Designation: ~~F1959/F1959M – 24~~ F1959/F1959M – 24a

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.*

[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 ~~Jan. 1, 2024~~March 1, 2024. Published ~~February 2024~~March 2024. Originally approved in 1997. Last previous edition approved in ~~2023~~2024 as ~~F1959/F1959M – 23a.~~F1959/F1959M – 24. DOI: ~~10.1520/F1959_F1959M-24.~~10.1520/F1959_F1959M-24A.

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:*

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.

[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., P.O. Box 1331, Piscataway, NJ 08854-1331.
[4] Technical Manual of the American Association of Textile Chemists and Colorists.

3.1.7.2 *Discussion—*
This rating may also be set to any value less than the ATPV/EBT to allow for variation in design, manufacture, or test laboratory results. For example, if a fabric is tested multiple times, the lowest ATPV/EBT 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.

3.1.18 *fabric weight, n—in arc testing*, the measured value of a specific sample of the fabric mass per unit area expressed in grams per square meter (ounces per square yard), that is used to generate the fabric's arc rating.

3.1.19 *fabric weight, actual, n*—the measured value of a sample of fabric mass per unit area expressed in grams per square meter (ounces per square yard), from a lot of fabric as produced by the fabric manufacturer; this measurement is done in accordance with Test Methods D3776/D3776M before washing and after conditioning in accordance with Test Method D1776/D1776M.

[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.

3.1.20 *fabric weight, arc test, n*—the measured value of a specific sample of the fabric mass per unit area expressed in grams per square meter (ounces per square yard), that is used to generate the fabric's arc rating according to Test Method F1959/F1959M.

3.1.20.1 *Discussion*—
This weight is sometimes referred to as "AAD" or "Average Areal Density" on arc test reports. Before recording this weight, fabric is prepared in accordance with the preparation instructions of Test Method F1959/F1959M without conditioning in accordance with Test Method D1776/D1776M. Weight of the prepared fabric is required to be recorded prior to arc testing.

3.1.21 *fabric weight, nominal, n*—the target mass per unit area expressed in grams per square meter (ounces per square yard), for all production fabrics.

3.1.21.1 *Discussion*—
This is the official published weight and should not change once established for each unique fabric identifier. Manufacturers may have different acceptable variances to the published weights.

3.1.22 *heatflux, n*—the thermal intensity indicated by the amount of energy transmitted divided by area and time kW/m^2 [cal/cm^2s].

3.1.23 *ignition, n*—the initiation of flaming and combustion.

3.1.24 *incident energy monitoring sensors, n*—sensors mounted on each side of the panel, using the calorimeters described in ~~6.3~~6.5, not covered by test material, used to measure incident energy.

3.1.25 *incident energy (E_i), n*—the total heat energy received at the surface of the panel as a direct result of an electric arc.

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

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

3.1.28 *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 or breakopen; the low value of the range begins with the lowest incident energy indicating a positive result, and the high value of the range is the highest incident energy indicating a negative result.

3.1.28.1 *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.

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

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

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

3.1.32 *Stoll curve*[5], *n*—an empirical predicted second-degree skin burn injury model, also commonly referred to as the *Stoll Response*.

3.1.33 *X/R ratio*—the ratio of system inductive reactance to resistance. It is proportional to the L/R ratio of time constant, and is, therefore, indicative of the rate of decay of any DC offset. A large X/R ratio corresponds to a large time constant and a slow rate of decay.

3.2 For definitions of other textile terms used in this test method, refer to Terminologies D123, D4391, and F1494.

4. Summary of Test Method

4.1 This test method determines the heat transport response through a material, fabric, or fabric system when exposed to the heat energy from an electric arc. This heat transport response is assessed versus the Stoll curve.

4.1.1 During this procedure, the amount of heat energy transferred by the tested material 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 energies delivered to and through the specimens.

