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Standard Test Method for Man-In-Simulant Test (MIST) for Protective Ensembles[1]

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1. Scope

1.1 This test method specifies the test equipment and procedures for conducting tests to estimate the entry of chemical agent vapor simulant through protective ensembles while worn by test subjects.

1.2 This test method permits the evaluation of protective ensembles consisting of protective garments or suits, gloves, footwear, respirators, and interface devices.

1.3 The results of this test method yield local physiological protective dosage factors at individual locations of the human body as well as a systemic physiological protective dosage factor for the entire ensemble.

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 to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E171 Practice for Conditioning and Testing Flexible Barrier Packaging

F1052 Test Method for Pressure Testing Vapor Protective Suits

F1154 Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Durability of Protective Ensembles and Ensemble Components

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

F1494 Terminology Relating to Protective Clothing

F1731 Practice for Body Measurements and Sizing of Fire and Rescue Services Uniforms and Other Thermal Hazard Protective Clothing

2.2 *National Fire Protection Association (NFPA) Standards:*[3]

NFPA 1971 Standard on Protective Ensembles for Structural and Proximity Fire Fighting

NFPA 1994 Standard on Protective Ensembles for CBRN Terrorism Incidents

2.3 *U.S. Military Publication:*

Test Operations Procedure (TOP 10-2-022) Man-In-Simulant Test (MIST)—Chemical Vapor Testing of Chemical/Biological Protective Suits, September 2001.[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *chemical agent vapor simulant*, *n*—a substance used to replicate vapor characteristics of a chemical agent which is a more toxic substance.

3.1.1.1 *Discussion*—In this test method, methyl salicylate is used as a chemical agent vapor simulant for the blister agent, distilled mustard.

3.1.2 *chemical terrorism agent*, *n*—a liquid, solid, gaseous, or vapor chemical warfare agent or a toxic industrial chemical used to inflict lethal or incapacitating casualties, generally on a civilian population as a result of a terrorist attack.

3.1.3 *interface area*, *n*—a location on the body where two or more protective clothing items (for example, suits, garments,

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[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] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[4] U.S. Army Developmental Test Command (DTC), ATTN: CSTE-DTC-TT-S, Aberdeen Proving Ground, MD 21005-5055.

hoods, gloves, footwear, respirators, or other items) come into contact.

3.1.3.1 *Discussion*—Interfaces are potential breaches that could allow entry of chemicals into the interior of the protective ensemble.

3.1.4 *interface device*, *n*—an item of the ensemble that is intended to provide protection to the interface area.

3.1.5 *local physiological protective dosage factor (PPDF* $_i$*)*, *n*—a physiological protective dosage factor at a specific location on the body.

3.1.5.1 *Discussion*—In this test method, local physiological protective dosage factors are measured at 30 different locations on the body.

3.1.6 *onset of symptoms exposure dosage (OSED)*, *n*—the dosage that causes threshold effects to the average human.

3.1.7 *passive adsorbent dosimeters (PADs)*, *n*—~~adhesive backed patches, made of an absorbent material, which are placed on the skin at specific locations of the body, to collect any chemical vapor challenge that has infiltrated the protective ensemble.~~

~~3.1.7.1*Discussion*—In this test method, the PADs use a Tenax TA absorbent material.~~ —two-sided packets with one side made from a permeable film and the second side made from a chemically-impermeable film, which are filled with absorbent material, and are placed on the skin at specific locations of the body, to collect any chemical vapor challenge that has infiltrated the protective ensemble.

3.1.8 *physiological protective dosage factor (PPDF)*, *n*—the factor by which protection is improved against effects from vapor exposure for the protected individual compared with whole body exposure of the unprotected individual.

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

3.1.9.1 *Discussion*—For evaluating the vapor penetration and permeation resistance of protective ensembles against chemical agent vapor simulant, the protective ensemble includes all those clothing items or accessories, which are necessary to provide resistance to inward leakage by chemical vapors.

3.1.10 *systemic physiological protective dosage factor (PPDF*$_{sys}$*)*, *n*—a physiological protective dosage factor determined for the entire ensemble.

3.2 For definitions of other terms related to protective clothing used in this test method, refer to Terminology F1494.

4. Summary of Test Method

4.1 This test method establishes procedures for testing complete protective ensembles worn by test subjects when exposed to chemical agent vapor simulant. Methyl salicylate (MeS) is used to simulate chemical agent vapor penetration through ensemble interfaces and openings.

