Designation: F1959/F1959M – 24b

Standard Test Method for Determining the Arc Rating of Materials for Clothing[1]

This standard is issued under the fixed designation F1959/F1959M; 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.

1. Scope

1.1 This test method is used to determine the arc rating of materials intended for use as flame resistant clothing for workers exposed to electric arcs that would generate heat flux rates of approximately 2100 kW/m^2 [50 cal/cm^{2}s] using an open air arc.

1.2 This test method will determine the arc rating of materials which meet the following requirements: less than 150 mm [6 in.] char length and less than 2 s afterflame when tested in accordance with Test Method D6413.

1.2.1 It is not the intent of this test method to evaluate non flame-resistant materials.

1.3 The materials used in this test method are in the form of flat specimens.

1.4 This test method shall be used to measure and describe the properties of materials, products, or assemblies in response to convective and radiant energy generated by an electric arc under controlled laboratory conditions.

1.5 The values stated in SI units shall be regarded as standard except as noted. Within the text, alternate units are shown in brackets. The values stated in each system may not be exact equivalents therefore alternate systems must be used independently of the other. Combining values from the systems described in the text may result in nonconformance with the method.

1.6 This test method does not apply to electrical contact or electrical shock hazards.

1.7 *This standard shall not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.*

1.8 *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.* For specific precautions, see Section 7.

1.9 *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]

D123 Terminology Relating to Textiles

D1776/D1776M Practice for Conditioning and Testing Textiles

D3776/D3776M 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)

E457 Test Method for Measuring Heat-Transfer Rate Using a Thermal Capacitance (Slug) Calorimeter

F1494 Terminology Relating to Protective Clothing

F1506 Performance Specification for Flame Resistant and Electric Arc Rated Protective Clothing Worn by Workers Exposed to Flames and Electric Arcs

2.2 *ANSI/IEEE Standard:*[3]

Standard Dictionary of Electrical and Electronics Terms

2.3 *AATCC Standard:*[4]

AATCC Laboratory Procedure 1-2021 Home Laundering: Machine Washing

3. Terminology

3.1 *Definitions:*

[1] This test method 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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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331.

[4] Technical Manual of the American Association of Textile Chemists and Colorists.

3.1.1 *ablation, n—in electrical arc testing*, a physical response evidenced by significant erosion or the formation of one or more large holes in a layer of a multilayer system.

3.1.1.1 *Discussion*—Any layer in a specimen (other than the innermost layer) is considered to exhibit ablation when the material removal or any hole is at least 16 cm^2 [2.5 $in.^2$] in area or at least 8 cm [3.1 in.] in length in any dimension. Single threads across the opening or hole do not reduce the size of the hole for the purposes of this test method. Ablation in one or more layers of material in a mulitlayer system may remove energy from the specimen (see 11.3.7).

3.1.2 *ablation response energy (E_{ab}), n*—the incident energy on a multilayer system that results in a 50 % probability of the physical response of ablation.

3.1.3 *arc duration, n*—time duration of the arc, s.

3.1.4 *arc energy, vi dt, n*—sum of the instantaneous arc voltage values multiplied by the instantaneous arc current values multiplied by the incremental time values during the arc, *J*.

3.1.5 *arc gap, n*—distance between the arc electrodes, mm [in.].

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

3.1.6.1 *Discussion*—The arc rating is expressed in kJ/m^2 [cal/cm^2] and is derived from the determined value of ATPV or E_{BT} (should a material system exhibit a breakopen response below the ATPV value) or the arc rating limit. It can be expressed in short form as either ATPV, E_{BT} or AR_{Lim}.

3.1.7 *Arc Rating Limit (AR_{Lim}), n*—the maximum arc thermal energy protection that has been assigned to the product based on the manufacturer's specifications after verification with testing or limits of detection of the test method.

3.1.7.1 *Discussion*—In electrical arc panel testing of fabrics, the AR_{Lim} may be used when the practical limit of the equipment has been reached and the distribution of the data does not fulfill the data point distribution requirements for completion of the logistic regression analysis. The numerical value of AR_{Lim} assigned from the data set in this case is the value where all specimen responses are below the Stoll curve and without breakopen.

3.1.7.2 *Discussion*—This rating may also be set to any value less than the ATPV/E_{BT} to allow for variation in design, manufacture, or test laboratory results. For example, if a fabric is tested multiple times, the lowest ATPV/E_{BT} or a lower rating to account for variability may be assigned as agreed upon by the manufacturer and the lab, which is less than the arc rating determined in testing.

3.1.8 *arc thermal performance value (ATPV), n*—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[5] curve, kJ/m^2 [cal/cm^2].

3.1.8.1 *Discussion*—This is the value in kJ/m^2 [cal/cm^2] determined by use of logistic regression analysis representing the energy at which breakopen of the layer occurred.

3.1.9 *arc voltage, n*—voltage across the gap caused by the current flowing through the resistance created by the arc gap, *V*.

3.1.10 *asymmetrical arc current, n*—the total arc current produced during closure; it includes a direct component and a symmetrical component, *A*.

3.1.11 *blowout, n*—the extinguishing of the arc caused by a magnetic field.

3.1.12 *breakopen, n—in electric arc testing*, 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.

3.1.12.1 *Discussion*—The specimen is considered to exhibit breakopen when any hole is at least 1.6 cm^2 [0.5 $in.^2$] 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 test method. In multiple layer specimens of flame resistant material, all the layers must breakopen to meet the definition. In multiple layer specimens, if some of the layers are ignitable, breakopen occurs when these layers are exposed.

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

3.1.13.1 *Discussion*—This is the value in J/cm^2 [cal/cm^2] determined by use of logistic regression analysis representing the energy at which breakopen of the layer occurred.

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

3.1.15 *dimensional change, n—in testing flame resistant clothing,* a material response evidenced by change in specimen size, this may be positive or negative.

3.1.15.1 *Discussion*—In arc testing, dimensional change is typically described in relative terms by observation after the arc test exposure (for example, "moderate shrinkage" or "slight expansion").

3.1.16 *dripping, n—in testing flame-resistant clothing*, a material response evidenced by flowing of a specimen's material of composition.

3.1.17 *embrittlement, n*—the formation of a brittle residue as the result of pyrolysis or incomplete combustion.

[5] 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.