4.2 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 Curve or breakopen (should the specimen exhibit breakopen before the skin burn injury prediction is reached. The arc rating may also be expressed as an arc rating limit (AR_{Lim}) based on limits of the test apparatus or material performance. The AR_{Lim} is allowed to be a derated limit set by the manufacturer.

4.4 Material response shall be further described by recording the observed effects of the electric arc exposure on the specimens using the terms in 11.1.8.

5. Significance and Use

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

5.1.1 Because of the variability of the arc exposure, different heat transmission values may be 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 arc exposures performed under controlled laboratory conditions. Different exposure conditions have the potential to produce different results. In addition to the standard set of exposure conditions, other conditions representative of the expected hazard may be used and shall be documented in the reporting of the testing results.

6. Apparatus

6.1 *Test Apparatus for Determining Arc Rating Using Three Two-Sensor Panels and Monitor Sensors*—The test apparatus shall consist of three two-sensor panels, monitor sensors, supply bus and electrodes, electrical supply, test controller, and data acquisition system.

6.2 ~~*General Arrangement For Determining Arc Rating Using Three Two-Sensor Panels and Monitor Sensors*—~~*Calorimeter (Sensor) Construction:* ~~The test apparatus shall consist of supply bus, arc controller, recorder, arc electrodes, three two-sensor panels, and monitor sensors.~~

6.2.1 The calorimeter shall be constructed from electrical grade copper with purity greater than 99.9 %, UNS C11000. The copper disc shall have a thickness of 1.6 mm ± 0.1 mm, a diameter of 40 mm ± 0.1 mm, and a mass of 18 g ± 1 g. The thickness, diameter, and mass of each copper disc shall be measured to determine the actual response coefficient for each calorimeter that is used in heat capacity calculations. In the case of a group of copper discs having an average mass/area ratio within ±0.008 g/cm^2, the average value for the group of calorimeters may be used.

6.2.2 ~~*Arrangement of the Two-Sensor Panels*—Three two-sensor panels~~ A welded tip type K (NiCr-NiAl) thermocouple having a cross-sectional area of 0.05 mm^2 (No. 30 AWG) or equivalent, but not larger, shall be used ~~for each test and be spaced equally~~

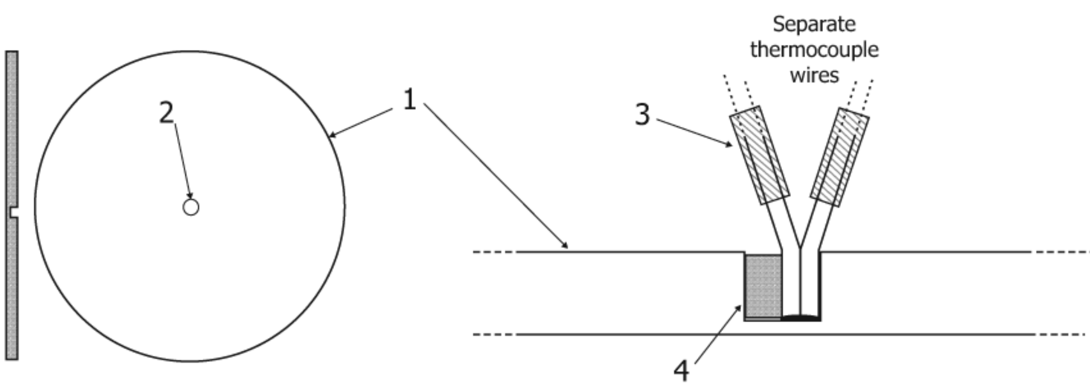
to construct the calorimeter. The thermocouple shall be installed inside the hole of the copper disc as shown in Fig. 1. ~~Each two-sensor panel shall have two monitoring sensors. One monitoring sensor shall be positioned on each side of the two-sensor panel as shown in~~The hole shall be drilled at the center of the copper disc to a depth of 1.3 mm ± 0.1 mm and a diameter to accommodate the bare thermocouple tip. The tip of the thermocouple shall be bare for the full length inside the copper disc. Copper filler material may be used to mechanically secure the thermocouple tip in place, soldering of the thermocouple is not permitted. The ~~Fig. 2.~~thermocouple wires shall be separated immediately upon exiting the copper disc. (See Test Method E457 for information regarding slug calorimeters.)