4.2 This test method tests the vapor penetration and permeation resistance of a protective ensemble by the placement of passive adsorbent dosimeters (PADs) containing sorbent material onto the test subjects at specific locations on the body.

4.3 After test subjects wearing the ensemble to be evaluated finish a series of activities inside the test chamber, these PADs are removed from the test subject and analyzed for MeS.

4.4 Data obtained from the individual PADs are used to assess the vapor penetration and permeation resistance of the ensemble at each body location and for the overall ensemble.

5. Significance and Use

5.1 This test method is intended to evaluate the penetration and permeation resistance for complete ensembles to vapors from chemical warfare agents and other chemical substances.

5.1.1 This test method differs from Test Method F1052 by providing an evaluation of ensembles worn on human test subjects and measuring the inward leakage of a chemical agent vapor simulant as it would be absorbed by the wearer's skin. Test Method F1052 is not applicable to the range of protective ensembles that are evaluated by this test method.

5.1.2 This test method differs from Test Method F1359 by using a chemical agent vapor simulant as compared to a liquid challenge and in the use of human test subjects. This test method further provides a quantitative assessment of inward leakage for the chemical agent vapor simulant.

5.1.3 The use of this test method to determine the inward leakage of other chemical vapor threats must be evaluated on a case-by-case basis.

5.2 This test method is applied to complete ensembles consisting of a suit or garment in combination with gloves, footwear, respirators, and interface devices.

5.2.1 This test method permits any combination or configuration of ensemble elements and components, including ensembles where the respirator covers the face or head.

5.2.2 This test method accommodates protective ensembles or protective clothing having any combination of the following characteristics:

(1) the protective ensemble or clothing is constructed of air permeable, semipermeable, or impermeable fabrics,

(2) the protective ensemble or clothing is of a single or multi-layered design, or

(3) the protective ensemble or clothing is constructed of inert or sorptive fabrics.

5.3 MeS has been used as a simulant for chemical warfare agents. MeS is primarily a simulant for distilled mustard (HD) with

a similar vapor pressure, density, and water solubility. The use of MeS in vapor form does not simulate all agents or hazardous substances to which ensemble wearers are potentially exposed.

5.4 The principal results of this test are physiological protective dosage factors that indicate the relative effectiveness of the ensemble in preventing the inward leakage of the chemical agent vapor simulant and its consequent dosage to the wearer's skin as determined by the use and placement of personal adsorbent devices (PAD) on human test subjects.

5.4.1 Specific information on inward leakage of chemical agent vapor simulant is provided by local physiological protective dosage factors for individual PAD locations to assist in determining possible points of entry of the chemical agent vapor simulant into the ensemble.

5.4.2 The determination of the local physiological protective dosage factors is based on ratio of the outside exposure dosage to the inside exposure dosage on the wearer's skin at specific locations of the body and accounts for the specific susceptibility of the average human's skin at those locations to the effects of blister agent, distilled mustard using the onset of symptoms exposure dosages (OSED) at different points on the body. The specific OSED values used in this test method are based on the exposure concentration of distilled mustard that cause threshold effects to the average individual human in the form of reversible skin ulceration and blistering (**1**).

5.4.3 The body locations chosen for the placement of PADs were chosen to represent the range of body areas on the human body, with preference to those body areas generally near interfaces found in common two-piece ensembles with separate respirator, gloves, and footwear. Additional locations are permitted to be used for the placement of PAD where there are specific areas of interest for evaluating the inward leakage of the chemical agent vapor simulant.

NOTE 1—Common interface areas for protective ensemble include the hood to respirator facemask, clothing or suit closure, upper torso garment to lower torso garment, garment sleeve to glove, and garment pant cuff to footwear.

5.4.4 An assessment of the vapor penetration and permeation resistance for the entire ensemble is provided by the determination of a systemic physiological protective dosage factor. The same PAD data are used in a body region hazard analysis to determine the overall physiological protective dosage factor accounting for the areas of the body represented by the location, and the relative effects of the nerve agent, VX. A systemic analysis assists in the evaluation for those chemical agents, such as nerve agents, affecting the human body through a cumulative dose absorbed by the skin (2).

