



Standard Test Method for Determining Arc Ratings of Hand Protective Products Developed and Used for Electrical Arc Flash Protection¹

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.

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 arc heat flux values from 84 to 25,120 kW/m² [2 to 600 cal/cm²s].

1.2 This test method will determine the arc rating of hand protective products made of materials which 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 or receive a reported 50 % probability of ignition of a material or flammable underlayer (see definition of ignition₅₀) by this method.

1.2.1 It is the intent of this test method to be used for hand protective products which are flame resistant or which 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.

1.2.2 It is not the intent of this test method to be used for glove materials, which have been tested by Test Method F1959/F1959M as flat panels of material then sewn into hand protective products. Materials for hand protective products, which are not normally produced in flat panels or which display shrinkage making the material unacceptable to test on panels, shall be tested using this standard.

1.2.3 Rubber insulating gloves meeting Specification D120 and leather protectors meeting Specification F696 are not covered by this test method and are specifically excluded from its Scope.

1.2.4 Hand protective products tested by this 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 which could reduce or eliminate the arc rating of the hand protective products.

1.2.5 Gloves tested by this method provide no protection from electric shock. Insulated gloves for protection from electric shock are addressed under other standards including ASTM D120. 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 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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

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*

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.

Current edition approved June 1, 2013. Published July 2013. DOI: 10.1520/F2675_F2675M-13.

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 and health practices and determine the applicability of regulatory limitations prior to use. For specific precautions, see Section 7.

2. Referenced Documents

2.1 ASTM Standards:²

D120 Specification for Rubber Insulating Gloves

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

F696 Specification for Leather Protectors for Rubber Insulating Gloves and Mittens

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 Stoll⁴ curve, cal/cm².

3.1.3 *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.

3.1.3.1 *Discussion*—The specimen is considered to exhibit breakopen when any hole is at least 3.2 cm² [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.

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

3.1.4.1 *Discussion*—This is the value in J/cm² [cal/cm²] determined by use of logistic regression analysis representing the energy at which breakopen of the layer occurred.

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

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

3.1.7 *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.

3.1.8 *ignition₅₀*, *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.

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

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

3.1.11 *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.

3.1.11.1 *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.

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

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

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

3.1.15 *Stoll⁴ 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, **D123** Terminology Relating to Textiles, **D4391** Terminology Relating to the Burning Behavior of Textiles, **F819** Terminology Relating to Electrical Protective Equipment for Workers, **F1494** Terminology Relating to Protective Clothing, or IEEE Standard Dictionary of Electrical and Electronics Terms.

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.

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, 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 of second-degree burn as determined by the Stoll Curve⁴ 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 12.6.

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 on Figs. 1 and 2. Fig. 1 below shows two of four hand protective product holders.

6.1.1 *Arrangement of the Hand Protective Product Holder Panels*—Hand protective product holder(s) (one sensor per hand protective product) and monitor sensors (two for each hand protective product holder) shall be used for each test and be spaced equally as shown in Fig. 2. Fewer or more hand protective product holders may be used if the positioning and distance requirements of Section 6 are met. The monitoring sensors shall be positioned between hand protective products.

6.1.2 *Hand Protective Product Holder Construction*—Hand protective product holders and each monitor sensor holder shall be constructed from non-conductive heat resistant material with a thermal conductivity value of $< 0.15 \text{ W/mK}$, high temperature stability, and resistance to thermal shock.

NOTE 1—Wood and aluminum covered with calcium silicate with inert fillers and reinforcing agents has been used successfully.

6.1.3 Each hand protective product holder monitor sensor shall be constructed of an instrumented vertical standoff mounted on a horizontal plate. Each standoff shall be 31.8 cm [12.5 in.] tall, 7.6 cm [3 in.] wide and 1.3 cm [0.5 in.] thick. Hand protective product holder dimensions are selected to accommodate a hand protective product with hand-width of 254 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.

6.1.4 Each hand protective product holder may be adjustable from 20.0 cm [8 in.] to 60.0 cm [12 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 [16 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 holders may be at different distances as long as calculations take distance into account.

NOTE 2—It has been found that some hand protective products require more pressure to maintain contact of the hand protective product material with the sensor. Springs or other means may be used to assure that the glove material maintains contact with the sensor.

6.1.5 One sensor shall be mounted on each standoff as shown in Fig. 2. The centers of all sensors shall be at 28 cm [11 in.] elevation relative to the horizontal mount plate. The surface of each sensor shall be parallel and normal to the centerline of the arc electrodes. The distance from the center of the monitor sensor to the center of each hand protective product holder shall be 12.7 cm [5 in.]. Each sensor shall be mounted flush with the surface of the standoffs.

6.1.6 Additional sensors are allowed for installation as monitor and panel sensors for experimental purposes. The information from these sensors shall not be used as substitutes for the current test apparatus in the determination of ATPV, breakopen, or ignition₅₀ performance.