~~6.1.1.1 Monitor sensors located at a radius different from the two-sensor panels shall be employed when the incident energy from the arc exposure results in monitor sensor temperature values that exceed the maximum allowed operating characteristic of the copper calorimeter. See 11.1.1. Monitor sensors shall be positioned whereby there is a clear, unobstructed path between the sensors and the arc electrode centerline.~~

6.2.3 ~~*Panel Construction*—Each two-sensor panel and each monitor sensor holder shall be constructed from non-conductive heat resistant material with~~ The insulating material in which the calorimeter disc is inserted shall have a thermal conductivity ~~value of <0.15~~not exceeding 0.23 W ~~W/mK, high temperature stability, and resistance to thermal shock. The~~/mK at temperatures up to 500 °C (1). Due to the mechanical properties of the material, the board shall be ~~nominally~~ 1.3 cm [0.5 in.] or greater in thickness. The shape of the surrounding board may be circular or rectangular of any practical size but shall extend a minimum of 5 mm past the edge of the copper disk.

6.2.4 ~~Each two-sensor panel shall be 20.3 cm by 54.6 cm ± 1.3 cm [8 in. by 21.5 in. ± 0.5 in.] as shown in~~A circular cavity is machined in the front of the insulating material to accommodate the copper disc so that the surface of the copper disc will be flush with the surface of the surrounding surface. The supporting shoulder shall be equal to or greater than 1.0 mm, but not be more than 1.6 mm, that ~~Fig. 2. Each two-sensor panel~~ is, the inner diameter shall be not less than 36 mm and not greater than 38 mm. See Fig. 2 and Notes 3-8~~monitoring sensors shall be independently adjustable from 20.0 cm [8 in.] to 60.0 cm [24 in.] from the centerline of the arc electrodes as shown in~~. The cavity, when new, shall have a diameter which provides friction fit of the copper disc. Additional support shall ~~Fig. 1 and~~be provided ~~Fig. 3.~~by ~~R~~four~~$_1$ is the radius from the centerline of the arc electrodes to the surface of the two-sensor panels and r~~stainless steel shirt pins with a flat stainless steel head, cut to a practical length (for example, 5 mm) and hammered~~$_2$ is the radius from the centerline of the arc electrodes to the surface of the monitor sensors.~~straight or slightly inclined into the board, sitting half on the disc and half on the board.

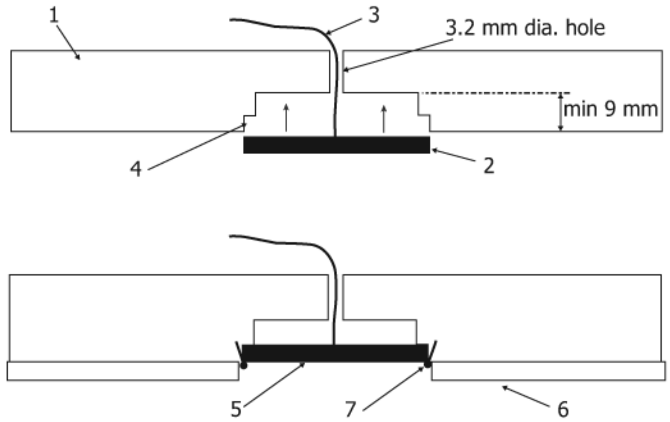
~~6.1.4 Two sensors shall be mounted in the panel as shown in Fig. 2. Each sensor shall be mounted flush with the surface of the mounting board.~~



