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# Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Durability of Protective Ensembles and Ensemble Components[1]

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## INTRODUCTION

Workers involved in the production, use, storage, maintenance, and transportation of chemicals can be exposed to numerous substances capable of causing harm upon contact with the human body. The deleterious effects of these chemicals can range from acute trauma, such as dermatitis or burns, to chronic degenerative disease, such as cancer or pulmonary fibrosis. Since engineering controls may not eliminate all possible exposures, attention is often given to reducing the potential for direct skin contact through the use of protective clothing that resists degradation, penetration, and permeation.

Chemical-protective ensembles range from outfits of gloves, boots, and coveralls to totally-encapsulating ensembles employing self-contained or airline-supplied, breathing apparatus. The ensemble of chemical-protective clothing in combination with gloves, boots, a breathing apparatus, and other auxiliary protective equipment can provide maximum protection to wearers in situations when no contact with hazardous chemicals is permitted. Chemical-protective ensembles are often selected on the basis of material chemical resistance, but equally important are the comfort, fit, functionality, and overall integrity of the ensemble allowing the wearer to safely carry out his or her assigned tasks. Few standards, if any, apply to the design and manufacture of chemical-protective ensembles. Additionally, protective clothing designs vary depending on different end use applications in industrial settings, hazardous waste site clean up, and emergency response. As a consequence, users are faced with a variety of commercial products and generally depend on manufacturer sales information to decide which protective clothing is appropriate for their own application. Other protective equipment such as gloves, boots, respiratory protective equipment, communications systems, and cooling devices must also be selected and integrated with the chemical-protective clothing to provide an ensemble with adequate protection.

This standard is intended to provide standardized methods for qualitatively evaluating the comfort, fit, function, and durability of chemical-protective ensembles and ensemble components. It may also be used by protective clothing manufacturers to assess current or proposed designs.

## 1. Scope

1.1 These practices are intended for evaluating chemical-protective ensembles and ensemble components to determine the suitability of the ensemble or ensemble components in a work environment on the basis of its comfort, fit, function, and durability.

1.1.1 *Option A* is a manned exercise scenario intended to test the strength and durability of the ensemble components.

1.1.2 *Option B* is a manned work task scenario intended to determine human factor characteristics and the ability of the suited test subject to perform tasks that may be encountered on a routine basis in a typical work environment.

[1] These practices are under the jurisdiction of ASTM Committee F23 on Personal Protective Clothing and Equipment and are the direct responsibility of Subcommittee F23.30 on Chemicals.

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1.2 These practices apply to most chemical-protective ensembles and ensemble components.

1.3 The values as stated in inch-pound units are to be regarded as the standard. The values in parentheses are given for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific safety precautions are given in Section 7.

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

F1052 Test Method for Pressure Testing Vapor Protective Suits

F1359 Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin

2.2 *OSHA Specifications:*[3]

29 CFR Part 1910.25 Portable Wood Ladders

29 CFR Part 1910.26 Portable Metal Ladders

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *chemical-protective suit ensemble, n*—the combination of protective clothing with respiratory protective equipment, hoods, helmets, gloves, boots, communications systems, cooling devices, and other accessories intended to protect the wearer from a chemical hazard when worn together.

3.1.2 *degradation, n*—the deleterious change in one or more properties of a material.

3.1.3 *hazardous chemical*—any solid, liquid, gas, or mixture thereof that can potentially cause harm to the human body through inhalation, ingestion, or skin absorption.

3.1.4 *penetration, n*—for chemical protective clothing, the movement of substances through voids in protective clothing materials or item on a non-molecular level.

3.1.4.1 *Discussion*—Voids include gaps, pores, holes and imperfections in closures, seams, interfaces and protective clothing materials. Penetration does not require a change of state; solid chemical move through voids in the material as solids, liquids as liquids and gases as gases. Penetration is a distinctly different mechanism from permeation.

