INTERNATIONAL

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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

[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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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 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.~~

3.1.3 *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 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.

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[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.

3.1.4 *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/cm^2 [cal/cm^2] 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 *finished product, n*—a representative product as sold.

3.1.7.1 *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).

3.1.8 *glove, n*—a covering for the hand which has separate sections for the thumb and fingers or a mitten which has separate sections for the thumb and multiple fingers.

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*.

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 *Definitions of Terms Specific to This Standard:*

3.2.1 *attachments, n*—an additional material applied to a specific area of protective product to make the portion of the protective product more resistant to wear, to fit better, such as a cinch or elastic, or to add protection, such as impact protection.

3.2.2 *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).

3.2.2.1 *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.

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

3.2.3 *protector, n*—a glove designed to be worn over dielectric rubber insulating gloves.

3.2.3.1 *Discussion*—
A protector is designed to provide mechanical and thermal protection for the dielectric rubber insulating glove.

3.3 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~~ <0.20 W/mK at temperatures up to ~~500 °C~~ 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~~ 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.

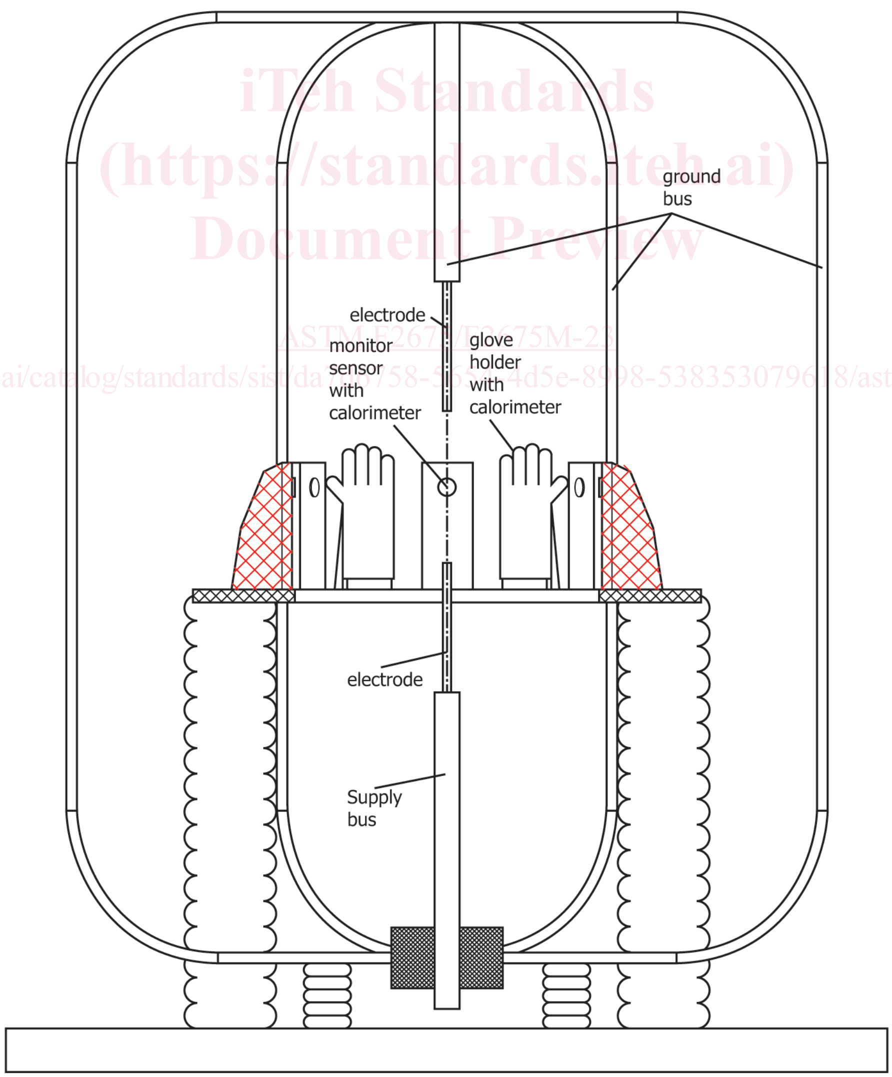

FIG. 1 Test Set Up Illustration

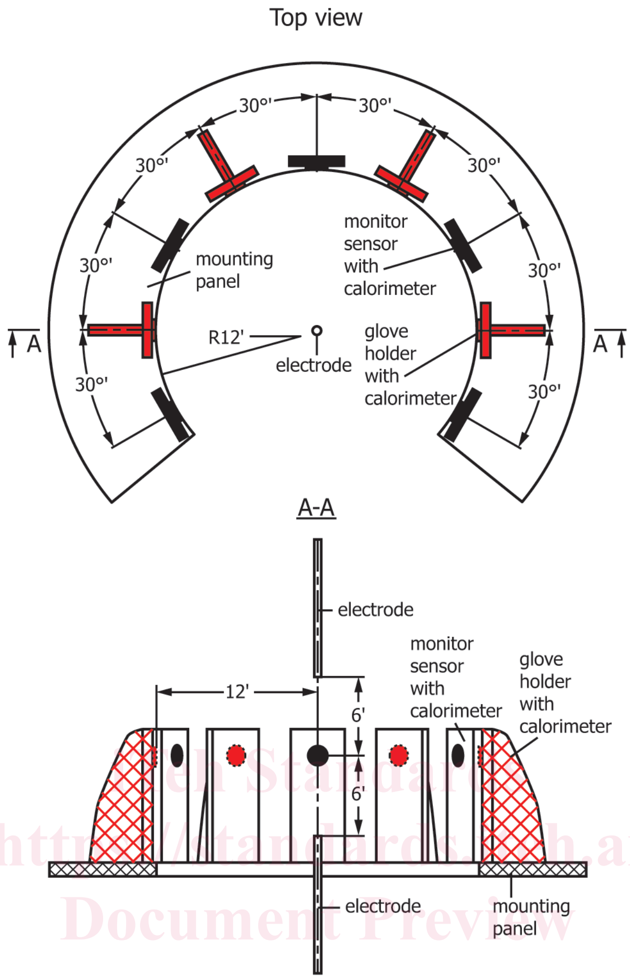

FIG. 2 Test Rig Illustration

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 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 ensure 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 hand protective device holder 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, EBT, $Ignition_{50}$, or ignition withstand performance.

6.2 *Sensors:*

6.2.1 The hand protective product holder and monitor heat sensors are 4 ± 0.05 cm diameter circular copper slug 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.

6.3 *Supply Bus and Electrodes*—A typical arrangement of the supply bus and arc electrodes is shown in Fig. 1. The arc shall be in a vertical position as shown.

6.3.1 *Electrodes*—Make the electrodes from stainless steel (Alloy Type 303 or Type 304) rod of a nominal ~~19 mm [0.75 in.]~~ 19 mm [0.75 in.] diameter. Length of ~~45.0 cm [18 in.]~~ 45.0 cm [18 in.] initially has been found to be adequate.

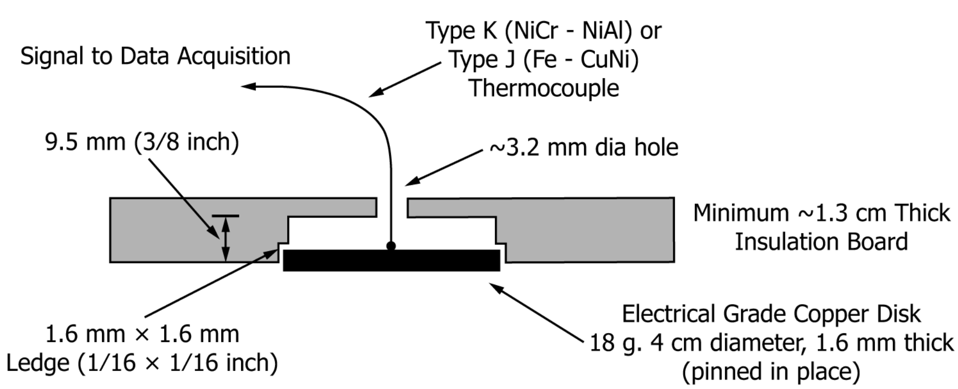

FIG. 3 Calorimeter and Thermocouple Detail

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:F18-1001. Contact ASTM Customer Service at service@astm.org.