~~r_1 = radius of two-sensor panels~~
~~r_2 = radius of monitor sensors~~
~~r_1; r_2 = 20 cm to 60 cm [8 in. to 24 in.]~~

Item:	
1	Copper disc, diameter: 40 mm ± 0.1 mm, thickness: 1.6 mm ± 0.1 mm, weight: 18 g ± 1 g
2	Hole for thermocouple, diameter to fit thermocouple tip, depth: 1.3 mm ± 0.1 mm
3	Type K thermocouple wire, welded tip fully inserted in the hole
4	Copper filler material peened to secure and maintain full contact of thermocouple wire to disc

FIG. 1 ~~Arrangement of Three Panel Sensors with~~ Example of Calorimeter Construction ~~Monitor Sensors~~



Item:

1	Calcium silicate insulating material, minimum 1.3 cm thick
2	40 mm Copper disc as assembled in Fig. 1
3	Type K thermocouple, 30 AWG
4	Supporting shoulder for disc, 1 mm to 1.6 mm wide, depth of 1.6 mm for disc
5	Copper disc fully inserted into the insulating board
6	High temperature insulating board as protective heat shield for monitor sensors ONLY, 40.5 mm to 42 mm hole, 3 mm thick
7	Stainless steel pins (3-5 may be used to secure the disc in place)

FIG. 2 ~~Two Sensor Panel (Face View) with Monitor Sensors~~Calorimeter and Thermocouple Installation Detail

~~6.1.5 Additional calorimeters 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 ignition performance.~~

6.3 ~~*Sensors:*~~ *Two-Sensor Panel Test Assembly*—Each two-sensor panel shall consist of two sensors, an insulating board, a support frame for the fabric, a fabric clamping system and two monitor sensors.

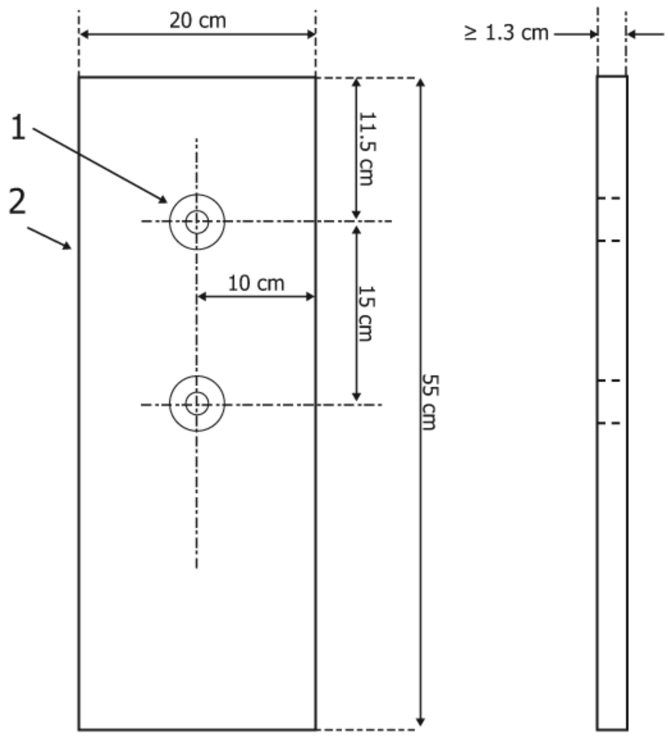
6.3.1 The insulating board shall be 20 cm × 55 cm ± 1.3 cm [8 in. × 21.5 in. ± 0.5 in.] made of electrical and heat-resistant material having a thermal conductivity not exceeding 0.30 W⁄mK at temperatures up to 200 °C. The front edges of the board shall be rounded to have a smooth edge as to allow the fabric to slide. Two sensors (see Fig. 2) shall be inserted into the front board placed on the vertical center line of the insulated board, as shown in Fig. 3, and flush with the surface. Alternatively, two copper discs can be mounted directly into the insulating board. In this case, the insulating board shall meet the material property requirements of 6.2.3 and the copper discs shall be mounted and fitted into the insulating board according to the requirements of 6.2.4. The two-sensor panel shall be constructed to protect the two thermocouple wires fully from the side and back from the influence (for example, heat, contamination) of and eventual damage caused by the arc event.

