Designation: F2675/F2675M – 22$^{\varepsilon 1}$

Standard Test Method for Determining Arc Ratings of Hand Protective Products Developed and Used for Electrical Arc Flash Protection[1]

This standard is issued under the fixed designation F2675/F2675M; 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.

ε[1] NOTE—In Note 4, Example (2), the arc rating AR_{LIM} of 18 cal/cm^2 was corrected editorially to 14 cal/cm^2 in June 2022.

1. Scope

1.1 This test method is used to determine the arc rating of hand protective products in the form of gloves, glove materials, glove material systems, or other protective products designed to fit on the hand and specifically intended for electric arc flash protection use as protective accessories for workers exposed to electric arcs. The arc rating is determined in the test with an arc that has a heat flux value of 2100 kW/m^2 [50 cal/cm^2/s].

1.2 This test method will determine the arc rating of hand protective products made of materials that meet the following requirements for flame resistance: less than 150 mm [6 in.] char length, less than 2 s afterflame and no melt and drip when tested in accordance with Test Method D6413, receive a reported 50 % probability of ignition of a material or flammable underlayer (see definition of ignition$_{50}$) by this method, or that have been evaluated and pass the ignition withstand requirements of this test method.

1.2.1 It is the intent of this test method to be used for hand protective products that are flame resistant or that have an adequate flame resistance for the required hazard (see 1.2). Non-flame resistant hand protective products may be used as under layers in multiple-layer systems or tested for ignition probability or ignition withstand.

1.2.2 Hand protective products tested by this test method are new and ratings received by this method may be reduced or eliminated by hydrocarbon loading (gasoline, diesel fuel, transformer oil, etc.), sweat, dirt, grease, or other contaminants. The end user takes responsibility for use of hand protective products tested by this method when contaminated in such a manner that could reduce or eliminate the arc rating of the hand protective products.

1.2.3 This test method is designed to provide information for gloves used for electric arc protection only. This test method is not suitable for determining electrical protective properties of hand protective products.

1.3 This test method is used to measure and describe the properties of hand protective products in response to convective and radiant energy generated by an electric arc under controlled laboratory conditions.

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

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined

1.6 *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 that takes into account all of the factors, which are pertinent to an assessment of the fire hazard of a particular end use.*

1.7 *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.

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

[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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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

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

F819 Terminology Relating to Electrical Protective Equipment for Workers

F1494 Terminology Relating to Protective Clothing

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

2.2 *ANSI/IEEE Standard:*[3]

Standard Dictionary of Electrical and Electronics Terms

3. Terminology

3.1 *Definitions:*

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

3.1.2 *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[4] curve, cal/cm^2.

3.1.3 *base product, n*—a representative specimen of the finished product. Specimens are as close as possible to the finished product but may exclude trims, labels, coatings or accessories located in the area of the calorimeter (palm or dorsal).

3.1.3.1 *Discussion*—The base product specimen does not include heat sealed labels, impact protection or coatings that do not cover the entire device but would interfere with the calorimeter reading.

3.1.3.2 *Discussion*—Palm-coated gloves can be the base product when they can be arc rated on the dorsal side.

3.1.4 *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.

3.1.4.1 *Discussion*—The specimen is considered to exhibit breakopen when any hole is at least 3.2 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.

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

3.1.5.1 *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.

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

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

3.1.8 *finished product, n*—a representative product as sold.

3.1.8.1 *Discussion*—A base product is tested for determination of arc rating; additional tests to verify compliance with ignition withstand (Table 1 or Table 2) are then required on the finished product(s).

3.1.9 *ignitability, n (ignitable, adj)—in electric arc exposure*, the property of a material involving ignition accompanied by heat and light, and continued burning resulting in consumption of at least 25 % of the exposed area of the test specimen.

3.1.10 *ignition$_{50}$, n—in arc testing*, the incident energy on a material or flammable underlayer that results in a 50 % probability of ignition of a material or flammable underlayer.

3.1.11 *ignition withstand, n—in arc testing*, an arc testing protocol for evaluating ignition of a material used for arc flash protection when the material cannot be evaluated by a flame test or when a material cannot pass a flame test.

3.1.12 *material response, n*—material response to an electric arc is indicated by the following terms: breakopen, melting, dripping, charring, embrittlement, shrinkage, and ignition.

3.1.13 *melting, n—in testing flame resistant clothing*, a material response evidenced by softening of the material.

3.1.14 *mix zone, n—in arc testing*, the range of incident energies, which can result in either a positive or negative outcome for predicted second-degree burn injury, breakopen or underlayer ignition. The low value of the range begins with the lowest incident energy indicating a positive result, and the high value or the range is the highest incident energy indicating a negative result.

3.1.14.1 *Discussion*—A mix zone is established when the highest incident energy with a negative result is greater than the lowest incident energy with a positive result.

3.1.15 *peak arc current, n*—maximum value of the AC arc current, *A*.

[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 Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854, http://www.ieee.org.

