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

This standard is issued under the fixed designation F1154; 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 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~~ Protective clothing is generally used 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,~~ other items to form an ensemble of clothing and equipment. Generally, as the risks for exposure to chemical, biological, thermal, physical, and other hazards increase, it becomes increasingly important that the ensemble provide consistent and overall performance in protecting the wearer. At the same time, the more encumbered the individual wearer, the more likely that ensembles comprising multiple elements and components will impact the ability of the wearer to carry out different tasks and remain comfortable without increased physiological stress, particularly for clothing that incorporates barrier layers. The majority of industry test methods address specific performance attributes for protecting against specific types of hazards, but do not address particular designs or assess the impact of all elements and components forming the ensemble. These elements may comprise various types of protective clothing, ranging from partial body such as aprons and sleeve protectors to fully encapsulating suits that also must be integrated with various types of respirators, gloves, footwear, head protection such as helmets, cooling devices, communications systems, and ~~cooling devices must also be selected and integrated with the chemical-protective clothing to provide an ensemble with adequate protection.~~ undergarments. Therefore, there is a need for methodology that

[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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allows the assessment of how well ensembles affect wearer comfort and function, as well as providing for evaluation of fit and any impact of wearing on the overall integrity intended for the ensemble.

This standard is intended to provide standardized methods for qualitatively evaluating the comfort, fit, function, and durability of ~~chemical-protective~~protective ensembles and ensemble components. It may also be used by protective clothing manufacturers to assess current or proposed designs. This standard has utility for a variety of applications, including chemical-protective ensembles, ensembles used in various healthcare settings or against other types of biological hazards, and different ensembles that may include some form of barrier layer in their various elements or components.

1. Scope

1.1 These practices are intended for evaluating ~~chemical-protective~~protective ensembles and ensemble ~~components~~elements 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~~ evaluate the impact of the ~~ensemble components.~~ensembles and ensemble elements on wearer mobility when worn in a series of different physical exercises that are intended to evaluate the range of motion permitted by the ensemble or ensemble element.

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.~~ impact of the ensemble or ensemble element on wearer function.

1.1.3 Recording the length of time used to complete these tasks provides a means for quantifying the impact of the ensemble or ensemble element on the wearer function.

1.1.4 Relating the ability of the subject to completely perform all tasks provides a qualitative assessment for the impact of the ensemble or ensemble element on wearer function.

1.1.5 The optional evaluation of ensembles or ensemble elements for liquid or vapor integrity following the exercise protocols provides a basis for evaluating the impact of wearing on ensemble or ensemble element integrity.

1.2 These practices apply to ~~most chemical-protective~~ protective ensembles and ~~ensemble components.~~certain ensemble elements that are used for protection against different chemical, biological, physical, thermal, and other hazards, but are primarily useful for ensembles that include barrier layers such as liquid splash-protective ensembles used for protection against hazardous chemicals or highly infectious diseases, or vapor-protective ensembles used for chemical protection.

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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.* Specific safety precautions are given in Section 7.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F1052 Test Method for Pressure Testing Vapor Protective Suits

~~F1359~~F1359/F1359M Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a ~~Mannequin~~Manikin

F1494 Terminology Relating to Protective Clothing

F2668 Practice for Determining the Physiological Responses of the Wearer to Protective Clothing Ensembles

F3031 Practice for Range of Motion Evaluation of First Responder's Protective Ensembles

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:*~~*Definitions:*

[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.

3.1.1 ~~*chemical-protective suit ensemble,*~~ *ensemble component, 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.~~an item used as part of the protective ensemble that provides additional protective or functional performance, but is not necessarily an item of protective clothing.

3.1.1.1 *Discussion*—

Examples of ensemble components are cooling devices, communications systems, fall protection harnesses, and undergarments. In cases where the respirator does not also provide skin protection, the respirator is also considered an ensemble component.

~~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.~~

3.1.2 ~~*penetration,*~~ *ensemble element, n*—~~for chemical protective clothing, the movement of substances through voids in protective clothing materials or item on a non-molecular level.~~an item of protective clothing used in the protective ensemble that provides direct protection of the individual.

3.1.2.1 *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.~~ Examples of ensemble elements include full-body protective clothing such as coveralls, two-piece splash suits, surgical gowns, and encapsulating suits; and partial-body protective clothing such as aprons, smocks, laboratory coats, hoods, sleeve protectors, gloves, footwear, and respirators where the respirator facepiece functions to provide protection to the wearer's face.