6.3.2 A support frame shall be used to hold the panel perpendicular to the electrodes and maintain the test specimen at the correct distance and height. An example of a support frame is shown in Fig. 4. Alternate insulating material may be used for the panel construction not in contact with the calorimeter. The material for the support frame may be any suitable, structurally-stable and flame-resistant material.

6.3.3 *Monitor Sensors*—~~The panel and monitor sensors shall be copper slug calorimeters constructed from electrical grade copper with a single thermocouple wire installed as identified in~~Monitor sensors are located on each side of the two-sensor panel to measure the incident energy. The size and support for the monitor sensor can be arranged to fit the panel construction but shall be constructed to protect the copper disc fully, from the side and back, from the ~~Fig. 5 (see Test Method~~influence (for example, heat, ~~E457 for information regarding slug calorimeters).~~contamination) of and eventual damage caused by the arc event.

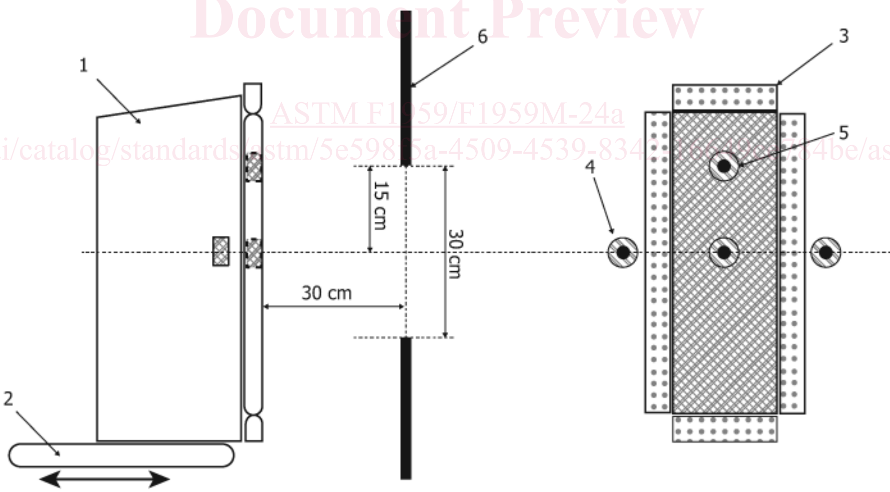
6.3.3.1 To prevent damage of the insulating material surrounding the copper disc from the intense heat of the arc, an additional thin heat shield (refractory sheet) may be used to protect the insulating material of the sensor. This sheet shall be electrically insulating and not exceed 3 mm [⅛ in.] thickness.

NOTE 1—The use of a heat shield helps to minimize damage to the surface of the insulating material. Calcium silicate insulating material is used in the sensor construction because it has low thermal conductivity, has a lower melting temperature, and may be damaged when directly exposed to the arc.



Item:
1 Calorimeter
2 Two sensor panel

FIG. 3 ~~Sliding~~ Two Sensor Panel



Item:
1 Panel structural support frame, see 6.3
2 Support table or base, adjustable to allow fine adjustment of front panel
3 Clamping Mechanism, see 6.3.5, 4 sides
4 Incident energy monitors (two each for each panel, see Fig. 6 for positioning)
5 Two sensors mounted in the panel
6 Stainless steel electrodes

FIG. 4 ~~Calorimeter and Thermocouple Detail~~ Example of Two Sensor Panel Positioning with Stainless Steel Electrodes

6.3.3.2 The heat shield covering the insulating material of the sensor shall have a hole slightly larger in diameter (not more than 2 mm larger) than the calorimeter and shall be centered over the calorimeter as shown in Fig. 2. The thin shield may be fixed by screws onto the surface of the sensor, no closer than 1.5 cm from the copper disc.

