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Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical-Protective Suit Ensembles[1]

This standard is issued under the fixed designation F 1154; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 clothing ensembles range from outfits of gloves, boots, and coveralls to totally-encapsulating chemical-protective suits employing self-contained or airline-supplied, or both, breathing apparatus. The ensemble of a chemical-protective suit 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 suits are often selected on the basis of material chemical resistance, but equally important are the comfort, fit, functionality, and overall integrity of the suit 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 suits. Additionally, protective suit 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 suits are 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 suit to provide an ensemble with adequate protection.

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

1. Scope

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

1.1.1 *Option A* is a manned exercise scenario intended to test the strength and durability of the garment material and seams.

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.

1.2 These practices apply to all types of chemical-protective suits and auxiliary protective equipment including, but not limited to, splash-protective suits, totally encapsulating chemical-protective suits, and gas-tight, totally encapsulating chemical-protective suits.

1.3 The values as stated in inch-pound units are to be regarded as the standard. The values in brackets 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.

[1] These practices are under the jurisdiction of ASTM Committee F23 on Protective Clothing and are the direct responsibility of Subcommittee F23.60 on Ensemble Performance.

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2. Referenced Documents

2.1 *ASTM Standards:* [2]

F 1052 Practice for Pressure Testing of Gas-Tight Totally Encapsulating Chemical Protective Suits

F 1359 Practice for Determining the Liquid-Tight Integrity of Chemical Protective Suits or Ensembles Under Static Conditions

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 a chemical-protective suit (totally encapsulating, splash-protective) with the wearer's respiratory protective equipment, gloves, boots, communications system, and cooling device, or some combination of those.

3.1.2 *degradation, n*—the deleterious change in one or more physical properties of a protective clothing material due to surface contact with a chemical.

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 *overall gas penetration resistance, n,*—the integrity of a totally encapsulating chemical protective suit to resist the inward leakage of gases when exposed to a hazardous chemical environment.

3.1.4.1 *Discussion*—For the purpose of this practice, overall gas penetration resistance is demonstrated by the limited flow of a gas under pressure from the inside of an inflated totally encapsulating chemical protective suit at a prescribed pressure and time interval.

3.1.5 *overall liquid penetration resistance, n*—the integrity of a chemical protective suit to resist the inward leakage of liquids when exposed to a hazardous chemical environment.

3.1.5.1 *Discussion*—For the purpose of this practice, overall liquid penetration resistance is demonstrated by the absence of liquid on the inside of a chemical protective suit when exposed to a liquid spray at a prescribed flow rate, orientation of liquid contact, and time interval.

3.1.6 *penetration, n*—in a protective clothing material or item, the process by which a solid, liquid, or gas moves through closures, seams, interstices, and pinholes or other imperfections on a non-molecular level.

3.1.7 *permeation, n*—the process by which a chemical moves through a protective clothing material on a molecular level.

3.1.7.1 *Discussion*—Permeation involves the following: (*1*) sorption of molecules of the chemical into the contacted (challenge side) surface of the material, (*2*) diffusion of the sorbed molecules in the material, and (*3*) desorption of the molecules from the opposite (collection side) surface of the material.

3.1.8 *protective clothing material, n*—any material or combination of materials used in an item of clothing for the purpose of isolating parts of the wearer's body from direct contact with a hazardous chemical.

3.1.9 *splash-protective suit*—a one or multi-piece garment which is constructed of protective clothing materials, designed and configured to protect the wearer's torso, head, arms, and legs against liquid splashes of hazardous chemicals.

3.1.10 *totally encapsulating chemical-protective suit*—a full body garment that is constructed of protective clothing materials; covers the wearer's torso, head, arms, and legs; may cover the wearer's hands and feet with permanently or tightly attached gloves and boots, completely encloses the wearer by itself or in combination with the wearer's respiratory equipment, gloves, and boots.

4. Summary of Practices

4.1 In Option A, the integrity of the chemical-protective suit, its materials and scams, 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 suit ensemble is 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 suit ensemble 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 overall integrity.

5.2 These practices are suitable for both end users and manufacturers to evaluate chemical-protective suit ensemble performance characteristics.

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

5.2.2 Manufacturers of chemical-protective clothing and equipment may use these practices to determine the qualitative performance characteristics in existing or proposed chemical-protective suit and equipment 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

[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.

exercise routine. Option B permits a *qualitative* evaluation of chemical-protective suit ensemble function. Each procedure can be used to assess chemical-protective suit 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 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 suit ensemble, although thermal comfort of the suit ensemble may be subjectively evaluated.

5.6 End users and manufacturers of chemical-protective suit ensembles should consider these practices to be *minimum* procedures for evaluating protective ensemble 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 lbs [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 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 lbs [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 equipment shall take into account the length of the test and the burden on the test subject.