6.2 Sensors:

6.2.1 The hand protective product holder and monitor heat sensors are $4 \pm 0.05 \text{ cm}$ diameter.

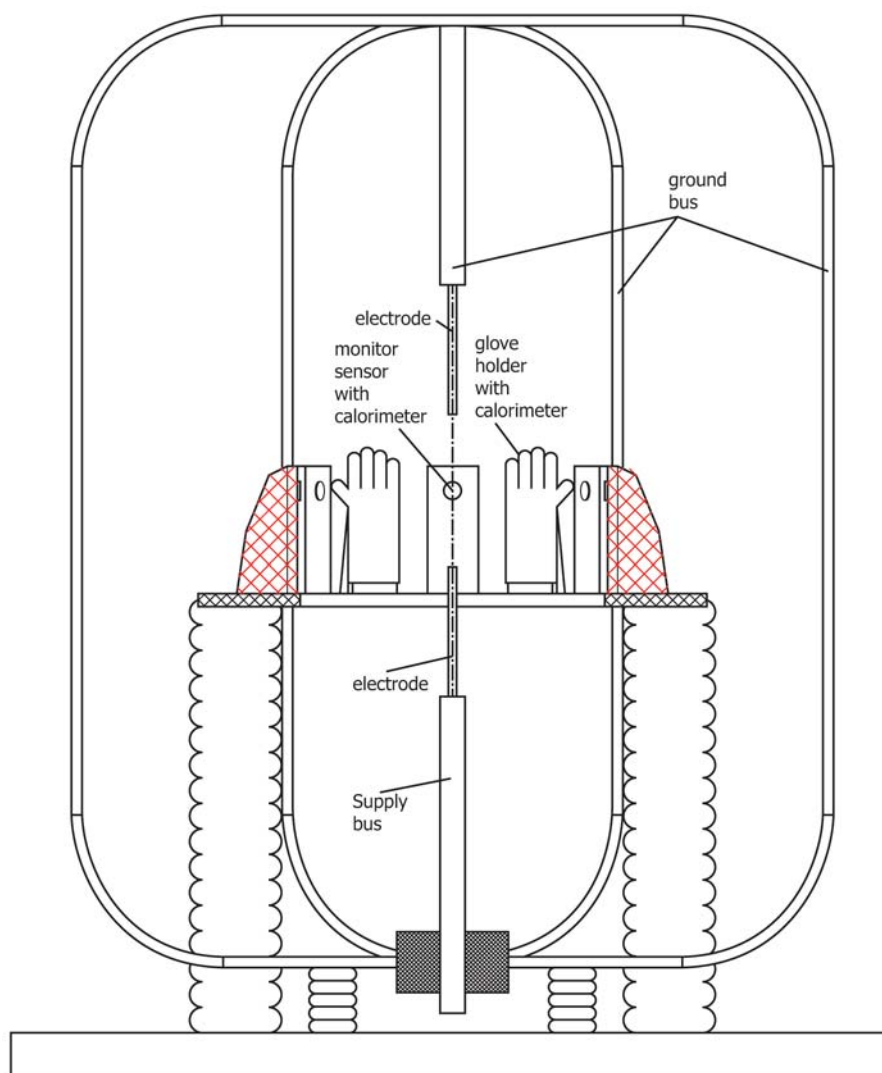


FIG. 1 Test Set Up Illustration

calorimeters constructed from electrical grade copper, each with a mass of 18 ± 0.05 g (prior to drilling) with a single ANSI type J (Fe/Cu-Ni) or ANSI type K (Ni-Cr/Ni-Al) thermocouple wire bead (0.254 mm wire diameter or finer – equivalent to 30 AWG) installed as indicated in 6.1 and shown in Figs. 2-5 (see Test Method E457 for information regarding slug calorimeters). Each sensor holder assembly shall be constructed from non-conductive heat resistant material with a thermal conductivity value of <0.15 W/mK, high temperature stability, and resistance to thermal shock. The board face containing the sensor shall be nominally 1.3 cm [0.5 in.] or greater in thickness. The sensor is held into the recess of the board by pinning, for example by using three straight pins, trimmed to a nominal length of 5 mm and placing them equidistant around the edge of the sensor so that the heads of the pins hold the sensor to the surface.

6.2.2 The exposed surface of the copper slug calorimeters shall be painted with a thin coating of a flat black high temperature spray paint with an emissivity of >0.9 . The painted sensor shall be dried before use and present a uniformly applied coating (no visual thick spots or surface irregularities).

Use an external heat source, for example, an external heat lamp, as required to completely drive off any remaining organic carriers in a freshly painted surface.

6.2.2.1 *Discussion*—An evaluation of the emissivity of the painted calorimeters used in this test method is available from ASTM; “ASTM Research Program on Electric Arc Test Method Development to Evaluate Protective Clothing Fabric; ASTM F18.65.01 Testing Group Report on Arc Testing Analysis of the F1959/F1959M Standard Test Method—Phase 1.” This report contains information on paint(s) successfully used.⁵

6.2.3 The thermocouple wire is installed in the calorimeter as shown in Fig. 5.

6.2.4 Alternate calorimeters are permitted for use as monitor sensors provided they are calibrated and have a similar response to those in 6.2.1. The use of a different thermocouple junction, exposed surface area, slug material, and mass are allowed and their performance shall be documented in the test results.

⁵ Available from ASTM International Headquarters. Request F1959-101.