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## Standard Specification for Arc and Flame Resistant Rainwear<sup>1</sup>

This standard is issued under the fixed designation F1891; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 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*

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F18 on Electrical Protective Equipment for Workers and is the direct responsibility of Subcommittee F18.65 on Wearing Apparel.

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*to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

D123 Terminology Relating to Textiles

D751 Test Methods for Coated Fabrics

D1117 Guide for Evaluating Nonwoven Fabrics (Withdrawn 2009)<sup>3</sup>

D1388 Test Method for Stiffness of Fabrics

D3393 Specification for Coated Fabrics—Waterproofness

D3776 Test Methods for Mass Per Unit Area (Weight) of Fabric

D4391 Terminology Relating to The Burning Behavior of Textiles

D6413 Test Method for Flame Resistance of Textiles (Vertical Test)

F1494 Terminology Relating to Protective Clothing

F1958/F1958M Test Method for Determining the Ignitability of Non-flame-Resistant Materials for Clothing by Electric Arc Exposure Method Using Mannequins

F1959/F1959M Test Method for Determining the Arc Rating of Materials for Clothing

#### 2.2 Federal Specifications:<sup>4</sup>

Federal Test Method Standard (FTMS) No. 191A Method 5516

Federal Test Method Standard (FTMS) No. CCC-T-191b Method 5204

#### 2.3 AATCC Standards:<sup>5</sup>

AATCC Test Method 127 Water Resistance: Hydrostatic Pressure Test

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

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

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

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

<sup>5</sup> AATCC Technical Manual, available from American Association of Textile Chemists and Colorists, One Davis Dr., PO Box 12215, Research Triangle Park, NC 27709-2215.

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *afterflame, n*—persistent flaming of a material after the ignition source has been removed.

3.1.1.1 *Discussion*—*In arc testing*, a visible flaming on or near a test specimen which persists after the arc exposure has ended. The afterflame ceases when flaming is no longer visible.

3.1.2 *afterflame time, n*—the length of time for which a material continues to flame after the ignition source has been removed.

3.1.2.1 *Discussion*—*In arc testing*, the length of time for which a specimen continues to exhibit a visible flaming as determined by a time display video recording of the specimen during arc testing.

3.1.3 *arc rating, n*—value attributed to materials that describes their performances to an exposure to an electric arc discharge.

3.1.3.1 *Discussion*—The arc rating is expressed in cal/cm<sup>2</sup> and is derived from the determined value of ATPV or  $E_{BT}$  (should a material system exhibit a breakopen response below the ATPV value).

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

3.1.5 *arc thermal performance value (ATPV), n—in arc testing*, the incident energy on a material or multilayer system of materials that results in a 50 % probability that sufficient heat transfer through the tested specimen is predicted to cause the onset of a second-degree skin burn injury based on the Stoll curve, cal/cm<sup>2</sup> (j/cm<sup>2</sup>).

3.1.6 *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 thermal energy to pass through the material.

3.1.6.1 *Discussion*—The specimen shall be considered to exhibit breakopen when any hole is at least 3.2 cm<sup>2</sup> (0.5 in.<sup>2</sup>) in area or at least 2.5 cm (1.0 in.) in any dimension. Single threads across the opening or hole do not reduce the size of the hole for the purposes of this practice. In multiple layer specimens of flame resistant materials all the layers must breakopen to meet the definition. In multiple layer specimens, if any of the specimen layers are ignitable, these hole dimension criteria for breakopen are applied to the FR layer covering ignitable layer that is closest to the heat exposure surface.

3.1.7 *breakopen threshold energy ( $E_{BT}$ ), n*—the incident energy on a material or system of materials that results in a 50 % probability of breakopen.

3.1.7.1 *Discussion*—Both  $E_{BT}$  and ATPV are determined and reported for the purposes of this specification.

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 ( $\text{cal}/\text{cm}^2$ ), 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 *Definitions*—For definitions of other textile terms used in this specification refer to Terminology **D123**, **D4391** and **F1494**.

## 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 **F1959/F1959M**.

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, **F1958/F1958M** or **F1959/F1959M** 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 ( $\text{oz}/\text{yd}^2$ ),
- 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, shall 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 reduces the risk of 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 **D3776**, 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