6.3.4 *Emissivity Primer*—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). ~~Note that an external heat source, for example, an external heat lamp, may be required to completely drive off any remaining organic carriers in a freshly painted surface.~~

6.3.4.1 An external heat source such as an external heat lamp or heat gun may be used to dry the freshly painted surface.

6.3.4.2 ~~*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 Standard Test Method—Phase 1."

~~6.2.3 The thermocouple wire is installed in the calorimeter as shown in Fig. 6.~~

6.3.5 *Clamping Mechanism*—~~Alternate calorimeters are permitted for use as monitor sensors provided they are calibrated and have a similar response to those~~ Each two-sensor panel shall have four clamps (one on each side) which hold the specimen in place, an example of a system is shown in ~~6.2.1~~Fig. 4 and Fig. 5. 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.~~clamp system shall cover the full perimeter of the panel and allow the material to shrink during arc exposure. Each clamp shall apply between 4.4 N and 6.7 N [1 lbf and 1.5 lbf] to secure the material to the edges of the two-sensor panel. Other means of mounting, which meet the above objectives, may also be employed.

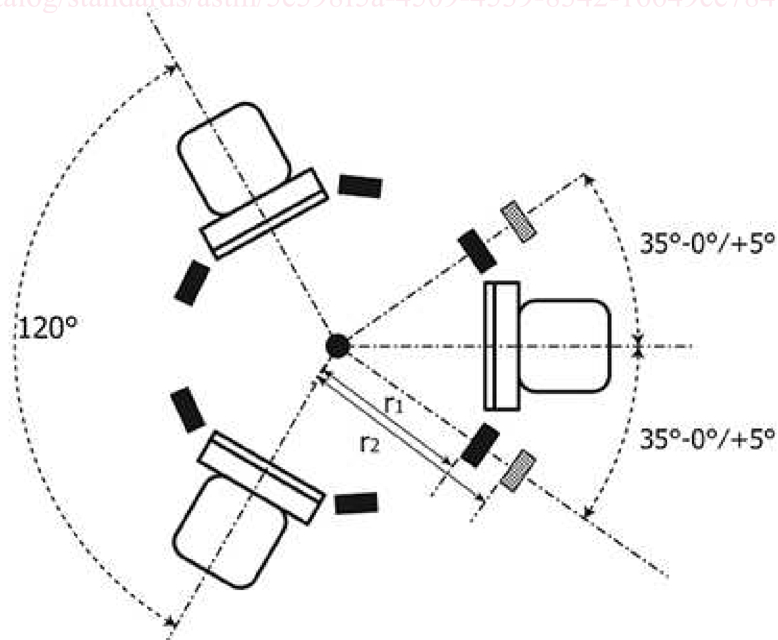
NOTE 2—A spring scale has been found to be a satisfactory way to measure the clamping force. The clamp force is measured just at the instant the mechanism starts to move from the panel.

NOTE 3—An example of an insulating board material for mount of calorimeters is a calcium silicate insulating material. Other materials meeting the criteria may be used.

NOTE 4—An example of insulating board material for panel construction and clamps is a calcium silicate insulating material. Other materials meeting the criteria may be used.