3.1.3 ~~*permeation,*~~ *liquid splash-protective ensemble, n*—~~for chemical protective clothing, the movement of chemicals as molecules through protective clothing materials items by the processes of (~~protective ensemble used to protect the wearer from liquid splashes ~~1) absorption of the chemical into the contact surface of the material, (2) diffusion of the absorbed molecules throughout the material, and (~~and other~~3) desorption of the chemical from the opposite surface of the material.~~ forms of incidental liquid contact.

~~3.1.5.1 *Discussion*—~~

~~Permeation is a distinctly different mechanism from penetration.~~

3.1.4 *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;~~hazard, or, isolating the external environment from contamination by the wearer of the clothing.

3.1.5 *protective ensemble, n*—the combination of ensemble elements and ensemble components to protect the wearer from an exposure hazard when worn together.

3.1.5.1 *Discussion*—

In these practices, the applicable protective ensemble is principally intended to provide protection from hazardous chemicals, highly infectious diseases, and other hazardous substances that require barrier layers in the protective clothing or ensemble elements. Examples of ensembles include liquid splash-protective ensembles and vapor-protective ensembles.

3.1.6 *vapor-protective ensemble, n*—protective ensemble used to protect the wearer from exposure to chemical vapors and gases.

3.2 For definitions of other protective clothing terms used in these practices, refer to Terminology F1494.

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.~~

4.1 ~~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.~~ Two options are provided for evaluating

the comfort, fit, function, and durability of protective ensembles and ensemble elements using a test subject. These options are performed either separately or in combination.

4.1.1 In Option A, the impact of the protective ensembles or ensemble elements on wearer mobility is evaluated by subjecting the protective ensemble to a manned exercise scenario. The time for the test subject to complete all exercises is recorded. The protective ensemble, ensemble elements, and components are inspected prior to and after the series of exercises to assess damage or changes that may have occurred as a result of the exercises. The test subject qualitatively rates the ease of movement for each of the exercises.

4.1.2 In Option B, the function of the 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. The time for the test subject to complete all tasks is recorded. As in Option A, the protective ensemble, ensemble elements, and components are inspected prior to and after the series of tasks to assess damages or changes that may have occurred as a result of the exercises, and the test subject qualitatively rates the ease of performing each work task.

4.1.3 Additional evaluations or assessments are applied for specific types of ensembles or ensemble elements depending on their features, including visual acuity and field of vision (through a visor provided as part of the ensemble that covers the respirator facepiece) and the time required for the test subject to remove and replace their hands in the gloves of the protective ensemble (for encapsulating suits where wearers are intended to be able to remove their hands for adjusting their respirator equipment or wipe their visor).

4.1.4 Integrity testing is applied to ensembles after one or both options to determine if the ensemble provides acceptable levels of integrity following the performance of the exercises or tasks. Liquid splash-protective ensembles are evaluated for liquid penetration resistance in accordance with Test Method F1359/F1359M, and vapor-protective ensembles are evaluated using pressure testing in accordance with Test Method F1052.

4.2 For each option, the fit and comfort of the ~~chemical-protective~~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~~ have utility in evaluating the 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~~ protective ensembles or ensemble elements in terms of comfort, fit, function, and durability. Limited quantitative measures are also provided.

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

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

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

5.3 ~~Procedure~~Option A permits a *qualitative* evaluation of ~~chemical-protective suit integrity (materials, seams, and components)~~ protective ensemble or ensemble element mobility by subjecting the protective ensemble to a manned exercise routine. Option B permits a *qualitative* evaluation of ~~ensemble and component~~ protective ensemble or ensemble element 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 primarily for qualitative purposes only. In general, results from use of these practices on one type of ensemble may not be comparable to other test results on a different ensemble due to the subjective nature of test results.

5.5 Certain aspects of these practices are quantitative. The effect of wearing the ensemble or ensemble element can also be assessed by the measurement of the time to complete the exercise and tasks defined in Option A and Option B, respectively. Further, liquid penetration resistance testing is applied to liquid splash-protective ensembles in accordance with Test Method F1359/F1359M, and pressure testing is applied to vapor-protective ensembles in accordance with Test Method F1052 to determine if the exercises or tasks affect the durability of the protective ensemble or ensemble element to provide acceptable levels of integrity. Depending on the ensemble configuration, specific evaluations and assessments are used to determine the effect of the ensemble or ensemble element on the wearer's visual acuity, their field of vision, and their ability to remove and reinsert their hands into gloves when attached to encapsulating protective ensembles.

5.6 Quantitative practices for determining the specific impact of the protective ensemble on the wearer's range of motion are found in Practice F3031.

5.7 These practices are not intended to assess heat stress resulting from wearing a ~~chemical-protective~~protective ensemble, although thermal comfort of the suit ensemble may be subjectively evaluated. Use Practice F2668 for measuring the physiological impact of wearing ensembles or ensemble elements on wearers.

