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# Standard Performance Specification for Flame Resistant and Electric Arc Rated Protective Clothing Worn by Workers Exposed to Flames and Electric Arcs<sup>1</sup>

This standard is issued under the fixed designation F1506; 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 performance specification identifies minimum performance requirements to determine the (a) arc rating of fabrics, (b) flame resistance of fabrics and subassemblies, (c) mechanical durability of the fabrics and subassemblies, (d) the minimum garment construction and performance requirements, and (e) the garment labeling requirements for the completed protective clothing worn by workers exposed to flames and electric arcs.

1.1.1 The minimum requirements for garment labeling are intended to provide end users with adequate information to select garments with the appropriate arc rating.

1.1.2 End users are required to perform an assessment to determine the level of hazard and the required arc rating of the protective clothing for their individual hazards.

1.1.2.1 The end user risk assessments are outside the scope of this standard.

1.2 This performance specification does not address coated or laminated protective clothing commonly used for rainwear applications in an arc hazard environment. Performance requirements related to this category of protective clothing are detailed in Specification **F1891**.

1.3 This performance specification does not address hand protection. Performance and test requirements related to hand protection are detailed in OSHA 1910.138, Specification **D120**, and Test Method **F2675/F2675M**.

1.4 The care and maintenance requirements for laundering electric arc flash protective clothing are outside the scope of this standard. Refer to Guides **F1449** or **F2757** related to industrial or home laundering.

1.5 *This standard should be used to evaluate and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions. It*

*should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions.*

1.5.1 The results of this evaluation may be used as elements of a fire-risk assessment that takes into account all of the factors that are pertinent to an assessment of the fire hazard of a particular end use.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.7 The following precautionary caveat pertains only to the test methods portion, Section 7, of this performance 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *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:*<sup>2</sup>

**D120** Specification for Rubber Insulating Gloves

**D123** Terminology Relating to Textiles

**D1424** Test Method for Tearing Strength of Fabrics by Falling-Pendulum (Elmendorf-Type) Apparatus

**D2261** Test Method for Tearing Strength of Fabrics by the Tongue (Single Rip) Procedure (Constant-Rate-of-Extension Tensile Testing Machine)

**D2724** Test Method for Bond Strength of Bonded, Fused, and Laminated Apparel Fabrics

**D3786** Test Method for Bursting Strength of Textile Fabrics—Diaphragm Bursting Strength Tester Method

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<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.

- D5034** Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)
- D6413** Test Method for Flame Resistance of Textiles (Vertical Test)
- D7138** Test Method to Determine Melting Temperature of Synthetic Fibers
- F1449** Guide for Industrial Laundering of Flame, Thermal, and Arc Resistant Clothing
- F1891** Specification for Arc and Flame Resistant Rainwear
- F1959/F1959M** Test Method for Determining the Arc Rating of Materials for Clothing
- F2675/F2675M** Test Method for Determining Arc Ratings of Hand Protective Products Developed and Used for Electrical Arc Flash Protection
- F2757** Guide for Home Laundering Care and Maintenance of Flame, Thermal and Arc Resistant Clothing
- 2.2 *AATCC Test Methods:*<sup>3</sup>
- Method 61** Colorfastness to Washing, Domestic and Laundering, Commercial: Accelerated
- Method 132** Colorfastness to Dry-Cleaning
- Method 135** Dimensional Changes Automatic Home Laundering of Woven and Knitted Fabrics
- Method 158** Dimensional Changes on Drycleaning in Perchloroethylene: Machine Method

2.3 *Federal Standards:*

- 29 CFR 1910.138** Hand Protection<sup>4</sup>

2.4 *NFPA Standard:*<sup>5</sup>

- NFPA 2112** Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire

### 3. Terminology

3.1 *Definitions*—For definitions of textile terms used in this performance specification, refer to Terminology **D123**.

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.1.1 *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.

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

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

3.2.3 *arc rating, n*—value attributed to materials that describes their performance to exposure to an electrical arc discharge.

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

3.2.4 *arc thermal performance value (ATPV), n*—in arc testing, the incident energy on a material or a 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<sup>6</sup> curve, kW/m<sup>2</sup>(cal/cm<sup>2</sup>).

