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Standard Test Method for Determining the Protective Performance of a Shield Attached on Live Line Tools or on Racking Rods for Electric Arc Hazards[1]

This standard is issued under the fixed designation F2522; 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 heat attenuation factor (HAF), the effective heat attenuation factor (EHAF), and the shields mechanical strength (SMS) of a shield attached on live line tools or racking rods intended for protection of workers exposed to electric arcs.

1.2 The materials used in this test method of worker protection are in the form of a shield attached on live line tools or on the racking rods.

1.3 The protective shield described in this test method shall be transparent and shall be easily attached and removed from live line tools or from racking rods.

1.4 The protective shield described in this test method has 24-in. (0.61-m) diameter and can be used for most applications, however for special cases, the shield can have different sizes to suit the protective requirements of the application.

1.5 This standard shall be used to measure and describe the properties of materials, products, or assemblies in response to incident energies (thermal-convective, and radiant and pressure wave) generated by an electric arc under controlled laboratory conditions and does not purport to predict damage from light, resultant pressure impact other than the pressure and thermal aspects measured.

1.6 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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 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]
D4391 Terminology Relating to The Burning Behavior of Textiles
F1959/F1959M Test Method for Determining the Arc Rating of Materials for Clothing

3. Terminology

3.1 *Definitions:*

3.1.1 *arc, n*—conductive path in air for the electric current caused by ionization of air between two electrodes.

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

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[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 F18.35 on Tools ~~and~~& Equipment.

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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.

3.1.3 *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*.

3.1.4 *arc gap, n*—distance between the arc ~~electrodes.~~electrodes, cm [in.].

3.1.5 *arc voltage, n*—voltage across the gap caused by the current flowing through the resistance created by the arc gap, V. See also Terminology D4391.

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

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

3.1.8 *closure, n*—point on supply current wave form where arc is initiated.

~~3.1.9 *delta peak temperature, n*—difference between the maximum temperature and the initial temperature of the sensor during the test, °C.~~

3.1.9 *effective heat attenuation (EHAF)/cone of protection (COP) factor, n*—the percentage of the incident heat energy that is attenuated by the shield at the location of the worker.

3.1.10 *fragmentation, n*—molten metal fragments or other fragments emitted from an electric arc.

3.1.11 *heat attenuation factor (HAF), n*—the percentage of the incident heat energy that is blocked by the safety shield material.

3.1.12 *heat flux, n*—the thermal intensity indicated by the amount of energy transmitted divided by area and time W/m^2 [cal/cm^2s].

3.1.13 i^2t,*n*—sum of the instantaneous arc current values squared multiplied by the incremental time values during the arc, A^2/s.

3.1.14 *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.

3.1.15 *ignition, n*—the initiation of combustion.

3.1.16 *incident energy (E_i), n*—the amount of energy (total heat, cal/cm^2) received at a surface as a direct result of an electrical arc discharge as measured by temperature rise on copper calorimeters.

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

3.1.18 *pressure wave, n*—a certain force over an area created by air movement caused by an electric arc.

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

3.1.20 *sensors, n*—copper calorimeter, instrumented with a thermocouple contained in a dielectric, heat protective housing for use in measuring energy.

3.1.21 *shield mechanical strength value (SMS) factor, n*—the mechanical ability of the shield to withstand the electric arc pressure wave and fragmentation.

~~3.1.23 *time to delta peak temperature, n*—the time from beginning of the initiation of the arc to the time the delta peak temperature is reached, s.~~

3.1.22 *X/R ratio, n*—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.

4. Summary of Test Method

4.1 This test method determines the heat attenuation factor (HAF) of the shield material, the effective heat attenuation factor (EHAF) at the location where the worker may be while holding the hot stick or racking rod to which the shield is attached, and the shield mechanical strength (SMS). The copper calorimeters (incident energy monitoring sensors) are placed for the HAF at the shield (front and back), and for the EHAF test at the probable location of the worker's hand, head, side of the face, chest, and legs when exposed to the heat energy from a controlled electric arc. The SMS value of the shield is obtained from visual observations of the HAF test for the ability of the shield to absorb and deflect the fragmentation shrapnel, not break or ignite, not to move from its attachment, and not to bend more then 20 degrees.

4.2 During HAF and EHAF tests, the center of the shield is aligned with the mid point of the arc gap. During this procedure, the amount of heat energy reduced (blocked) by the shield is measured during exposure to an electric arc.

4.3 The heat energy of the arc exposure is measured with calorimeters. The rate at which the temperature of the calorimeters increases is a direct measure of the heat energy received.

4.4 The shield protective performance for this test method is determined from the heat attenuation factor (in percent) at the shield location, and from the effective heat attenuation factor at the worker location. The effective heat attenuation factor in percent is the difference in the incident energy generated by the arc flash before and after the shield was used.

