisfactory: _____	
	Battledress trial: _____	
	MOPP4 trial: _____	
	Operator questionnaires: _____	
	Heat stress problems?: _____	
	Ready for next test: _____	
	All data calculated and assembled: _____	
	Other: _____	
35. Second compatibility test performed		_____
	Meteorological conditions satisfactory: _____	
	Battledress trial: _____	
	MOPP4 trial: _____	
	Operator questionnaires: _____	
	Heat stress problems?: _____	
	Ready for next test: _____	
	All data calculated and assembled: _____	
	Other: _____	
36. Decontamination and other waste properly packaged and disposal of it		_____
Disposal completed		_____
37. Test item(s) returned		_____

APPENDIX B. QUADRIPARTITE STANDARDIZATION AGREEMENT 747 EDITION 1.

DECLARATION OF ACCORD

1. SCOPE OF AGREEMENT.

This agreement has been approved for use by the Armies of the United States, United Kingdom, Australia, and Canada as the standard NBC Contamination Survivability Criteria to be applied to all mission-essential military equipment.

The United States, United Kingdom, Canada, and Australia agree that they will, in the course of designing and testing mission-essential military equipment, use the NBC Contamination Survivability Criteria detailed in this agreement. The subscribing Armies also agree that, once applied to a developmental piece of equipment, the criteria will be modified only if they cannot be met for proven economic, technical, or operational reasons.

The subscribing Armies further accept that they will consult and in every possible case reach mutual agreement on all changes of modifications affecting the agreed degree of standardization before the introduction of such changes or modifications. This agreement may be reviewed or canceled by agreement of the subscribing Armies.

2. CONTINUITY AND RELATED AGREEMENTS.

a. Continuity: QSTAG 747 was prepared as a result of recommendations made, and is based on a concept paper agreed at the Third Meeting of the Quadripartite Working Group on Nuclear-Biological-Chemical Defense held in May 81. A final draft of QSTAG 747 was accepted at 9 QWG/NBCD held in May 90. The United States is the Custodian Army.

b. Related Agreements: QSTAG 244, QSTAG 260.

3. RELEASE TO NATO.

This QSTAG will be released to the North Atlantic Treaty Organization by the Primary Standardization Office.

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4. National Ratifying References - Details of Implementation.

Nation	Ratifying Reference	National Implementing Document	Date of Implementation Services				
			Forecast	Actual	A	N	A F
US	AMCICP-AA(34-1d) dated 6 Feb 91	Quantitative NBC Contam. Surviv'ty Criteria & Prog Mang't Directive for CW Defense		Feb 89	X	-	R
UK	LSOR4/8333	TBA	On Promulgation		X	-	X
CA	2510-5-747 (DNBCC) dated 26 Oct 90	CFB 316, Vol 12		Jan 91	X	X	X
AS	A90 31986 dated 25 July 1991	TBA	On Promulgation		X	X	X
NZ							

5. Reservations.

US: The US Air Force reserves the right to reduce contamination levels for liquid agents VX and HD based on standards expected to be developed by NATO.

BY THE WASHINGTON STANDARDIZATION OFFICERS:

//signed//
WILLIAM H. FORSTER
Major General
United States Army

//signed//
EDMUND F.G. BURTON
Brigadier
British Army

//signed//
IAN C. DOUGLAS
Brigadier General
Canadian Forces

//signed//
JOHN H. ROBBINS
Brigadier
Australian Army

12 Aug 1991
(Date Signed)

NBC CONTAMINATION SURVIVABILITY CRITERIA FOR MILITARY EQUIPMENT

DETAILS OF AGREEMENT

1. INTRODUCTION.

1.1 PURPOSE.

The purpose of this agreement is to standardize quantitative criteria for all mission-essential military equipment to survive the effects of nuclear, biological, and chemical (NBC) contamination and the resulting decontamination process.

1.2 SCOPE AND USE.

1.2.1 Standard criteria, expressed in terms of decontaminability, hardness, and compatibility, are provided to ensure that the mission-essential military equipment survives the effect of:

- contamination by chemical and biological agents.
- radioactive contaminants and neutron induced activity.
- decontamination processes.

(Criteria for surviving the initial effects of nuclear weapons are excluded from the scope of this agreement and are covered separately in QSTAGS 244 and 620.)

1.2.2 These NBC Contamination Survivability Criteria will be stated as essential characteristics in appropriate requirements documents and used to design and test the survivability of mission-essential equipment under development. Once applied to a developmental piece of equipment, these criteria will be modified only upon consideration of proven economic, technical, and/or operational reasons.