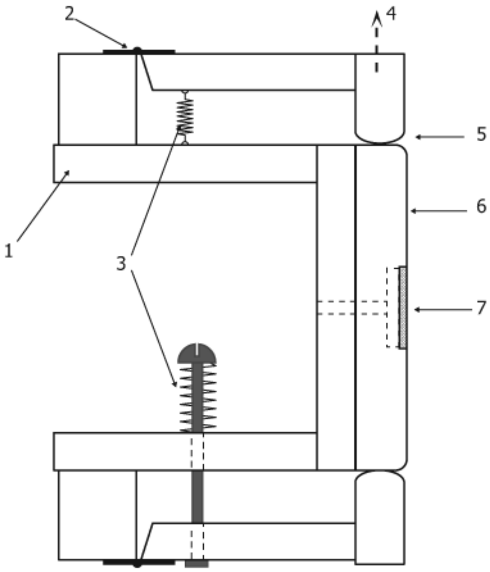
NOTE 5—"Friction fit" means that when the disc has been put in place and then the front board turned upside down, the disc will not fall out.

NOTE 6—A friction fit of the copper disc into the insulating board is to prevent hot gases from heating up the side or entering behind the disc and deteriorating the sides of the cavity



NOTE 1—Drawing showing alternate positions of incident energy monitor sensors; see Table 1 for distance of r_1 and r_2 based on range on incident energy.

FIG. 6 ~~Thermocouple Wire Installation~~Arrangement of Three Two-Sensor Panels with Monitor Sensors



Item:	
1	Support frame
2	Hinged fabric clamping mechanism
3	Typical spring clamp arrangement, springs in compression or tension, alternate methods which meet the above objectives, may also be employed
4	Springs to provide 4.4 N to 6.7 N of force
5	Rounded edges on clamp piece, r = 12 mm
6	Two-sensor panel, rounded edges, r = 12 mm
7	Calorimeter

FIG. 5 ~~Calorimeter~~Two Sensor Panel Clamping Mechanism

NOTE 7—To minimize the contact area between the shoulder of the ledge and the backside of the copper disc, the shoulder of the ledge can be machined slightly angled inwards (for example, by a few degrees), that is, away from the backside of the copper disc.

NOTE 8—After having verified that the disc has been mounted flush with the surface of the surrounding insulating board and has the required friction fit to the insulating board, the disc can be secured in place by pins (for example, at least 3 pins) equally spaced around the circumference of the disc.

NOTE 9—A high temperature refractory sheet should be 3 mm or ⅛ in. thick.

6.4 *Arrangement of the Two-Sensor Panels and Monitor Sensors*—The configuration of three panels shall be used for each test and the panels shall be spaced at 120°, having a distance as indicated in Table 1 and shown in Fig. 6.

6.4.1 One monitor sensor shall be positioned on each side of a two-sensor panel. The monitor sensor shall be positioned perpendicular to radius drawn from the center line of the electrodes to the center of the monitor sensor. The angle α between the radius drawn to the center of the monitor sensors and the radius drawn to the center line of the panel surface shall adjust to the range, as indicated in Table 1, from the center line of the arc electrodes (see Fig. 6). Distances r_1 and r_2 have been found to be practical, thus shall be selected for different incident energy exposures (see Table 1).

6.4.2 The actual distance of the monitor sensors and two-sensor panels (r_1, r_2) shall be measured and the value used to determine the multiplier for the incident energy calculation in 12.3.1. The actual distance of each panel and monitor sensor shall be measured to a precision of ±2 mm. The multiplier factor shall be the square of the ratio of the actual distance of the monitor sensor divided

TABLE 1 Positioning of Two-sensor Panels and Monitor Sensors depending on Incident Energy Exposure

Target incident energy	0 kJ/m^2 to 2300 kJ/m^2 0 cal/cm^2 to 55 cal/cm^2	>1675 kJ/m^2 >40 cal/cm^2
Position of two-sensor panels	305 mm ± 5 mm	305 mm ± 5 mm
Monitor sensors:	Position 1	Position 2
Distance between vertical centre line of electrodes and centre of monitor sensor surface	r_1 340 mm ± 5 mm	r_2 410 mm ± 5 mm
Angle between perpendicular line to panel surface and perpendicular line to monitor sensor surface	35° -0°/+5°	35° -0°/+5°