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Standard Specification for Arc and Flame Resistant Rainwear¹

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1. Scope

1.1 This specification establishes applicable test methods, minimum physical and thermal performance criteria, a suggested sizing guide, and suggested purchasing information for rainwear for use by workers who may be exposed to thermal hazards of momentary electric arcs and open flames.

1.1.1 This specification does not apply to the electrical contact hazards or electric shock hazards involved with electric arcs.

1.1.2 This specification does not apply to flash fire hazards such as industrial hydrocarbon flash fires or other petrochemical flash fire hazards.

1.2 The objective of this specification is to prescribe fit, function and performance criteria for rainwear that meets a minimum level of thermal and physical performance when exposed to a laboratory-simulated electric arc or flame exposure.

1.3 This specification is not intended to serve as a detailed manufacturing or purchasing specification, but can be referenced in purchase contracts to ensure that minimum performance requirements are met.

1.4 Controlled laboratory tests used to determine compliance with the performance requirements of this specification shall not be deemed as establishing performance levels for all situations to which wearers of this protective clothing may be exposed.

1.5 The in-service care and use of this rainwear is beyond the scope of this specification.

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

1.7 The following safety hazards caveat pertains only to Sections 7 and 9, of this specification: *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.*

2. Referenced Documents

2.1 ASTM Standards:

- D 123 Terminology Relating to Textiles²
- D 751 Test Methods for Coated Fabrics³
- D 1117 Guide for Evaluating Nonwoven Fabrics²
- D 1388 Test Method for Stiffness of Fabrics²
- D 3393 Specification for Coated Fabrics—Waterproofness³
- D 3776 Test Method for Mass Per Unit Area (Weight) of Fabric⁴
- F 1958 Test Method for Determining Ignitability of Non-Flame-Resistant Materials for Clothing by the Electric Arc Exposure Method Using Mannequins⁵
- F 1959/F 1959M Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing⁵

2.2 Federal Specifications:

- Federal Test Method Standard (FTMS) No. 191A Method 5903.1⁶
- Federal Test Method Standard (FTMS) No. 191A Method 5516⁶
- Federal Test Method Standard (FTMS) No. CCC-T-191b Method 5204⁶

2.3 AATCC Standards:

- AATCC Test Method 135 Dimensional Changes Automatic Home Laundering of Woven and Knitted Fabrics⁷01a

3. Terminology

3.1 Definitions:

3.1.1 *afterflame time, n*—the length of time afterflame continues after the ignition source has been removed.

3.1.1.1 *Discussion*—For arc testing, the time begins when the arc current ceases and ends when visible flame ends.

3.1.2 *arc rating, n*—the maximum incident energy (E_1) resistance demonstrated by a material prior to breakopen or at the onset of a second degree burn.

3.1.2.1 *Discussion*—When the arc thermal performance value (ATPV) of the material cannot be determined due to

² Annual Book of ASTM Standards, Vol 07.01.

³ Annual Book of ASTM Standards, Vol 09.02.

⁴ Annual Book of ASTM Standards, Vol 07.02.

⁵ Annual Book of ASTM Standards, Vol 10.03.

⁶ Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

⁷ AATCC Technical Manual, available from American Association of Textile Chemists and Colorists, One Davis Dr., PO Box 12215, Research Triangle Park, NC 27709-2215.

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breakopen, the arc rating is determined by measuring the breakopen threshold energy (E_{BT}) per Test Method F 1959/F 1959M. When the arc rating represents the arc thermal performance value, it is indicated as arc rating (ATPV); when representing the breakopen threshold energy, it is indicated as arc rating (E_{BT}).

3.1.3 *arc resistant, adj*—the property of a material or clothing system that provides thermal protection from an arc exposure.

3.1.4 *arc thermal performance value (ATPV), n—in arc testing*, the incident energy on a fabric or material that results in sufficient heat transfer through the fabric or material to cause the onset of a second-degree burn based on the Stoll curve.