8. Procedures

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

8.1.1 Type of item (totally encapsulating chemical-protective suit, splash-protective suit, breathing apparatus, 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 suit features; and

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

8.2 Visually inspect each chemical protective suit for flaws or defects in the base materials and seam construction. An illustration of the chemical-protective suit, such as that given in Fig. 1, may be used to mark and record the location of suit

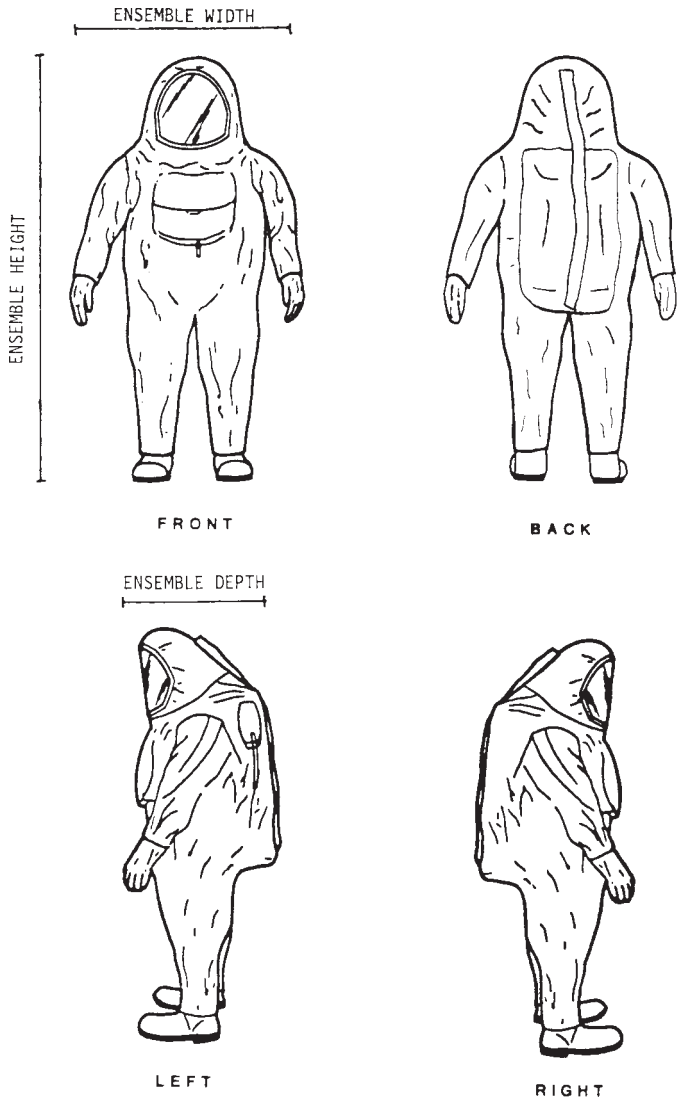

FIG. 1 Suit Diagram

imperfections. Evaluate the integrity of the chemical protective suit or suit ensemble for overall gas penetration resistance using Practice F 1052 or overall liquid penetration resistance using Practice F 1359, as appropriate. Ensure that the test suit and equipment are the right size for the test subject. Disregard any garment that may fail prematurely due to workmanship or does not meet the "pass" criteria established in Practice F 1052. If the chemical protective suit rips, tears, or is punctured during evaluation, discontinue testing.

8.3 Using tape measure, or anthropometer, and weighing scales, measure the test subject dimensions and body weight with underclothing. Test subject dimensions include, but are not limited to the following:

8.3.1 Standing height,

8.3.2 Neck to crotch height,

8.3.3 Crotch height (inseam),

8.3.4 Hip breadth,

8.3.5 Waist,

8.3.6 Chest circumference,

8.3.7 Shoulder breadth, and

8.3.8 Arm (sleeve) length.

8.4 Put on protective ensemble.

8.5 Using weighing scales, measure ensemble weight by weighing test subject wearing complete ensemble, and subtracting body weight with underclothing to find total ensemble weight. Individual ensemble equipment weight may be determined separately. Measure any appropriate ensemble dimensions including, but not limited to, the following:

8.5.1 Ensemble height,

8.5.2 Ensemble maximum width, and

8.5.3 Ensemble maximum depth. (See Fig. 1 for illustrations of dimensions.)

8.6 Measure ambient temperature and relative humidity. If tests are performed outside, it is recommended that wet bulb glove temperature (WBGT)[4] be measured and reported in accordance with the Threshold Limit Values and Biological Exposure Indices for 1987–1988.[5]

8.7 Perform either Procedure A or B.

8.8 *Procedure A*:

8.8.1 Kneel on left knee, kneel on both knees, kneel on right knee, stand. Repeat exercise four times.

8.8.2 Duck squat, pivot right, pivot left, stand. Repeat exercise four times.

8.8.3 Stand erect. With arms at sides, bend body to left and return, bend body forward and return, bend body to right and return. Repeat exercise four times.

8.8.4 Stand erect. Extend arms overhead in the lateral direction, then bend elbows. Repeat exercise four times. Extend arms overhead in the frontal direction, then bend elbows. Repeat exercise a total of four times.