5.4.5 Examples of analyses applying PAD data for the assessment of ensemble inward leakage resistance are provided in NFPA 1971, *Standard on Protective Ensemble for Structural and Proximity Fire Fighting*, and NFPA 1994, *Standard on Protective Ensemble for CBRN Terrorism Incidents*.

5.4.6 The general procedures in this test method are based on Test Operations Procedure (TOP 10-2-022), Man-In-Simulant Test (MIST) - Chemical Vapor Testing of Chemical/ Biological Protective Suits.

5.5 The human subject activities simulate possible causes of changes in ensemble vapor barrier during expected activities. These activities are primarily based on stationary activities provided in Part A of Practices F1154 and are intended to create movements that are likely to affect the integrity of the ensemble and its interface areas. Additional activities (such as dragging a dummy and climbing a ladder) have been added to simulate activities that might be used by first responders during emergency events such as rescuing victims from a terrorism incident involving chemical agents. The test method permits the modification of the activity protocol to simulate the specific needs of the protective ensemble application.

5.6 The length of the human subject exposure to the chemical agent vapor simulant is set at 30 min in the test chamber with a 5 min decontamination period. This test duration is intended to replicate a possible exposure of a first responder during a terrorism incident involving chemical agents. If a self-contained breathing apparatus is used, a 60-min rated respirator must be used or provisions made for supplemental umbilical air (through a supplied air system). The test method permits the adjustment of the exposure period to simulate the specific needs of the protective ensemble application.

5.7 Test results generated by this test method are specific to the ensemble being evaluated. Changing any part of the ensemble necessitates a new set of testing for the modified ensemble.

5.8 Additional information on man-in-simulant testing is provided in (**3**).

6. Facilities and Apparatus

6.1 *Test Chamber*—A sealed chamber having the following characteristics:

6.1.1 Provides a minimum volume of sufficient dimensions to permit free movement of the test subject(s) when fully dressed in the ensemble.

6.1.2 Maintains a temperature of 27 ± 5°C (80 ± 10°F) and relative humidity of 65 ± 20 %.

6.1.3 Provides a nominal range of wind speed of 0.9–2.2 m/s (2–5 mph).

6.2 *Other Test Facilities*—Areas for the test operator(s), dressing, decontamination, first stage undressing, and second stage undressing.

6.2.1 A test operator area shall be located immediately adjacent to the test chamber and shall include the monitoring equipment for the test chamber MeS concentration, temperature, humidity, and air speed. The test operator area shall include a means for test operators to directly observe test subject(s) in the chamber.

6.2.2 The dressing area shall be located away from the test chamber to ensure that this area is free from contamination by the test agent.

6.2.3 The area for decontamination shall be well ventilated, physically isolated from the test chamber, and one that permits ready drainage of wash water.

6.2.4 The first stage undressing area shall be adjacent to the decontamination area, but well away from the test chamber.

6.2.5 The second stage undressing area shall be adjacent and accessible to the first stage undressing area.

6.3 *MeS Generator*, a vapor generator that must be capable of operation by remote control from the test operator area and shall be able to dispense MeS at the controlled rate required to maintain vapor concentration at a level that is ±15 mg/m^3 of the target concentration. (also see 12.1.2).

6.4 *MeS Detector*, a detector capable of providing a real-time analysis of the MeS concentration in the test chamber.

6.5 *Refrigerator*—capable of maintaining a temperature of 4.0 ± 3°C (38.6 ± 5°F).

6.6 *Analytical equipment and supplies*, used for extracting MeS from the adsorbent used in the PADs and providing an analysis of the extracted MeS concentration. The sensitivity of the analytical technique shall provide for a detection limit of 3 mg-min/m^3(approximately 30 ng MS per PAD). The analytical technique shall be linear up to at least a dose of 1000 mg.min/m^3, with a coefficient of variation on replicate spiked dosimeter samples of less than 15 %.

NOTE 2—Examples of suitable analytical techniques include gas chromatography with thermal desorption of the adsorbent in the PAD, and high performance liquid chromatography with methanol extraction of the adsorbent in the PAD.

7. Supplies

7.1 *Passive Adsorbent Dosimeter (PAD)*—an item placed on the skin of a human test subject for adsorbing chemical challenge vapor that penetrates the ensemble, which can be later analyzed to determine the dose received at a specific body location. PADs are adhesive-backed foil packets measuring 25 mm by 35 mm by 0.02 mm, which contain an adsorbent material covered by a high-density polyethylene barrier film.