3.1.5 *breakopen, n—in testing thermal protective materials*, a material response evidenced by the formation of one or more holes in the material which may allow flame to pass through the material.

3.1.5.1 *Discussion*—In electric arc testing, the specimen shall be considered to exhibit breakopen when any hole is at least $\frac{1}{2}$ in.² in area or at least 1 in. in any dimension.

3.1.6 *breakopen threshold energy (E_{BT}), n—in electric arc testing*, the average of the five highest E_i values that did not cause specimen breakopen and did not cause sensor temperature rise to exceed the Stoll Curve.

3.1.6.1 *Discussion*— E_{BT} is determined when ATPV and HAF cannot be determined due to breakopen.

3.1.7 *breakopen threshold energy above stoll (E_{BTAS}), n—in electric arc testing*, the average of the five highest E_i values which did not cause specimen breakopen regardless of whether sensor temperature rise exceeds the Stoll curve or not.

3.1.7.1 *Discussion*— E_{BTAS} is determined in addition to ATPV and HAF.

3.1.8 *char length, n—in measuring flame resistance of textiles*, the distance from the fabric edge which was directly exposed to the flame to the furthest point of visible fabric damage after a specified tearing force has been applied.

3.1.9 *charring, n*—the formation of carbonaceous residue as the result of pyrolysis or incomplete combustion.

3.1.10 *design test, n—for arc and flame resistant rainwear*, one made on a sample treated as representative of an industrial product; these tests will not generally be repeated in quantity production.

3.1.10.1 *Discussion*—Perform the design test only when a new or modified rainwear material, substrate, coating or adhesive is used to manufacture rainwear. A change in rainwear material could be, but is not limited to, any of the following: The composition, weight or supplier of the substrate, or both, coating, laminate, or adhesive.

3.1.11 *dripping, n—in testing thermal protective fabrics, coated fabrics or laminates*, a material response evidenced by flowing of the fiber polymer, the fabric, or the fabric coating, and the evidence of droplets from the material.

3.1.12 *electric arc ignition, n—as related to electric arc exposure*, a response that causes the ignition of textile material which is accompanied by heat and light, and then subsequent burning for at least 5 s, or consumption of at least 25 % of the test specimen area.

3.1.13 *embrittlement, n*—the formation of a brittle residue

as the result of pyrolysis or incomplete combustion.

3.1.14 *flame resistance, n*—the property of a material whereby flaming combustion is prevented, terminated, or inhibited following application of a flaming or nonflaming source of ignition, with or without subsequent removal of the ignition source.

3.1.15 *heat attenuation factor (HAF), n—in electric arc testing*, the percent of the incident energy which is blocked by a material at an incident energy level equal to ATPV.

3.1.16 *human tissue heat tolerance, n—in testing of thermal protective materials*, the amount of thermal energy transferred to human tissue, which is predicted to cause a second degree burn; the Stoll curve.

3.1.17 *incident energy (E_i), n—in electric arc testing*, the total heat energy received at a surface as a direct result of an electric arc.

3.1.17.1 *Discussion*—In an arc test, incident energy for a specimen is determined from the average temperature rise response of the two monitor sensors adjacent to the test specimen.

3.1.18 *melting, n*—the liquefaction of material under the influence of heat.

3.1.19 *shrinkage, n*—a decrease in one or more dimensions of an object or material.

3.1.19.1 *Discussion*—Shrinkage shall be determined as follows: before mounting the material specimen for arc exposure, measure the specimen width in inches (cm) at the mid point along the long dimension of the specimen. After arc exposure, measure the specimen width in inches (cm) at the point of greatest specimen shrinkage. The “shrinkage” in inches (cm) of the specimen is determined by subtracting the specimen width after arc exposure from the specimen width before arc exposure. The percent shrinkage is determined by dividing the “shrinkage” by the “specimen width” (before arc exposure) and multiplying by 100.

3.1.20 *stoll curve, n*—curve used to predict the onset of second degree burn injury.