4.5 Heat transfer data can be used to predict the onset of second degree burn using the Stoll curve.

4.6 This procedure incorporates incident heat energy monitoring sensors.

4.7 Further description of the shield reduction of the electric arc exposure on the worker is presented in Sections 12 and 13.

5. Significance and Use

5.1 This test method is intended for determining the heat attenuation factor (HAF) of a shield material and the effective heat attenuation factor (EHAF) at the location of the worker. This can be obtained by measuring the reduction of the arc incident energy levels caused by a shield attached on a live line tool (hot stick) or on a racking rod and designed for protection for workers exposed to electric arcs. The shield mechanical strength (SMS) can be obtained from visual observations of the high speed video recordings of each shot during HAF tests.

5.1.1 Because of the variability of the arc exposure, different heat transmission values and pressure may result for individual sensors. The results of each sensor are evaluated in accordance with Section 12.

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

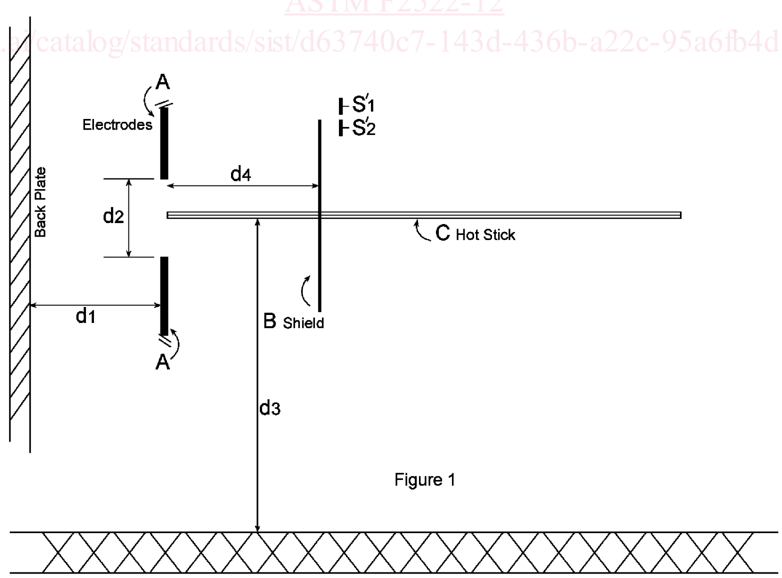
5.3 This test method specifies a standard set of exposure conditions. Different exposure conditions may produce different results.

NOTE 1—In addition to the standard set of exposure conditions, other conditions representative of the expected hazard may be used and shall be reported should this data be cited.

6. Apparatus

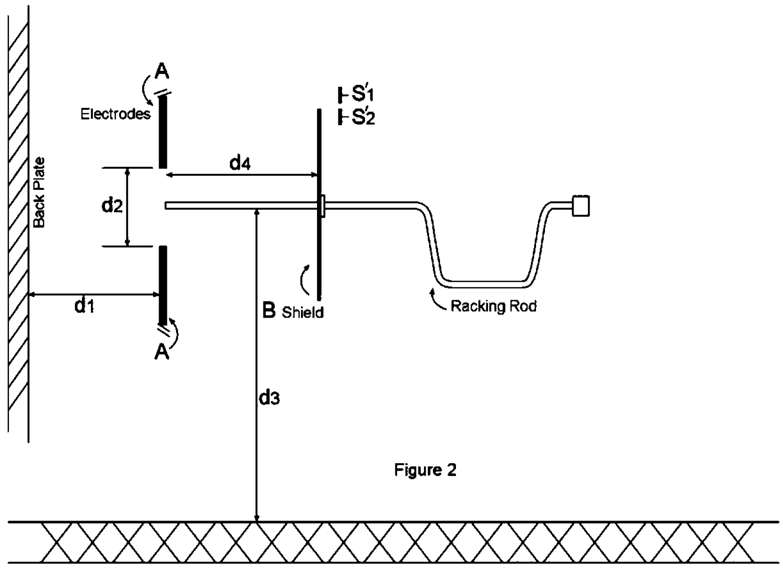
6.1 *General Arrangement for Determining Heat Attenuation Factor (HAF) of the Shield*—The test apparatus shall consist of supply bus, arc controller, recorder, arc electrodes, the shield, and incident energy monitoring sensors. The arc exposure in the form of heat attenuation factor at the shield location shall be monitored with two incident energy monitoring sensors. Figs. 1 and 2 show the test set-up and the location of the shield on the hot stick and on the racking rod and the location of sensors. Fig. 2 has the same test set-up as Fig. 1, except the shield is attached on the racking rod.