8.8.5 Stand erect. Extend arms perpendicular to the sides of torso. Twist torso left and return, twist torso right and return. Repeat exercise four times.

8.8.6 Stand erect. Reach arms across chest completely to opposite sides. Repeat exercise four times.

8.8.7 Walk a distance of 100 yds [91 m] (or walk in place for a minimum duration of 3 min).

8.8.8 Crawl on hands and knees a distance of 20 ft [6 m] (or crawl in place for a minimum duration of 1 min).

8.9 *Procedure B*:

8.9.1 Individually lift four boxes (as described in 6.1) from the floor and place on a table. Return each box to the floor.

8.9.2 Place a 55-gal [208-L] drum (as described in 6.2) on a handtruck and move 25 ft [7.6 m]. Remove drum from handtruck. Replace drum on handtruck and move to original position. Remove drum from handtruck.

8.9.3 Uncoil and coil hose, connect and disconnect both couplings (as described in 6.8).

8.9.4 Open and close the overhead valve (described in 6.4) a minimum of four complete turns.

8.9.5 Remove and install bolt with wrench (as described in 6.5 and 6.7).

8.9.6 Remove and install screw with screwdriver (as described in 6.6).

[4] See *Threshold Limit Values and Biological Exposure Indices*, pp. 68–69 for information on wet bulb globe temperature.

[5] Available from American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Bldg. D-5, Cincinnati, OH 45211.

8.9.7 Climb up to fifth rung of ladder (as described in 6.9).

8.10 Remove protective ensemble. Where applicable, record whether the test subject can remove the ensemble without the assistance of another person.

8.11 Allow test subject to rest. Following rest period, have test subject complete subjective critique of ensemble performance. See Annex A1 for an example ensemble critique form.

8.12 Visually inspect each chemical-protective suit for signs of wear (abrasion, cuts, punctures, tears). An illustration of the chemical-protective suit, such as that given in Fig. 1, may be used to mark and record the location of observed wear of the suit. Test gas-tight, totally encapsulating chemical-protective suits for any changes in gas-tightness using Practice F 1052. Test liquid tight, totally encapsulating chemical protective suits for any change in liquid tightness using Practice F 1359.

9. Report

9.1 For each protective ensemble tested, prepare a report which includes, but is not limited to, the following:

9.1.1 Descriptions and dimensions of the chemical-protective suit and ensemble components;

9.1.2 Test subject body dimensions and body weight with underclothing;

9.1.3 Chemical protective suit ensemble weight, maximum width, maximum depth, and any appropriate ensemble dimensions when worn;

9.1.4 Environmental conditions in which the testing was conducted;

9.1.5 Visual inspection and integrity test results before and after testing as required in either Practice F 1052 or F 1359.

9.1.6 Observations on the ability of the test subject to perform each exercise in Option A or each work task in Option B while wearing the protective ensemble; and

9.1.7 Any other observations or relevant measurements made during the tests.

9.2 Attach to the report test subject critiques and any photographs or diagrams illustrating visual inspection results before and after suit testing.

10. Keywords

10.1 chemical-protective clothing; penetration, gas; penetration, liquid; suitability; work environment; suit ensembles

ANNEX

(Mandatory Information)

A1. SAMPLE POST TEST SUBJECT QUESTIONNAIRE

Name:					
Organization and Address:					
Ensemble Description:					
Chemical Protective Suit—					
Respiratory Protective Equipment—					
Gloves—					
Boots—					
Communications System—					
Cooling Device—					
Undergarments—					
Other clothing or equipment—					
Ambient Temperature—			Relative Humidity—		
Assessment of Ensemble Function:					
1—Extremely Easy, 5—Extremely Difficult					
Procedure A Exercises:					
Kneeling	1	2	3	4	5
Duck squats	1	2	3	4	5
Body bends	1	2	3	4	5
Overhead arm extensions	1	2	3	4	5
Torso Twists	1	2	3	4	5
Cross body arm reaches	1	2	3	4	5
Walking	1	2	3	4	5
Crawling	1	2	3	4	5
Specific Comments:					
Procedure B Tasks:					
Box lifting	1	2	3	4	5
Drum moving	1	2	3	4	5
Hose coiling/uncoiling	1	2	3	4	5
Valve manipulation	1	2	3	4	5
Wrench manipulation	1	2	3	4	5
Screwdriver use	1	2	3	4	5
Ladder climbing	1	2	3	4	5
Specific Comments:					
General Ensemble Function:					

General mobility	1	2	3	4	5
Ease of putting on	1	2	3	4	5
Ease of removing	1	2	3	4	5
Vision	1	2	3	4	5
Specific Comments:					
Assessment of Ensemble Comfort and Fit:					
1—Excellent fit and comfort					
5—Does not fit—completely uncomfortable					
Height	1	2	3	4	5
Hips	1	2	3	4	5
Legs	1	2	3	4	5
Feet	1	2	3	4	5
Shoulders	1	2	3	4	5
Arms	1	2	3	4	5
Hands	1	2	3	4	5
Head area	1	2	3	4	5
Specific Comments:					