3.1.20.1 *Discussion*—The values which make up the Stoll curve are listed in Table X5.1.

3.1.21 *thermal exposure, n*—the intensity of heat energy to which a fabric is exposed.

3.1.21.1 *Discussion*—As related to electric arc testing, the level of incident energy, in calories per centimetre squared (cal/cm^2), that is transferred to the material surface as determined by measuring the rise in temperature on monitor copper calorimeters, positioned adjacent to the material.

3.1.22 *thermal protection, n—of a material*, the property that characterizes overall performance relative to reducing the transfer of heat that is sufficient to cause a second-degree burn.

3.1.22.1 *Discussion*—Thermal protection of a material and the predicted second-degree burn injury can be quantified by the measured sensor response and the observed breakopen material response which indicate how well the material blocks heat from the sensor surface and how well the material resists breakopen.

3.1.23 *thermal resistance, n*—the reciprocal of thermal transmittance.

3.1.24 *thermal material response, n*—in the testing of thermal protective materials, the effects that are observed concurrent and subsequent to thermal exposure, which can include phenomena such as breakopen, charring, embrittlement, melting, shrinkage, etc.

3.1.24.1 *Discussion*—In electric arc testing, the thermal material response can be a result of intense radiant energy, convective energy, molten metal splatter from electrodes or shock wave from rapidly expanding heated, ionized air, or any combination of these.

3.1.25 *thermal transmittance, n*—time rate of unidirectional heat transfer per unit area, in the steady-state, between parallel planes separated by unit difference of temperature of the planes.

3.2 For definitions of other textile terms used in this specification refer to Terminology D 123.

4. Significance and Use

4.1 This specification covers the minimum performance criteria for arc resistance, flame resistance and other requirements for rainwear used by workers who may be exposed to thermal hazards of momentary electric arcs or flame.

4.1.1 Material response characteristics, resulting from the arc exposure shall be reported as a part of the thermal performance characteristics (see 9.3.4).

4.2 This specification establishes minimum performance criteria for rainwear material and rainwear seams that will provide workers with protection from rain under conditions of possible exposure to the thermal hazards of momentary electric arcs and open flames.

4.3 Rainwear material that meets the thermal and physical performance criteria of this specification has been subjected to an electric arc exposure test, Test Method F 1959/F 1959M.

NOTE 1—When rainwear is worn over conventional clothing or flame resistant garments, the rainwear material in combination with fabric(s) worn under the rainwear may also be subjected to the electric arc exposure test, Provisional Test Methods PS 57 or F 1959/F 1959M and the results reported.

4.4 The purchaser has the option to perform or have performed any of these tests in order to verify the performance of the rainwear. Claims for failure to meet the specification are subject to verification by the manufacturer.

4.5 This specification for rainwear shall not be construed as a requirement for the use of any particular rainwear material.

5. Ordering Information

5.1 The following items should be considered by the purchaser when buying rainwear under this specification and included, as necessary, in purchasing documents:

- 5.1.1 Type of material,
- 5.1.2 Fabric weight (oz/yd²),
- 5.1.3 Type and material of fasteners (buttons, snaps, zippers or hook and loop fasteners),
- 5.1.4 Reflective material sections (optional),
- 5.1.5 Style and design or catalog number,
- 5.1.6 Hood design (attached or detachable),
- 5.1.7 Sizes,
- 5.1.8 Color,
- 5.1.9 Special identification markings (optional),

5.1.10 Jacket length, and

5.1.11 Notation of conformance to this specification.

6. Materials and Manufacture

6.1 The rainwear shall be manufactured of materials and constructed using seams that meet the requirements for leak resistance.

6.2 Positive closures, such as buttons or snaps, should be constructed so that they are covered by the rainwear outer layer material. This will result in the garment having a multiple layer construction in the area of the closure. This will also prevent the positive closure from being directly exposed to the hazard.

NOTE 2—In limited testing, some uncovered closures may melt and fuse. Constructing the closures so that they are covered as described above eliminates the melting and fusing observed with uncovered closures.