3.2.5 *breakopen threshold energy (E<sub>BT</sub>), n*—the incident energy on a material or material system that results in a 50 % probability of breakopen.

3.2.5.1 *Discussion*—This is the value in J/cm<sup>2</sup> (cal/cm<sup>2</sup>) determined by use of logistic regression analysis representing the energy at which breakopen of the layer occurred.

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

3.2.6.1 *Discussion*—Perform the design test only when a new or modified textile material, that is, fabric, is used to manufacture apparel. A modification in the fabric could be, but is not limited to, any of the following: the supplier, composition, weave type, weight, or dyeing and finishing process.

3.2.7 *fabric identifier, n*—for electric arc protective clothing, a unique indicator used to directly associate a specific flame resistant fabric and its manufacturing and performance information.

3.2.7.1 *Discussion*—As related to electric arc protective clothing, fabric manufacturing information includes, but is not limited to the materials of construction (for example, fibers and the chemical treatment system if used), fabric design (for example, weave, knit, or nonwoven structure information, nominal basis weight and thickness, dyeing information if required, and flame resistant chemical treatment specifics if required), and Fabric Producer information. Fabric performance information includes, but is not limited to the fabric performance testing results for the performance specification requirements noted within this standard.

3.2.8 *fabric producer, n*—for electric arc protective clothing, the manufacturer(s) who produce and/or are responsible for the quality assurance testing and electric arc rating of a finished fabric used in garment construction.

3.2.8.1 *Discussion*—As related to electric arc protective clothing, an arc protective finished fabric is comprised of any or all of the following: (1) a planar woven, knit, or nonwoven structure produced from fibers and/or yarns, (2) is colored (dyed, pigmented, or otherwise meeting a garment manufacturer specification), and (3) is treated with flame retardant

<sup>3</sup> AATCC Technical Manual, available from American Association of Textile Chemists and Colorists, PO Box 12215, Research Triangle Park, NC 27709-2215.

<sup>4</sup> Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, <http://www.osha.gov>.

<sup>5</sup> Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, <http://www.nfpa.org>.

<sup>6</sup> Derived from: Stoll, A. M., and Chianta, M. A., "Method and Rating System for Evaluations of Thermal Protection," *Aerospace Medicine*, Vol 40, 1969, pp. 1232-1238 and Stoll, A. M., and Chianta, M. A., "Heat Transfer through Fabrics as Related to Thermal Injury," *Transactions—New York Academy of Sciences*, Vol 33(7), Nov. 1971, pp. 649-670.

chemicals where required to meet the flame resistance requirements identified in this standard.

3.2.9 *findings*—miscellaneous fabrics in garments such as zipper tapes, linings, pockets, waistbands, and facings.

3.2.10 *garment tracking and identification code, n—for electric arc protective clothing*, a unique identifier or code used to directly associate a specific flame resistant garment of single or multilayer construction and its manufacturing and performance information.

3.2.10.1 *Discussion*—As related to electric arc protective clothing, garment manufacturing information includes, but is not limited to the materials of construction (sewing thread, fabrics, fasteners, closures, and associated hardware), fabric information utilized in garment design (for example, single and multilayer Fabric Producer information and fabric lot information), garment design information (for example, fabric layering information for multi-layer systems), and garment design information (for example, garment assembly facility identifier and identification number, lot number, or serial number). Garment performance information includes, but is not limited to the overall fabric system performance testing results for the performance specification requirements noted within this standard (for single or multilayer garment systems).

3.2.11 *momentary electric arc*—a discharge of electricity through a gaseous media, normally characterized by a voltage drop in the immediate vicinity of the electrodes, approximately equal to the ionization potential of the gaseous media.

3.2.12 *protective clothing, n—as related to electric arc rated garments*, an item of clothing that is specifically designed and constructed for the intended purpose of covering all, or parts of the body, to reduce the severity of injury when exposed to flames and electric arcs.

3.2.12.1 *Discussion*—Protective clothing can include a variety of items designed, constructed, and intended to be worn on the body.