1.2.3 These criteria are engineering design criteria intended for use only in a developmental setting. 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, or specify survivability in training environments.

1.3 DEFINITIONS.

1.3.1 NBC Contamination Survivability - capability of a system and its crew to withstand an NBC-contaminated environment, including decontamination, without losing the ability to accomplish the assigned mission. Characteristics of NBC Contamination Survivability are decontaminability, hardness, and compatibility.

1.3.2 Mission-Essential Equipment - equipment necessary to accomplish primary or secondary missions of a unit or organization.

1.3.3 Mission-Essential Functions - minimum operational tasks that a system is required to perform in order to accomplish its mission profile.

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

1.3.5 Decontaminability - ability of a system to be rapidly and effectively decontaminated to reduce the hazard to personnel operating, maintaining, and resupplying it.

1.3.6 Hardness - ability of a system to withstand the damaging effects of NBC contamination and any decontamination agents and procedures required to decontaminate it.

1.3.7 Compatibility - ability of a system to be operated, maintained, and resupplied by personnel wearing the full NBC protective ensemble.

2. BACKGROUND.

2.1 The nuclear, biological, and chemical threat to ABCA nations is well documented. It follows that ABCA armies must be trained, organized, and equipped to operate effectively on a battlefield that includes nuclear, biological, and chemical environments. Accordingly, mission-essential items of materiel must survive these environments.

2.2 The Quadripartite Working Group on NBC Defense approved in May 1981 a concept for survivability of materiel contaminated by chemical or biological agents or residual nuclear radiation. This QSTAG is based on that concept.

3. PHILOSOPHY.

3.1 Criteria standardized herein are based on the following philosophy:

A soldier or crew surviving an NBC attack should be able to continue using mission-essential systems and equipment in a full protective ensemble if necessary. When the mission permits, the systems and equipment should be capable of rapid restoration to such a condition that all essential operations can be continued in the lowest protective posture consistent with the mission and threat, and without long-term degradation of the materiel.

3.2 NBC contamination is pervasive and can be widespread, but does not generally damage

equipment immediately. Thus, equipment would be available for continued use in the mission and could be employed if the soldier can perform his tasks while protected from the toxic effects. Likewise, since equipment is not immediately damaged by NBC contaminants, it should be capable of being decontaminated and restored to conditions such that the soldier can operate in clothing consistent with the threat and such 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 soldier.

4. CHARACTERISTICS OF NBC CONTAMINATION SURVIVABILITY.

NBC contamination survivability is comprised of the three elements of decontaminability, hardness, and compatibility. To survive NBC contamination, equipment must meet criteria of all three.

4.1 Decontaminability.

4.1.1 The ability of a system to be decontaminated to reduce the hazard to personnel operating, maintaining, and resupplying it is termed "decontaminability." Key words in this definition are the necessity to reduce the hazard to personnel. Thus, decontaminability criteria are related to personnel response to chemical and biological agents and to residual nuclear radiation.

4.1.2 Even under a "fight dirty" concept of operations where partial decontamination is the rule rather than the exception, decontaminability is required. NBC contaminants could eventually breach the shield of the protective ensemble and, when operations permit, should be removed where they present a hazard. Further, decontamination reduces the soldier's vulnerability when the shield is dropped to satisfy basic physiological needs or to replace components of the NBC protective ensemble. Thus, decontaminability criteria are related to the response of unprotected personnel.

4.1.3 Decontaminability is enhanced by considering:

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

4.1.3.2 Design. Incorporate designs that reduce or prevent accumulation of NBC contamination and make those areas that are exposed readily accessible for decontamination.

4.1.3.3 Contamination Control. Employ devices and means that reduce the amount of contamination to be removed, such as positive overpressure systems for combat vehicles, packaging for supplies, and protective covers.

4.1.3.4 NBC Equipment. Provide for integration of NBC detection, measurement, decontamination, and contamination control devices. Consideration for integration of such devices at the earliest stage of the materiel acquisition process promotes maximum achievement of effective contamination avoidance, control, removal, and decontamination verification.

4.1.4 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 agent concentration to time, temperature, windspeed, and threat parameters.

4.2 Hardness.

4.2.1 The ability of a system to withstand the damaging effects of NBC contamination and decontamination agents and procedures require to carry out the decontamination process is termed "hardness." Although strongly related to decontaminability, hardness is a distinct characteristic; decontaminability is concerned with reducing the hazard to personnel as a result of decontamination efforts, while hardness is concerned with condition of the equipment after it has been subjected to an agent and decontamination.