7. Physical Requirements

7.1 Rainwear material shall meet the physical requirements of this specification initially as manufactured and shall meet this specification after five cleanings, when cleaned as directed by the care instructions from the manufacturer.

7.1.1 If no cleaning instructions are provided by the manufacturer, the garments shall be laundered five times in accordance with AATCC Method 135 (3, IV A iii).

7.1.2 The average weight of the rainwear material shall be determined in accordance with Test Method D 3776, Option C, using the following instructions: Five weight determination specimens, each consisting of a circle of material 3.5 in. (8.9 cm) in diameter, shall be taken from the sample of rainwear material which will be submitted for the material testing required in 7.2.1, 7.4.1, 9.2, and 9.3. If a single, continuous sample of rainwear material is used for all of the designated tests, one weight determination shall be done. If a different sample of rainwear material is used for one or more of the designated tests, a separate weight determination shall be done for each rainwear material sample. The five weight determination specimens shall be selected at approximately equally spaced intervals diagonally along the length of the rainwear material sample. For each weight determination that is done, the average weight for the five specimens and the weights of the individual specimens with the highest and lowest weights shall be reported to the testing laboratory. The supplier's nominal weight for the rainwear material shall also be reported to the testing laboratory.

7.2 *Leak Resistance—Fabric and Seams:*

7.2.1 The fabric of the sample rainwear shall withstand water pressure without leaking at 30 psig (207 kPa), when tested by Specification D 3393.

7.2.2 The seams of the sample rainwear material shall withstand water pressure with no evidence of water leakage at 3 psig (20.7 kPa) for 2 min, when tested by Federal Test Method Standard (FTMS) No. 191A Method 5516 as modified. (Note that this requirement is modified versus the parameters listed in the referenced test method.)

7.2.2.1 A pump device may be used to achieve 3 psig (20.7 kPa) if extension of the water column is not practical.

7.3 Markings and reflective materials attached to the rainwear shall be of the permanent type and electrically non-conductive, and shall not degrade the performance of the rainwear.

7.4 *Trapezoidal Tearing Resistance—Fabric:*

7.4.1 The rainwear material shall be tested for trapezoidal tearing resistance according to Test Methods D 1117 except that the measured value shall be the average of the five highest peak loads. Rainwear material shall have a trapezoidal tearing resistance of not less than 6 lb (2.7 kg) in the warp direction and 6 lb (2.7 kg) in the fill direction. Appendix X3 provides detailed information for the trapezoidal tearing resistance of rainwear material according to Test Methods D 1117.

8. Performance Requirements

8.1 Rainwear material shall conform to the requirements of 7.2.1 for leak resistance.

8.2 Rainwear shall be manufactured with seams that meet the criteria of 7.2.2 for leak resistance.

8.3 Markings and reflective materials shall conform to the requirements of 7.3.

8.4 Rainwear material shall conform to the requirements of 7.4 for trapezoidal tearing resistance.

8.5 The fabrics, stitchings, tapes, coatings, fasteners, and closures used to manufacture the rainwear should be made from electrically non-conductive materials. If conductive fasteners or closures, for example, zippers, snaps, or buttons, or combination thereof, are used, they shall be covered with a layer of rainwear material on the inside of the garment between the closure and the undergarment or skin.

8.5.1 *Discussion*—If fasteners or closures, for example, zippers, snaps, or buttons, or combination thereof, are used in a manner in which they are in contact with the skin, they can increase heat transfer and burn injury due to heat conduction to the skin. Using a layer of material between the conductive fastener or closure and the undergarment or skin can reduce heat transfer to the skin. There is no intent that this added layer of material can provide a reliable electrical insulation barrier.

8.6 The stitchings, thread, findings, zipper tapes, or fasteners, or combination thereof, used to manufacture the rainwear shall not degrade the flame resistance or thermal performance of the rainwear.