3.2.13 *radiant heat*—heat communicated by energy propagated through space and transmitted by electromagnetic waves.

3.2.14 *thermal hazard*—the heat energy sufficient to cause burn injury to human tissue subjected to a momentary electric arc.

3.2.15 *trims and findings, n—in textile manufacturing*, the generic term used to identify various component subassemblies, any of which can be used individually, or in combination, for the manufacturing of garments or other textile structures, excluding primary fabric.

3.2.15.1 *Discussion*—These component subassemblies include, but are not limited to, slide fasteners (zippers), hook and loop (touch fasteners), patches, logos, emblems, visibility enhancements, insignias, linings, pockets, waistbands, and facings.

3.2.16 *user*—the employer or entity purchasing the equipment to be utilized by workers for their protection; in the absence of such an employer or entity, the individual purchasing and utilizing the protective equipment.

## 4. Significance and Use

4.1 This specification provides performance properties for electric arc rated protective clothing using objective data that report the measurable results from recognized test methods. These measurable results provide information that the user can reference when selecting flame resistant and electric arc rated protective clothing.

4.1.1 This specification identifies the criteria for evaluating the performance of fabrics used to make electric arc rated protective clothing.

4.1.2 This specification identifies the criteria for evaluating the performance of trims and findings and visibility enhancements used for the manufacture of electric arc rated protective clothing.

4.1.3 This specification identifies the criteria for evaluating the structural integrity of the assembly used to construct the electric arc rated protective clothing.

4.1.4 The users can incorporate the information in this specification for purchase contracts to ensure that the quality controls used for the manufacturing of the protective clothing meet the performance requirements identified in the standard.

4.1.5 This specification provides guidelines for acceptable repairs.

4.2 The selection and use of any flame resistant and electric arc rated protective clothing requires a vigilant and ongoing assessment by the worker and the supervisory personnel to any other high energy hazards in the surrounding area. This ongoing risk assessment by workers and supervisors helps to confirm that the location and distance from their position, to any hazard having an incident energy, is not greater than the arc rating (ATPV or Ebt) of the protective clothing being worn.

4.3 Because work practices can vary due to many factors, the user purchasing this protective clothing is responsible to prepare complete and detailed instructions and policies regarding the use of this protective clothing. This allows for risk assessment of hazards, work practices, and other concerns to be addressed.

## 5. Materials and Manufacture

5.1 Material tests shall be performed on textile materials as they are delivered to the clothing manufacturer.

5.1.1 Material tests may be performed on samples taken from finished garments.

5.2 Lot size for the initial (without laundering) flammability test shall be 4572 m (5000 yd) of manufactured fabric or the manufactured yardage, whichever is less. One sample of 1.0 m shall be taken from each lot.

5.3 Lot size for all other tests except design tests shall be 45 720 m (50 000 yd) or at least every three months, whichever is more frequent. One sample of 4.0 m shall be taken from each lot.

5.4 Design tests shall be run on the original and when changes are made to flame resistant textile materials, for example, fiber type, yarn type, weaving style, fabric weight, dyeing, or finishing procedure.



## 6. Requirements

6.1 Thread, findings, and closures used in garment construction shall not contribute to the severity of injuries to the wearer in the event of a momentary electric arc and related thermal exposure.

6.1.1 Sewing thread utilized in the construction of garments shall be made of an inherently flame-resistant fiber and shall not melt below a temperature of 260°C (500°F) when tested in accordance with Test Method **D7138**. Only three specimens are required to be tested.

6.1.2 When fasteners or closures, for example, zippers, snaps, or buttons, or a 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 or melting onto the skin. Fasteners or closures that are used in this manner shall be covered with a layer of material between the fastener or closure and the skin. The material used for this purpose shall meet the requirements of this performance specification.

6.2 The properties of materials for basic protection level wearing apparel shall conform to the specifications in Table 1, Table 2 and Table 3 when evaluated in accordance with Section 7.

NOTE 1—Physical characteristic tests and values in Section 7 and Table 1 and Table 2 are based on experience from woven and knit fabrics currently in use and may not be applicable to other fabric types.