4.2.2 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.

4.3 Compatibility.

4.3.1 The ability of a system to be operated, maintained, and resupplied by personnel wearing the full NBC protective ensemble is termed "compatibility." Even if a piece of equipment is completely hardened against NBC contamination and decontaminants and can also be easily decontaminated, it still must have the capability of being operated effectively while in an NBC contaminated environment. Thus, in the development of equipment designed to perform mission-essential functions one must consider the combination of the equipment and personnel in anticipated NBC protection.

4.3.2 Collective protection enhances compatibility because it provides crew members a clean environment until they must exit to perform some essential task outside the enclosure. Unless individual protective gear is decontaminated or discarded, reentering crewmen will enter dirty. In some cases, agents may enter collective protection enclosures before the equipment is buttoned up. Thus, although collective protection may provide a "shirt sleeve" environment most of the time during a battle, it does not provide compatibility. However, for those systems for

which collective protection does provide a continuous clean environment, the combat developer may elect to fulfill the compatibility requirement by utilizing collective protection. In doing so, he accepts the possibility of crew degradation should contamination enter and the crew be forced to don the individual protection ensemble.

4.3.3 Criteria for compatibility were developed by considering mission profiles of classes of equipment designed to perform mission-essential function, analyzing performance degradation of crew member operating the equipment while in protective ensemble, determining allowable percentage degradations of mission-essential functions, and relating those degradations to time and temperature parameters.

5. STANDARDIZED CRITERIA.

5.1 Decontaminability Criteria. (See explanatory notes in paragraph 5.4.)

DECONTAMINABILITY CRITERION

(CONTAMINANTS)

The exterior and interior surfaces of materiel developed to perform mission-essential functions shall be designed such that NBC 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 1) to unprotected personnel working inside, on or 1 meter from the item. The following (worst case) conditions apply:

Exterior surfaces initially are uniformly and separately contaminated with 10 g/m^2 of thickened droplets of GD having a mass median diameter (MMD) of 2-5mm.

10 g/m^2 of unthickened VX.

10 g/m^2 of unthickened HD.

10^5 spores/ m^2 of biological agent 1-5 micrometers in size.

4 g/m^2 of insoluble radioactive contaminants 37-200 micrometers in size and 185 GBq/m^2 gamma activity.

Initial contamination levels on interior surfaces subject to contamination are a factor of 10 lower than on exterior surfaces in the absence of evidence to the contrary.

Decontamination begins 1 hour after contamination using standard field decontaminants or simulants, equipment and procedures; and the decontamination process, excluding monitoring,

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lasts no longer than 75 minutes.

Suitable simulants may be used in lieu of the stated threat agents.

Exposure of unprotected personnel to the decontaminated materiel is not to exceed 12 hours based on the mission profile determined by the combat developer.

Surface temperature is 30°C and exterior wind speed no greater than 1 m/s (3.6 km/h).

(INDUCED ACTIVITY)

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 (rad) to the crew of the equipment, the neutron induced activity in the item will result in no more than a negligible risk (as defined in table 1) to unprotected personnel arriving at H+2 and remaining inside, on, or 1 meter from the item for a period of time based on the mission profile, not to exceed 12 hours.

5.2 Hardness Criterion. (See explanatory notes in paragraph 5.4.)

HARDNESS CRITERION

Materiel developed to perform mission-essential functions shall be hardened to ensure that degradation over a 30-day period of no more than 20 percent in selected quantifiable mission-essential performance characteristics is caused by 5 exposures to NBC contaminants, decontaminants, and decontaminating procedures encountered in the field.

5.3 Compatibility Criterion. (See explanatory notes in paragraph 5.4.)

COMPATIBILITY CRITERION

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

In meteorological conditions of areas of intended use.

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-NBC environment.

5.4 Explanatory Notes.

5.4.1 Selected negligible risk values are in table 1.

5.4.2 A 1-hour delay prior to beginning decontamination allows time for agent sorption, yet is generally not too long enough to allow elimination of surface hazard by weathering.

5.4.3 Initial contamination levels for interiors are a factor of 10 lower to account for the protection provided by the enclosure. 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.

5.4.4 Seventy-five minutes is a typical time for decontaminating items with present decontamination procedures.

5.4.5 Although surface temperatures of equipment in the field will frequently exceed 30°C, this temperature is optimum for assessing decontaminability because it allows sufficient contamination to remain after the 1-hour sorption/weathering process, yet, causes sufficient outgassing of residual agent following decontamination to adequately evaluate the decontaminability process.