[4] 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.

3.1.16 *RMS arc current, n*—root mean square of the AC arc current, *A*.

3.1.17 *shrinkage, n—in testing flame resistant clothing*, a material response evidenced by reduction in specimen size.

3.1.18 *Stoll*[4] curve, *n*—an empirical predicted second-degree skin burn injury model, also commonly referred to as the *Stoll Response*.

3.2 For other definitions see Terminologies D123, D4391, F819, F1494, or IEEE Standard Dictionary of Electrical and Electronics Terms.

4. Summary of Test Method

4.1 This test method determines the heat transport response through a hand protective product material or hand protective product material system when exposed to the heat energy from an electric arc. This heat transport response is assessed versus the Stoll curve criteria, an approximate human tissue tolerance predictive model that projects the onset of a second-degree burn injury.

4.1.1 During this procedure, the amount of heat energy transferred by the tested hand protective products is measured during and after exposure to an electric arc.

4.1.1.1 The thermal energy exposure and heat transport response of test specimens are measured with copper slug calorimeters. The change in temperature versus time is used, along with the known thermo-physical properties of copper to determine the respective heat energy delivered to and through the specimens.

4.2 Hand protective product material performance for this procedure is determined from the amount of heat transferred by and through the tested material.

4.3 Heat transfer data determined by this test method is the basis of the arc rating for the material.

4.3.1 The arc rating determined by this test method is the amount of energy that predicts a 50 % probability crossing the Stoll Curve criteria[4] or breakopen (should the specimens exhibit breakopen before the skin burn injury prediction is reached).

4.4 Hand protective product material response is further described by recording the observed effects of the electric arc exposure on the specimens using the terms in 12.7.

5. Significance and Use

5.1 This test method is intended for the determination of the arc rating of a hand protective product material, or a combination of hand protective product materials.

5.1.1 Because of the variability of the arc exposure, different heat transmission values are observed at individual sensors. Evaluate the results of each sensor in accordance with Section 12.

5.2 This test method maintains the specimen in a static, vertical position and does not involve movement except that resulting from the exposure.

5.3 This test method specifies a standard set of exposure conditions. Different exposure conditions have the potential to produce different results. In addition to the standard set of exposure conditions, other conditions are allowed and shall be documented in the reporting of the testing results.

6. Apparatus

6.1 *General Arrangement For Determining Arc Rating Using Hand Protective Product Holders and Monitor Sensor*—The test apparatus shall consist of supply bus, arc controller, recorder, arc electrodes, hand protective product holder(s) (one sensor per hand protective product holder), and monitor sensors as shown in Figs. 1 and 2. Fig. 1 shows two of four hand protective product holders.

6.1.1 *Arrangement of the Hand Protective Product Holder*—Hand protective product holder(s) and monitor sensors shall be spaced as shown in Fig. 2 at 30° angle. Fig. 2 is circular placement with open front with shared monitors. Fig. 2 shows a full circular layout with individual monitors for each test panel.

6.1.2 *Hand Protective Product Holder Construction*—The hand protective product holders shall be constructed from non-conductive heat resistant material. The material surrounding the calorimeter shall have a thermal conductivity <0.20 W/mK at temperatures up to 500 °C (see Note 1). The calorimeter shall be mounted flush with the surface of the insulating holder material. The calorimeter can be mounted directly into the front board or alternatively be mounted into an insulating ring which is inserted into the front board. The insulating material surrounding the calorimeter shall be at least 5 mm larger than the diameter of the copper disc. An example of a product holder with the calorimeter mounted directly into the panel board is shown in Fig. 1.

NOTE 1—An example of an insulating board material for mount of calorimeters is a calcium silicate insulating material, for example, Marinite Grade P or C.

6.1.3 Each hand protective product holder monitor sensor shall have a structural vertical standoff board mounted to a horizontal base. Each standoff board shall be 7.6 cm [3 in.] wide and minimum 1.3 cm [0.5 in.] thick and 40.6 cm [16 in.] tall. A smooth fill form is required at the back of the board to fill the cavity of the glove and hold the hand protective product material taut to the front face against the calorimeter. The hand protective product holder dimensions can accommodate a hand protective product with hand-width of 254 mm to 279 mm (US size 10 hand protective product). Different dimensions are allowed for monitor sensor standoff as long as the position and orientation of the monitor meets angular orientation requirements in the standard.

6.1.4 Each hand protective product holder may be adjustable from 20.0 cm [8 in.] to 60.0 cm [24 in.] from the centerline of the arc electrodes and monitor sensor position may be adjustable from 20.0 cm [8 in.] to 60.0 cm [24 in.] from the centerline of the arc electrodes to allow for greater energy levels in testing. A factor shall be used to calculate incident energy based on the distance of the monitor sensor to the arc. The hand width distance shall be maintained in such a manner to allow hand protective products to fit on the stand in the sensor area as they would fit on a hand. Fig. 2 is an example of one test set up. Monitor sensors and hand protective product