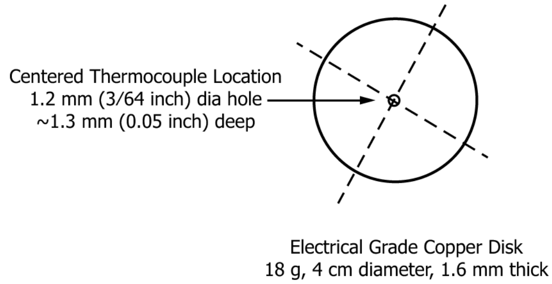

FIG. 4 Copper Calorimeter Detail

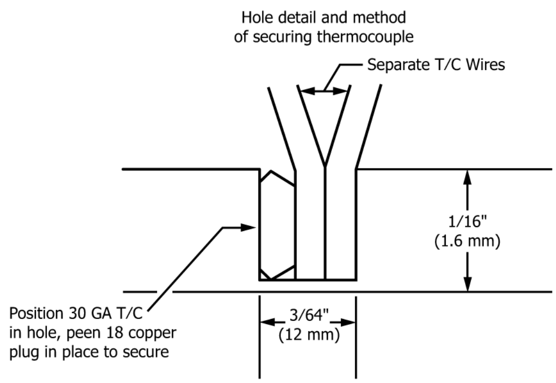

FIG. 5 Thermocouple Installation

6.3.2 *Fuse Wire*—A fuse wire, connecting the ends of opposing electrodes tips, is used to initiate the arc. This wire is consumed during the test; therefore, its mass shall be very small to reduce the chance of molten metal burns. The fuse wire shall be a copper wire with a diameter not greater than ~~0.5 mm [0.02 in.].~~0.5 mm [0.02 in.].

6.4 *Electric Supply*—Electric supply shall be sufficient to sustain symmetrical alternating arc current of ~~8000 ± 500 A~~ 8000 A ± 500 A RMS value within electrode gap of ~~300 ± 10 mm~~ 300 mm ± 10 mm for a duration from 0.05 s up to 2.5 s [from ~~3 to 150 cycles~~ 3 cycles to 150 cycles of 60 Hz power frequency, from ~~2.5~~2.5 cycles to 125 cycles of 50 Hz power frequency]. The X/R ratio of the test circuit shall be such that the test current contains a DC component resulting in the first peak of the test current having a magnitude of 2.3 ± 0.1 times the symmetrical RMS value.

6.5 *Test Circuit Control*—The symmetrical and peak components of an arc current in several consecutive exposures constituting one rating (series of test trials necessary to achieve set of 20 data points) shall not deviate more than 5 % from the selected test level. A make switch shall be capable of point on wave closing within ±10 electrical degrees in several consecutive exposures constituting one rating. Arc current, arc duration, and arc voltage shall be measured for each arc exposure. Arc energy shall be calculated for each arc exposure. Arc current and arc voltage shall be displayed in graph form and stored in digital format.

6.6 *Data Acquisition System*—The system shall be capable of recording voltage, current, and the calorimeter outputs as required by the test. The system shall be capable of recording voltage, current, and sufficient calorimeter outputs as required by the test. The recording of signals from all sources shall be initiated by a common trigger signal to have no more than ~~20 ms~~ 20 ms delay between the initiation of the arc and the calorimeter signal recording.

6.6.1 The temperature data (calorimeter outputs) shall be acquired at a minimum sampling rate of 100 samples per second per calorimeter and a system bandwidth of 20 Hz. The acquisition system shall be able to record temperatures to 500 °C. The temperature shall be reported with three significant digits and have an accuracy of at least ±0.75 °C or 2 %, whichever is greater. (This does not include the accuracy of the calorimeter).