5.8 ~~End~~ It is recommended that end users and manufacturers of ~~chemical-protective~~protective ensembles and ensemble ~~components should~~ elements 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~~ensemble element performance characteristics. Additional tests and procedures that relate directly to their particular ~~application.~~ application are also recommended where appropriate. Each facility performing these practices ~~should~~ is encouraged to 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~~1.5 ft^3 ~~(0.03 m~~(0.03 m^3) and not exceeding ~~2 ft~~2 ft^3 ~~(0.06 m~~(0.06 m^3) and filled with a non-hazardous material weighing ~~20 lb (9.1 kg).~~ 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~~ 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~~ is 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~~ 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.~~ assembly and disassembly operations.

6.8 *Hoses*—Two vinyl or chloroprene hoses with a 1-in. (25-mm) outside diameter. Individual hose length shall be ~~25-ft~~25 ft (7.6 m). One hose should have ~~screw type~~ 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~~ (support the ladder with at least one assistant and ~~used~~use 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~~120 °F (–28.5 to ~~49.2°C).~~49.2 °C).

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

6.14 *Eye Chart*—A Snellen eye chart for a 20-ft (6-m) distance.

6.15 *Timing Device*—A stopwatch or other timing device.

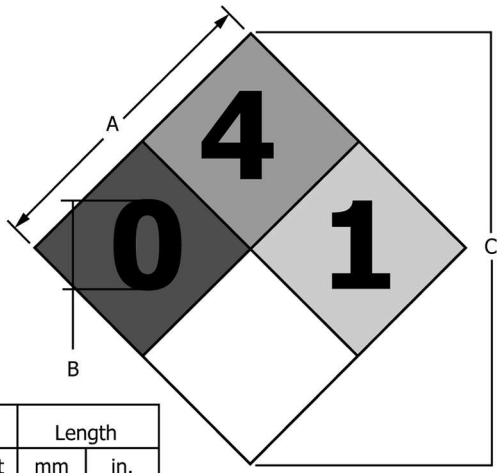
6.16 *Protractor*—A protractor or other device to measure the angle of a placard positioned relative to the test subject.

6.17 *Placard*—A hazardous materials placard as specified in Fig. 1. Random numbers between 0 and 4 shall be placed in each of the quadrants. Multiple placards shall be made available with different number sets for providing different placards to the same test subject.

7. Safety Precautions

7.1 ~~A~~ Have 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~~ Stop testing and remove the subject ~~removed~~ from the protective ensemble or ensemble element for any of the following reasons: request of the test ~~subject, or~~ subject; indications of shortness of breath, difficulty in breathing, fatigue, flushed face, profuse sweating, erratic movements, coughing, nausea, or cramps in the test ~~subject.~~ subject; and any safety concerns on the part of the safety monitor.



	Length	
Measurement	mm	in.
A	64	2.5
B	25	1
C	90	3.5

FIG. 1 Placard for Assessing Protective Ensemble Field of Vision

7.3 ~~Test subjects should be~~Only use test subjects that are in good physical ~~condition,~~ condition (who are medically cleared by a healthcare professional for the type of stress to be applied), experienced in the use of protective clothing, and are well hydrated before performing these tests.

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

7.5 ~~The selection of breathing apparatus~~ When selecting breathing apparatus, other types of respirators, and other ensemble ~~components shall~~ elements or components, take into account the length of the test and the burden on the test subject.

NOTE 2—When a self-contained breathing apparatus is used, a self-contained breathing apparatus having minimum rated service time of 45 min is usually required.

8. Procedures

8.1 Select the ~~chemical-protective~~ protective ensemble, ensemble elements, and ensemble 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,~~ (suit or garment, respirator, glove, boot, helmet, ~~etc.);~~etc.),

8.1.2 ~~Manufacturer;~~Manufacturer,

8.1.3 Model ~~number, serial number;~~ number and serial number (if applicable),

8.1.4 ~~Size;~~Size,

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

8.1.6 Special component ~~features;~~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~~2, 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.~~

8.2.2 Disregard any garment ~~that may fail prematurely due to workmanship or does not meet the "pass" criteria established in Practice~~ with workmanship issues observed during the inspection.~~F1052 or F1359.~~

8.3 Using tape ~~measure,~~measure or anthropometer, and weighing scales, measure the test subject dimensions and body weight with ~~underclothing.~~ underclothing present, if an assessment of fit is to be made. Test subject dimensions include, but are not limited to, the following:

8.3.1 Standing height,

8.3.2 ~~Neck to crotch~~ Neck-to-crotch height,

8.3.3 Crotch height (inseam),