6.2 *General Arrangement for Determining Effective Heat Attenuation Factor (EHAF) at the Location of the Worker*—The test apparatus shall consist of supply bus, arc controller, recorder, arc electrodes, a shield, and incident energy monitoring sensors. The arc exposure in the form of effective heat attenuation factor at the location of the worker shall be monitored with a minimum of six incident energy monitoring sensors. Figs. 3 and 4 show the test set-up and the location of the shield and the sensors. The shield for the EHAF test is at the same location as in the HAF tests (Figs. 1 and 2) and the sensors are located approximately 5 ft (1.52 m) from the electric arc center. Fig. 4 has the same test set-up as Fig. 3, except the shield in Fig. 4 is attached on the racking rod, and in Fig. 3 the shield is attached on a hotstick.



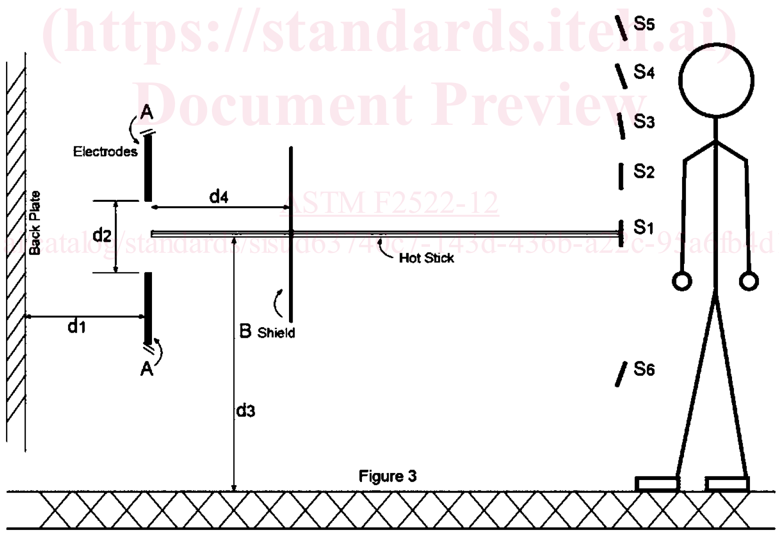
d1 = 24 in. (0.61 m), distance from the wall (back plate) to the arc electrodes
d2 = 6 in. (0.15 m) (gap) between electrodes
d3 = 53 in. (1.35 m), parallel distance of the hot stick or the racking rod above the floor
d4 = 24 in. (0.61 m), distance of the shield from the electrodes
d5 = 4 in. (0.10 m), vertical distance between centers of S'1 and S'2
S'1 and S'2 = 24.5 in. (0.62 m), approximate horizontal distance of the sensors from the electrodes
S1, S2, S3, S4, S5, and S6 are located vertically, and S1 is 5 ft (1.52 m) from the arc center

FIG. 1 Test Set-up for HAF Measurements with Shield on a Live Line Tool



d1 = 24 in. (0.61 m), distance from the wall (back plate) to the arc electrodes
d2 = 6 in. (0.15 m) (gap) between electrodes
d3 = 53 in. (1.35 m), parallel distance of the hot stick or the racking rod above the floor
d4 = 24 in. (0.61 m), distance of the shield from the electrodes
d5 = 4 in. (0.10 m), vertical distance between centers of S'1 and S'2
S'1 and S'2 = 24.5 in. (0.62 m), approximate horizontal distance of the sensors from the electrodes
S1, S2, S3, S4, S5, and S6 are located vertically, and S1 is 5 ft (1.52 m) from the arc center

FIG. 2 Test Set-up for HAF Measurements with Shield on a Racking Rod



d1 = 24 in. (0.61 m), distance from the wall (back plate) to the arc electrodes
d2 = 6 in. (0.15 m) (gap) between electrodes
d3 = 53 in. (1.35 m), parallel distance of the hot stick or the racking rod above the floor
d4 = 24 in. (0.61 m), distance of the shield from the electrodes
d5 = 4 in. (0.10 m), vertical distance between centers of S'1 and S'2
S'1 and S'2 = 24.5 in. (0.62 m), approximate horizontal distance of the sensors from the electrodes
S1, S2, S3, S4, S5, and S6 are located vertically, and S1 is 5 ft (1.52 m) from the arc center

FIG. 3 Test Set-up for EHAF Measurement with Shield on a Live Line Tool

6.3 *General Arrangement for Determining Shield's Mechanical Strength (SMS)*—The evaluation of shield's mechanical strength value (SMS) is based on visual observations of the high speed video recordings of the arc tests made in 6.1 (HAF tests). The purpose of the SMS test is to determine the mechanical ability of the shield to withstand the electric arc pressure wave and fragmentation. The SMS value is determined by observing the HAF tests for the ability of the shield to absorb and deflect the fragmentation shrapnel, not break or ignite, not to move from its attachment, and not to bend more then 20 degrees.

6.4 *Electrodes*—A typical arrangement of the arc electrodes is shown in Fig. 1. The arc shall be in a vertical position as shown.