6.7 The system current, voltage and arc signal (if separate signal) data shall be acquired at a minimum rate of ~~2000 samples~~ 2000 samples per second and bandwidth of at least ~~200 Hz.~~ 200 Hz. The current and voltage measurement shall be reported with three significant digits and have an accuracy of at least ~~3 %.~~3 %.

6.7.1 The temperature data (copper slug calorimeter out-puts) shall be acquired at a minimum sampling rate of ~~20 samples~~ 20 samples per second per calorimeter. The acquisition system shall be able to record temperatures to ~~500 °C.~~ 500 °C. The temperature acquisition system shall have at least a resolution of ~~0.1 °C~~ 0.1 °C and an accuracy of ~~±0.75 °C.~~ ±0.75 °C.

6.7.2 The system current and voltage data shall be acquired at a minimum rate of 2000 samples per second. The current and voltage acquisition system shall have at least a resolution of 1 % of the applied voltage and current.

6.8 *Data Acquisition System Protection*—Due to the nature of this type of testing, the use of isolating devices on the calorimeter outputs to protect the acquisition system is recommended.

7. Precautions

7.1 The test apparatus discharges large amounts of energy. In addition, the electric arc produces very intense light. Take care to protect personnel working in the area. Position workers behind protective barriers or at a safe distance to prevent electrocution and contact with molten metal. Workers wishing to directly view the test shall use tinted glasses such as ANSI/ASC Filter Shade 12 protection and be at least 25 m [75 ft] away. If the test is conducted indoors there shall be a means to ventilate the area to carry away combustion products, smoke, and fumes. Air currents can disturb the arc reducing the heat flux at the surface of any of the calorimeters. Non-combustible materials suitable for the test area shall shield the test apparatus. Outdoor tests shall be conducted in a manner appropriate to prevent exposure of the test specimen to moisture and wind (the elements). The leads to the test apparatus shall be positioned to prevent blowout of the electric arc. The test apparatus shall be insulated from the ground for the appropriate test voltage.

7.2 The test apparatus, electrodes, and calorimeter assemblies become hot during testing. Use protective gloves and sleeves when handling these hot objects.

7.3 Use care if the specimen ignites or releases combustible gases. An appropriate fire extinguisher shall be readily available. Ensure all materials are fully extinguished.

7.4 Immediately after each test, the electric supply shall be shut off from the test apparatus and all other laboratory equipment used to generate the arc. The apparatus and other laboratory equipment shall be isolated and grounded. After data acquisition has been completed, appropriate methods shall be used to ventilate the test area before personnel entry. No one shall enter the test area prior to exhausting all smoke and fumes.

8. Sampling and Specimen Preparation

8.1 *Test Specimens for Hand Protective Product Holder Test*—New (unused) hand protective products of size 10 (when the hand protective product is numerically sized) shall be used in arc rating test, because a size 10 hand protective product fits the hand protective product holder snugly and in contact with the calorimeter. If the hand protective products are not numerically sized, use a hand protective product that can be adjusted to fit the hand protective product holder snugly and in contact with the calorimeter. A visual integrity check shall be performed before each test to ensure no damage, cuts or holes are on the hand protective product surface. If hand protective product size is not numerical, the size tested shall be reported.

8.2 Measure the thickness of eight base products to the nearest 0.1 mm in the area of the hand where the calorimeter will contact the base product during testing. The average product thickness shall be calculated, and upper and lower measurement of thicknesses shall be determined and each reported. The measurement shall be made with a thickness gauge having a resolution of ±0.1 mm having a foot no larger than 10 mm and pressure not exceeding 1.8 N. Other methods or apparatus for measuring thickness may be used; the test standard and details of the instrument shall be reported.

NOTE 3—Different materials such as leather or rubber insulating products may have alternate thickness measurement methods for quality control and conformance to other standards. The thickness reported by this method for leather protectors and rubber insulating gloves may differ and is not indicative of failure to meet those standards.