3.1.5 *permeation, n*—for chemical protective clothing, the movement of chemicals as molecules through protective clothing materials items by the processes of (*1*) absorption of the chemical into the contact surface of the material, (*2*) diffusion of the absorbed molecules throughout the material, and (*3*) desorption of the chemical from the opposite surface of the material.

3.1.5.1 *Discussion*—Permeation is a distinctly different mechanism from penetration.

3.1.6 *protective clothing, n*—an item of clothing that is specifically designed and constructed for the intended purpose of isolating all or part of the body from a potential hazard; or, isolating the external environment from contamination by the wearer of the clothing.

## 4. Summary of Practices

4.1 In Option A, the durability of the chemical-protective ensembles and ensemble components are evaluated by subjecting the protective ensemble to a manned exercise scenario. The suit is inspected prior to and after the series of exercises to assess any changes in the garment's integrity.

4.2 In Option B, the function of the chemical-protective ensemble and ensemble components are evaluated by observing the ability of a test subject to perform routine work tasks while wearing the protective ensemble. As in Procedure A, the suit is inspected prior to and after the series of tasks to assess changes in the garment's integrity.

4.3 For each option, the fit and comfort of the chemical-protective ensemble and ensemble components are assessed by measuring the test subject's body dimensions and mass, and the dimensions and mass of the ensemble. These measurements can be qualitatively used to evaluate fit and comfort by relating test subject and ensemble measurements to test subject responses following each test.

## 5. Significance and Use

5.1 These practices establish standard procedures designed for qualitatively evaluating the performance characteristics of chemical-protective suit ensembles in terms of comfort, fit, function, and durability.

5.2 These practices are suitable for both end users and manufacturers to evaluate performance characteristics of ensembles and ensemble components.

5.2.1 End users may use these practices to qualitatively determine how well ensembles and ensemble components (gloves, boots, breathing apparatus, communications systems, and cooling devices) meet their particular application.

5.2.2 Manufacturers of ensembles and ensemble components may use these practices to determine the qualitative performance characteristics in existing or proposed designs.

5.3 Procedure A permits a *qualitative* evaluation of chemical-protective suit integrity (materials, seams, and components) by subjecting the protective ensemble to a manned exercise routine. Option B permits a *qualitative* evaluation of ensemble and component function. Each procedure can be used to assess ensemble comfort and fit by relating test subject responses and by comparing the dimensions and weights of both the test subject and suit.

NOTE 1—The accumulation of suit and human subject dimension data may eventually be used by manufacturers or end users in standards to improve the sizing of chemical-protective suits and the integration of ensemble components in protective ensembles.

5.4 The use of these practices is for qualitative purposes only. In general, results from use of these practices on one type

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The *Code of Federal Regulations* is available from the Superintendent of Documents, Government Printing Office, Washington, DC 20401.

ensemble may not be comparable to other test results on a different ensemble due to the subjective nature of test results.

5.5 These practices are not intended to assess heat stress resulting from wearing a chemical-protective ensemble, although thermal comfort of the suit ensemble may be subjectively evaluated.

5.6 End users and manufacturers of chemical-protective ensembles and ensemble components should consider these practices to be *minimum* procedures for evaluating ensemble and component performance characteristics. Users of these practices may wish to consider additional tests and procedure that relate directly to their particular application. Each facility performing these practices should establish its own criteria for assessing acceptable ensemble performance.

## 6. Apparatus

6.1 *Fiberboard Boxes*—Four standard shipping containers of not less than 1.5 $ft^3$ (0.03 $m^3$) and not exceeding 2 $ft^3$ (0.06 $m^3$) and filled with a non-hazardous material weighing 20 lb (9.1 kg). The container shall be packed in such a way as to preclude any internal movement or shifting of the mass.

6.2 *Drum*—A standard 55-gal (208-L) drum that is filled with 200 lb (90 kg) of a non-hazardous material.