The active surface sampling area of a PAD is 4.3 ± 0.6 cm^2 and its uptake rate is 10 ± 2 cm^3/min. Specifications for preparation of PADs are provided in Appendix X1.[5,6]

NOTE 3—The barrier film has a penetration rate similar to human skin when exposed to MeS and acts as a pseudo-skin barrier.

7.2 *Test Activity Aids*

7.2.1 A 70-kg non-rigid, human dummy outfitted with a circular rope looped under the arms with sufficient length to permit dragging the dummy from the head side by a test subject.

7.2.2 A 2-m extension ladder, that is secured along side one of the test chamber walls.

7.2.3 A stool without a back, approximately 600 mm (24 in.) high.

7.3 *Decontamination Materials*

7.3.1 *Decontamination Equipment*—for spraying ensemble exterior during decontamination process.

7.3.2 *Liquid Soap*—mild household detergent that does not contain bleach and is free of fragrances.

7.4 *Analysis Materials*

7.4.1 Glass vials with a non-adsorbent lid liner of sufficient size to accommodate removed PADs.

7.4.2 Aluminum foil.

8. Reagent

8.1 *Test Simulant*—Methyl Salicylate (MeS - $C_8H_8O_3$) CAS # 119-36-8 with a minimum purity of 95 %.

9. Hazards and Safety Precautions

9.1 Review the use of MeS as chemical agent vapor simulant with respect to exposure to human test subjects. An analysis of possible percutaneous toxicity for MeS is presented in Appendix X2.

NOTE 4—MeS is more commonly known as oil of wintergreen and has a relatively low percutaneous toxicity. It is used as a denaturant and flavoring agent and medicinally is used as a topical anti-inflammatory and dermal keratolytic agent.

9.2 Use human test subjects that are medically and physically suitable to perform these tests without danger to themselves.

9.2.1 Ensure that a medical certificate for each test subject has been issued within 12 months prior to testing.

9.2.2 Select test subjects that are familiar with the use of protective ensembles and with the selected respirator.

9.2.3 Conduct qualitative or quantitative respirator fit test for each test subject before a MIST evaluation.

9.2.4 Each test subject must use a protective ensemble and a professionally fitted respirator at all times during MIST evaluations.

9.3 If necessary for the test facility, have the specific evaluation protocol reviewed and approved by a human subjects review board or similar panel to ensure the safety and health of the selected test subjects.

10. Sampling and Test Specimens

10.1 Test specimens shall consist of a complete ensemble with protective clothing, gloves and footwear and shall include the respirator where applicable.

10.1.1 Where the ensemble utilizes the respirator facepiece as the ensemble visor, the ensemble shall be tested with each type or model of the respirator specified by the manufacturer.

10.1.2 Where the respirator is completely encapsulated by the ensemble, the ensemble shall be tested with a respirator specified by the manufacturer.

10.2 A minimum of four specimens shall be tested. Specimens representing a minimum of two different ensemble sizes shall be tested.

10.3 Where the ensemble has multiple types of external fittings, each type of external fitting shall be present on each specimen at the time of testing.

10.4 The ensembles shall be selected to fit or be adjustable to fit the selected test subjects in accordance with the manufacturer's sizing provisions that are specific to each ensemble item.

NOTE 5—Additional information on sizing can be found in Practice F1731.

10.5 Ensembles or components of the ensemble that have been previously subjected to this test method shall not be subjected to additional tests unless it can be demonstrated that the ensemble or components are free of contamination.

NOTE 6—SCBA and some styles of footwear are likely to be acceptably decontaminated after washing and then air-drying three weeks in a ventilated space. Some items such as gloves and garments may not be easily decontaminated.

10.5.1 Underclothing and socks shall be permitted to be reused provided they have been laundered with a detergent that has been demonstrated not to cause interference with the analytical method.

[5] The sole source of supply of PADs known to the committee at this time is Syon, ITW Devcon, Danvers, MA 01923 ("Natick Sampler," Part Number 037-002101-113).

[6] If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

11. Conditioning

11.1 Specimens for conditioning shall be complete ensembles and shall include the respirator where the ensemble utilizes the respirator facepiece as the ensemble visor.

11.2 Each specimen shall be conditioned for a minimum of 4 h by exposure to a temperature of 27 ± 5°C (80 ± 10°F) and relative humidity of 65 ± 20 % as described in Specification E171 using a controlled temperature and humidity chamber or space.