8.3 Hand protective products shall be selected by the manufacturer at random or by another means to represent common hand protective products manufactured.

9. Calibration and Standardization

9.1 *Data Collection System Check*—The data collection system shall be checked to verify proper operation. This can be performed by using a thermocouple calibrator/simulator to inject a signal and allow verifications to be made at multiple points and at levels above 100 °C. Due to the nature of the tests frequent calibration checks are recommended. Other methods to effectively check the proper operation of the data collection system is acceptable.

9.2 *Calorimeter Calibration Check*—The calorimeters shall be checked to verify proper operation after assembly. Do this with the use of a fixed radiant heat source and comparison of individual calorimeters against each other using a reference calibrated or laboratory standard calorimeter or with alternative methods of verifying proper operation and response of the calorimeters.

9.3 *Arc Exposure Calibration*—Prior to each calibration, position the electrodes of the test apparatus to produce a ~~30.5 cm [12 in.]~~ 30.5 cm [12 in.] gap. The face of the monitor sensors is set parallel and normal to the centerline of the electrodes. The midpoint of the electrode gap shall be at the same elevation as the center point of the monitor sensors (see Fig. 2). Connect the fuse wire to the end of one electrode by making several wraps and twists and then to the end of the other electrode by the same method. The fuse wire is pulled tight and the excess trimmed. The test controller is then adjusted to provide the desired arc current and duration.

9.4 *Apparatus Operational Verification*—Position each hand protective product holder so that the surface of each panel sensor is ~~305 mm [12 in.]~~ 305 mm [12 in.] from, parallel and normal to the centerline of the electrodes. No test samples or any kind of cover are allowed for any sensor during calibration process. The monitor sensors shall be at either ~~305 mm or 340 mm.~~ 305 mm or 340 mm. The distance of all sensors shall be recorded to the nearest mm.

9.4.1 An arc discharge at the ~~8 kA ± 500A~~8 kA ± 500 A level and the arc duration at 10 cycles ~~(0.167 s)~~ (0.167 s) from 60 Hz supply or at ~~8.5 cycles (0.170 s) from 50 Hz~~ 8.5 cycles (0.170 s) from 50 Hz supply shall be performed.

9.4.2 The temperature versus time response curve from each sensor shall be converted into an incident energy versus time response curve. The maximum of the incident energy response curve for each sensor shall be determined and considered as the incident energy (total heat) in kJ/m^2 [cal/cm^2] measured by each sensor. Because the arc does not follow a path that is equidistant from each sensor, the resulting incident energy values vary between sensors.

9.4.3 The incident energy for each calorimeter shall be multiplied by the appropriate distance factor to the reference of 305 mm.

9.4.4 Calculate the average value of incident energies for all sensors.

9.4.5 The average value of the corrected incident energies for the sensors shall be 315 kJ/m^2 ~~±42 kJ/m~~± 42 kJ/m^2 [7.5 cal/cm^2 ± 1.0 cal/cm^2].

9.4.6 An arc exposure calibration test shall be conducted prior to the start of a test series and after each and any adjustment or failure of equipment.

9.4.7 The highest measured incident energy of any of the sensors shall not be more than 30 % greater than the average of the incident energies of these sensors and the lowest measured incident energy of any of these sensors shall not be more than 30 % lower than average. If these values are not obtained, inspect the test setup, and correct any possible problems that could produce less than desired results. To be considered verified, test apparatus shall meet the requirements of this paragraph for average, highest, and lowest values of measured incident energies.

9.5 *Confirmation of Test Apparatus Setting*—Confirm and report the test apparatus setting for each test from the controller equipment. Values to be reported are peak arc current, RMS arc current, arc duration, arc energy, and arc voltage. A graph of the arc current is plotted to ensure proper waveform. Record the ambient temperature and relative humidity.

10. Apparatus Care and Maintenance

10.1 *Initial Temperature*—Prior to each test, confirm that the sensors are at a temperature of ~~15~~15 °C to 35 °C. If necessary, the sensors shall be cooled with a jet of air or by contact with a cold surface.