5.4.6 Requiring low airspeeds (less than 3.6 km/hr) results in greater chemical agent concentrations over time.

5.4.7 A radioactive fallout contamination of 185 GBq/m² would result in a H+1 dose rate of approximately 5 cGy (rad)/hr at 1 meter from a typical large armored vehicle. Using 50 cGy (rad) as a negligible risk dose which could come from exposure over a mission profile period (maximum of 12-hours), one half from operational exposure (i.e., direct radiation from initial effects or from fallout on the ground) and the other half from equipment contamination, a decontaminability standard of 25 cGy (rad) dose per mission period is reasonable.

5.4.8 A neutron induced activity dose of 25 cGy (rad) per mission (maximum of 12-hour exposure) should be attainable for all items if reasonable attention is given to problem materials.

5.4.9 The "5 exposure" requirement in the hardness criterion refers to a cumulative total of contamination/decontamination cycles using one or more contaminants and associated decontamination processes.

Table 1. Negligible Risk Values for NBC Contaminants.

CONTAMINANT	VAPOR/AEROSOL	LIQUID ^b
CHEMICAL	(mg min/m ³)	(mg/70-kg man)
VX	0.25 (0.02 for visual acuity) ^a	1.4
GD	2.5 (0.5 for visual acuity) ^a	30
HD	50	180 (0.01 mg/cm ²) ^d
BIOLOGICAL ^c		
RADIOLOGICAL	(maximum of 12 hour exposure)	
Contaminants	25 cGy (rad)	
Induced Activity	25 cGy (rad)	

^a Applies to pilots.

^b Applies to skin dose, not absorption through the eyes.

^c Negligible risk values for biological agents are not determinable with the present database. Since extremely minute quantities of some biological agents can cause incapacitation, equipment should be designed to allow a residue of no more than 500 spores/m² of the specified initial contamination levels

^d Since the effect of HD is localized, it is not appropriate to consider a threshold dose of liquid HD as applying to the entire 70-kg man. Use of mass/body surface area (mg/cm²) units to describe the dose for which negligible effects are observed is preferable with the provision that the location and surface area must be specified, since mild incapacitation depends on where the contamination exists and the extent of body surface involved.

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APPENDIX C. ABBREVIATIONS.

ACAMS	- automatic continuous air monitoring system
AMC	- Army Materiel Command
AMCR	- Army Materiel Command Regulation
AR	- Army regulation
BG	- <i>Bacillus subtilis</i> var. <i>niger</i>
C _e	- effective average concentration
CGy	- centigray (rad)
CFU	- colony forming unit(s)
DA	- Department of the Army
DTP	- detailed test plan
DS-2	- decontaminating solution number 2
EA	- environmental assessment
FD/SC	- failure definition/scoring criteria
FM	- field manual
FP	- fluorescent particle
GD	- chemical agent soman
HD	- chemical agent distilled mustard
IAP	- independent assessment plan
IAW	- in accordance with
IEP	- independent evaluation plan
MED	- medical
MIL-STD	- military standard
MINICAMS®	- miniature automatic continuous air monitoring system
MIRAN®	- miniature infrared analyzer
MMD	- mass median diameter
MOPP4	- mission-oriented protective posture level 4
MOS	- military occupational specialty
NBC	- nuclear, biological, and chemical
NEPA	- National Environmental Policy Act
NIGA	- neutron-induced gamma activity
OMS/MP	- operational mode summary/mission profile
PAM	- pamphlet
psi	- pounds per square inch
QSTAG	- Quadripartite Standardization Agreement
RDT&E	- research, development, test, and evaluation
REC	- record of environmental consideration
RH	- relative humidity
RTM	- real-time monitor
SOMTE	- soldier, operator, maintainer, tester, and evaluator
SOP	- standing operating procedure

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TGD	- thickened soman
TOP	- test operations procedure
VX	- a persistent nerve agent

APPENDIX D. REFERENCES.

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Forward comments, recommended changes, or any pertinent data that may be of use in improving this publication to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TM-T, Aberdeen Proving Ground, Maryland 21005-5055. Technical information may be obtained from the preparing activity: Commander, U.S. Army Dugway Proving Ground, ATTN: STEDP-WD-C-CT, Dugway, Utah 84022-5000. Additional copies are available from the Defense Technical Information Center, 8725 John J. Kingman Road, Ft. Belvoir, Virginia 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.