8.7 Rainwear material shall conform to the requirements of 9.2 for flame resistance.

8.8 Rainwear material shall conform to the requirements of 9.3 for thermal resistance to an electric arc exposure.

9. Thermal Performance Requirements

9.1 If the rainwear is constructed of a single-layer fabric or a multi-layer fabric, then a single- or multi-layer sample of the rainwear as constructed shall be subjected to all thermal tests.

9.2 The rainwear fabric shall be tested for flame resistance by use of Federal Test Method Standard (FTMS) No. 191A Method 5903.1, Flame Resistance Cloth Vertical. Specimens shall not melt and drip when subjected to the flame or continue to burn for more than 2 s after removal of the ignition source. The char length shall be less than 6 in. (15 cm) for each specimen.

NOTE 3—Both melting and dripping must occur for a specimen to fail.

An indication of melting by itself shall not be interpreted as melting and dripping.

9.2.1 Rainwear material shall meet the requirements of 9.2 initially as manufactured and after five cleanings when cleaned as directed by care instructions from the manufacturer.

9.2.1.1 If no cleaning instructions are provided by the manufacturer, the garments shall be laundered three times in accordance with AATCC Method 135 (3, IV A iii).

9.3 Rainwear fabric shall be tested for thermal resistance to an electric arc exposure by the use of Test Method F 1959/F 1959M. Test parameters for Test Method F 1959/F 1959M shall be 8 ± 1 kA arc current, 12 in. electrode gap, stainless steel electrodes, 12 in. distance between the arc center line and the rainwear material specimen surface. Additional test parameters may also be used and the results reported on an optional basis.

NOTE 4—Test Method F 1959/F 1959M is a design test.

9.3.1 Rainwear material shall be tested in accordance with 9.3 after three washings followed by one drying. The washing shall be done as directed by care instructions from the manufacturer.

9.3.1.1 If no cleaning instructions are provided by the manufacturer, the garments shall be washed three times in accordance with the AATCC Method 135 (3, IV A iii) followed by one drying.

9.3.2 When rainwear is subjected to higher arc current exposures, the arc rating (ATPV) increases due to surface cooling effects or rainwear material changes, or both, during arc exposure. Consequently, Test Method F 1959/F 1959M arc test parameters are mandated in order to provide a consistent comparative database for rainwear fabrics. The specific parameter of 8 kA was selected due to ATPV changes leveling off close to a minimum value at this arc current level and due to relatively high availability of rainwear results at this arc current level.

9.3.3 The arc rating (ATPV) or arc rating (E_{BT}), heat attenuation factor (HAF) shall be determined according to Test Method F 1959/F 1959M and reported.

NOTE 5—The determination of E_{BTAS} is not discussed in Test Method F 1959/F 1959M. See 3.1.6 and Appendix X4 for information and examples on how to determine E_{BTAS} using the Test Method F 1959/F 1959M test method procedure. Determination of E_{BTAS} may require additional arc exposures at higher incident energy in order to reach the breakopen threshold energy level.

NOTE 6— E_{BTAS} is a term meant to be used to aid end users in matching rainwear to the appropriate protective ensemble. That is to say, after the electrical arc hazard's E_i has been quantified in terms of cal/cm^2 , the next step is to select a protective ensemble with an ATPV rating, quantified in terms of cal/cm^2 , that is equal to or greater than the electrical arc hazard's E_i . At this point rainwear to be worn as an outer layer can be matched to the subject ensemble by ensuring that the E_{BTAS} of the rainwear is equal to or greater than the ATPV rating for the ensemble it is to be placed over. If rainwear is to be relied on as one of the protective layers in a protective ensemble, then it needs to be tested as a multi-layer ensemble in accordance with Test Method F 1959/F 1959M and assigned an ATPV rating, which in turn has to be equal to or greater than the hazard in question. In other words, the E_{BTAS} is not to be used as a protective term in matching rainwear to a hazard, but rather is a breakopen term to be used to match rainwear to the protective ensemble that has already been appropriately matched with the hazard in question. It should be noted that