10.2 *Surface Reconditioning*—While the sensor is hot, wipe the sensor face immediately after each test to remove any decomposition products that condense and could be a source of measurement error. If a deposit collects and appears to be thicker than a thin layer of paint or the surface appears irregular, the sensor surface requires reconditioning. Carefully clean the cooled sensor with acetone or petroleum solvent, making certain to follow safe handling practices. Repaint the surface as noted in 6.2.2. Perform an arc exposure to cure the paint and check calibration according to 9.3 after resurfacing the sensors.

10.3 *Hand Protective Product Holder and Monitor Sensor Assembly Care*—The assembly shall be kept dry. The product holders and monitoring sensors shall be protected from water and moisture ingress during long periods between tests to prevent damage resulting from exposure. Due to the destructive nature of the electric arc, the monitoring sensor holders shall be covered with the same paint as the sensors. Re-coat the holders periodically to reduce deterioration.

11. Procedure

11.1 Test parameters shall be ~~8 ± 1 kA arc current, 30.5 cm [12 in.]~~ 8 kA ± 1 kA arc current, 30.5 cm [12 in.] electrode gap, stainless steel electrodes, ~~30.5 cm [12 in.]~~ 30.5 cm [12 in.] distance between the arc centerline and the sensor surface. Additional test parameters are also permitted and the results reported on an optional basis.

11.2 *Order of Tests:*

11.2.1 An arc rating of a hand protective product is the statistical value in nature. A minimum of 20 data points is required for arc rating value to be determined in a statistically reliable way. The test data obtained from one test trial constitutes all data points of the statistical analysis. An average of two adjacent monitor sensors is used to determine the incident energy (E_i) for each hand protective product holder. The test apparatus may have as many test stands as is practically possible. Four have been found to be effective but fewer are allowed as long as the positioning, distance and other requirements are met.

11.2.2 Each test trial shall consist of all hand protective product specimens of the same construction and materials, one hand protective product for each of four hand protective product holders. Each test trial constitutes all data points of the statistical analysis.

11.2.3 To determine one base product arc rating, a series of test trials shall be run over a range of incident energies to achieve the minimum of 20 data points. The incident energy range shall be achieved by increasing or decreasing the arc duration (cycles). The base product arc rating may be applied to all devices using that base material if they meet the minimum ignition withstand for the arc rating to be assigned. If the ignition withstand for that arc rating cannot be met, the base product rating can be lowered to an AR_{Lim} which the product, as sold, can meet.

11.2.3.1 A minimum of 20 incident energy results of monitor sensor and respective 20 energy results of two hand protective product holders' sensors are required for an ATPV, E_{BT} or ignition probability determination ($ignition_{50}$). Results shall meet conditions of 11.2.3.2 through 11.2.3.4.

11.2.3.2 The measured incident energy (an average value of the respective monitor sensors) on at least 15 % of hand protective product holders exposed to the arc must result in values that always exceed the Stoll curve predicted second-degree burn injury criteria (as determined by 12.2.1). In other words, values in this energy range always exceed the Stoll criteria.

11.2.3.3 The measured incident energy (an average value of the respective monitor sensors) on at least 15 % of hand protective product holders exposed to the arc must result in values that never exceed the Stoll curve predicted second-degree burn injury criteria (as determined by 12.2.1). In other words, values in this energy range never exceed the Stoll criteria.

11.2.3.4 The measured incident energy (an average value of the respective monitor sensors) on at least 50 % of the hand protective product holders exposed to the arc must result in values that are approximately equally populated within ±20 % of the final ATPV or E_{BT} (as determined by 12.2.1; see 11.2.6 discussion). Values in this energy range typically have mixed results—some values exceed and some values do not exceed the Stoll criteria.

11.2.4 All data points are valid unless a copper calorimeter temperature exceeds 400 °C for the monitor sensor described in 6.2.1, or there is a malfunction of the test or data acquisition equipment, or the specimen mounting fails.