11.3 Other conditioning shall be applied to the protective ensemble or ensemble components to simulate wear or use of the ensemble, as appropriate to the protective ensemble application.

NOTE 7—If protective ensembles are intended to be laundered and reused prior to chemical agent exposure, consider testing protective ensembles after suitable care procedures have been applied.

12. Procedure

12.1 *Pretest Chamber and Facility Preparation*

12.1.1 Locate three PADs for a total of nine, in each of the following three areas: the dressing area, the Stage 1 undress area, and the Stage 2 undress area to conduct background sampling and for quality control during the trial.

12.1.2 Establish the concentration of MeS in the test chamber at 100 ± 15 mg/m^3, as measured by a MeS detector of the chamber air.

12.1.2.1 Steps shall be taken to avoid generation of liquid aerosol.

12.1.3 Measure the concentration of MeS every 60 s using the real-time MeS detector to verify compliance with the concentration requirement, and take an air sample at least every 10 min to separately validate the real-time MeS detector measurements.

12.1.4 Establish the environmental conditions inside the test chamber at a temperature of 27 ± 5°C (80 ± 10°F) and a relative humidity of 65 ± 20 %

12.1.5 Establish an average wind speed of 1.6 m/s (3.5 mph) with the nominal range of wind speed of 0.9–2.2 m/s (2–5 mph) in the areas of the chamber where the test subjects will be performing their stationary activities.

12.2 *Pretest Test Subject Preparation*

12.2.1 Ensure that test subjects and test operators, which have contact with the test subjects, have followed pre-trial procedures, including proper hydration and the avoidance of personal hygiene products that contain MeS.

NOTE 8—Examples of products that may contain MeS are toothpaste, soap, and deodorant.

12.2.2 Place PADs on test subjects at the body region locations shown in Fig. 1.

12.2.2.1 Apply all PADs to the test subjects in the dressing area, which is free from contaminated items.

12.2.2.2 Locate cheek PADs entirely within the respirator facepiece. Locate any other face PADs entirely outside the seal of the respirator facepiece.

12.2.3 The test subject shall wear clothing under the protective ensemble as specified by the manufacturer. If no undergarments are specified or required by the manufacturer as part of the protective ensemble, the test subject shall wear a short sleeve cotton shirt and shorts or underwear.

12.2.4 Have the test subject don the protective ensemble and respirator in the dressing room in accordance with the manufacturer's instructions.

12.2.4.1 If taping is used to secure any part of the ensemble, note the specific type of tape, the placement of the tape, and the length of time required to complete the taping.

12.3 *Exposure Testing*

12.3.1 Set the test concentration of MeS in the test chamber at 100 ± 15 mg/m^3 before proceeding with the test.

12.3.2 During the test, place a minimum of four PADs inside the test chamber at different positions representative of the locations where the test subjects conduct their physical activities. PADs from the same lot as the PADs worn by the test subject(s) shall be used. The test chamber PADs shall be used to calibrate the PAD lot used in the analysis (12.5.2).

12.3.2.1 Expose the test chamber PADs in the test chamber for 30 min, +5 min/–0 min and then removed from the test chamber

12.3.3 After sealing the protective ensemble, have the test subject enter the test chamber and seal the test chamber.

12.3.4 The test subject shall enter the test chamber, within 60 min after removal of the protective ensemble from the conditioning environment.

12.3.4.1 More than one test subject shall be permitted in the chamber at the same time, provided that all test subjects can complete all tasks completely in the appropriate time period and that each test subject has an unobstructed direct path to the wind stream.

12.3.5 Test subject(s) shall perform the following physical activity protocol. An alternative physical activity protocol and length of test shall be permitted to better simulate the respective activities anticipated for the use of the specific protective ensemble. The test chamber MeS concentration shall remain within acceptable limits during the activity protocol.

12.3.5.1 *Activity 1*—Drag a 70-kg human dummy using a rope looped underneath the arms of the dummy using both hands for a distance of 10 m over a 15-s period. Stop and rest for 15 s. Perform activity twice. Based on the interior dimensions of the chamber, it shall be permitted to have the test subject drag the dummy in a back and forth or circular manner within the chamber.

12.3.5.2 *Activity 2*—Duck squat, pivot right, pivot left, stand. Rotate orientation 90° to wind stream. Perform activity eight