NOTE 2—Characteristics (for example, clothing ensembles, design, and laundry maintenance) of protective garments for basic protection level wearing apparel should be guided by the information contained in **Appendix X1**.

6.3 All repairs and alterations to arc and flame-resistant garments shall be performed compliant to the requirements in this specification. Repairs to critical seams shall be made with flame-resistant thread that meets the requirements of **6.1.1**.

6.3.1 Patches added to the clothing to repair any rip smaller than ½ in.<sup>2</sup> shall be made with FR fabric and FR thread (if sewn).

6.3.2 Patches added to the clothing to repair any rip larger than ½ in.<sup>2</sup> shall be made with FR fabric that has an arc rating equal to or greater than that of the garment and FR thread (if sewn).

NOTE 3—For extensive alterations, the manufacturer should be consulted for guidance.

6.4 Garments shall be labeled with the following information:

6.4.1 Meets requirements of Performance Specification **F1506**,

6.4.2 Manufacturer's name,

6.4.3 Fabric identifier,

6.4.3.1 The fabric identifier shall provide the Fabric Producer's name, and the Fabric Producer's style number or fabric name which complies with this performance specification. This information is permitted to be incorporated in an alphanumeric or similar distinguishing nomenclature (unique identifier) that is distinct to the Fabric Producer and the fabric.

6.4.3.2 Layered fabric garment components, such as jacket liners, constructed and tested as a bonded or quilted unit or

system, shall be permitted to be noted on the label by a single nomenclature or single unique identifier (as referenced in **6.4.4.1**). If any fabric layer of a bonded or quilted unit is changed, the name or unique identifier shall also be changed. Reflective trim, pockets, reinforcement patches, cuffs, collars, yokes, closures, seams, labels, and heraldry shall not be considered as extra layers.

6.4.4 *Garment Tracking and Identification Code:*

6.4.4.1 For garments designed to be separated, each separable layer shall have a garment tracking and identification code.

NOTE 4—An example of a separable garment would be a jacket with a removable liner.

6.4.5 Size and other associated standard labeling,

6.4.6 Care instructions and fiber content, and

6.4.7 Arc rating (ATPV) or arc rating ( $E_{BT}$ ).

6.4.7.1 When garments are made with a different number of fabric layers in different areas of the garment, the arc rating for each area shall be designated. Pockets, trim, closures, seams, labels, and heraldry shall not be considered as extra layers.

## 7. Fabric Test Methods

7.1 *Breaking Load*—Determine the breaking load of woven fabrics in accordance with Test Methods **D5034** (Grab test G: CRT or CRE). Woven fabrics must meet the requirements of **Table 1**.

7.2 *Tear Resistance*—Determine the tear resistance of woven fabrics in accordance with Test Method **D1424**. Woven fabrics must meet the requirements of **Table 1**.

7.2.1 As an option for selected materials, Test Method **D2261** may be employed. This option may be exercised upon agreement between the buyer and the seller. Woven fabrics must meet the requirements of **Table 1**.

7.3 *Bursting Strength*—Determine the bursting strength of knit and non-woven fabrics in accordance with Test Method **D3786**. Knit fabric must meet requirements of **Table 2**. For non-woven fabrics report measured values.

7.4 *Colorfastness:*

7.4.1 *Laundering*—Determine the colorfastness to laundering for fabrics that are launderable. Launder as directed by the garment manufacturer. Report measured values and laundering method.

7.4.1.1 If no laundering method is supplied by the garment manufacturer, launder in accordance with AATCC Method 61, 2A.

7.4.2 *Dry Cleaning*—For fabrics labeled “Dry Clean Only,” determine the colorfastness to dry cleaning in accordance with AATCC Method 132. Report measured values.

7.5 *Dimensional Change*—For laundry shrinkage, determine dimensional change as directed by the garment manufacturer. Report the wash method and the required maximum shrinkage values specified by garment manufacturer along with the test results.

7.5.1 If no criteria are supplied by the garment manufacturer, dimensional change of woven fabrics shall not exceed  $\pm 5$  %. For all other fabrics, report measured values. Use AATCC Method 135, using Conditions for Machine Cycle