6.3 *Handtruck*—A standard, commercial grade handtruck that is typically employed for the transportation of 55-gal (208-L) drums.

6.4 *Valve*—Any standard handwheel valve, or similar representation, that may be vertically mounted in such a manner to provide actuation in the overhead position (placed at least at the same height as the test subject). The valve handle should be a minimum of 7 in. (1179 ± 25 mm) in diameter and a maximum of 8 in. (203 mm) in diameter.

6.5 *Wrench*—A 10-in. (254-mm) crescent wrench.

6.6 *Screwdriver*—A 10-in. (254-mm) slotted end screwdriver.

6.7 *Blot and Screw Assembly*—A metal stand shall be threaded for a ½-13 UNC size bolt and a ⅜-16 UNC screw. A ½-13 UNC 2-in. (51-mm) long hex head bolt shall be provided for bolt installation and removal exercises. A ⅜-16 UNC 2-in. (51-mm) long slotted round head screw shall be used for screw installation and removal exercises. The metal stand shall be placed on a waist-high table for the operations.

6.8 *Hoses*—Two vinyl or chloroprene hoses with a 1-in. (25-mm) outside diameter. Individual hose length shall be 25-ft (7.6 m). One hose should have screw type connections and the other should have quick-connect connections. The type of connection shall be documented in the report.

6.9 *Ladder*—Nine-foot (2.7-m) or longer ladder (the ladder should be supported by at least one assistant and used in accordance with 29 CFR 1910.25 and 29 CFR 1910.26).

6.10 *Tape Measures*—Any non-rigid tape measure suitable for measuring human body dimensions, or anthropometer, (with graduations of 1/16 in. (1 mm)); a second rigid standard tape measure for measuring dimensions up to 8 ft (2.4 m).

6.11 *Weight Scales*—Human weighing scales with a range of 0 to 300 lb (0 to 136 kg).

6.12 *Thermometer*—A standard thermometer or other temperature measuring device capable of measuring environmental temperatures ranging from −20 to 120°F (–28.5 to 49.2°C).

6.13 *Wet Bulb Thermometer or Hygrometer*—Any device capable of making measurements for determining environmental relative humidities.

## 7. Safety Precautions

7.1 A safety monitor shall be present during all testing specified in this test method. The safety monitor shall continuously observe the condition of the test subject.

7.2 Testing shall be stopped and the subject removed from the protective ensemble for any of the following reasons: request of the test subject, or indications of shortness of breath, difficulty in breathing, fatigue, flushed face, profuse sweating, erratic movements, coughing, nausea, or cramps in the test subject.

7.3 Test subjects should be in good physical condition, experienced in the use of protective clothing, and well hydrated before performing these tests.

7.4 Emergency equipment, such as drinking containers filled with cold water and liquids such as fruit juices, etc., to replace body fluids, should be readily accessible at the test area.

7.5 The selection of breathing apparatus and other ensemble components shall take into account the length of the test and the burden on the test subject.

## 8. Procedures

8.1 Select the chemical-protective ensemble and components to be used during test. Record applicable data for each item including, but not limited to the following:

8.1.1 Type of component (garment, respirator, glove, boot, helmet, etc.);

8.1.2 Manufacturer;

8.1.3 Model number, serial number;

8.1.4 Size;

8.1.5 General description of suit, glove, boot, and visor materials;

8.1.6 Special component features; and

8.1.7 Any relevant component dimensions (that is, height and girth).

8.2 Before each exercise scenario:

8.2.1 Visually inspect each ensemble component for flaws or defects in the operation, materials, interfaces, and seams. An illustration of the ensemble, such as that given in Fig. 1, may be used to mark and record the location of imperfections.

8.2.2 Evaluate the ensemble barrier performance, if appropriate. For totally encapsulating vapor protective garments use Practice F1052. Evaluate the liquid penetration resistance of liquid protective ensembles using Practice F1359. Ensure that the test ensemble and equipment are the right size for the test subject.