Designation: F2676 – 09

# StandardTest Method for Determining the Protective Performance of an Arc Protective Blanket for Electric Arc Hazards[1]

This standard is issued under the fixed designation F2676; 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 evaluate the ability of the arc protective blankets to withstand the effects of arc flash and arc blast in a configuration in which the blanket is hung or anchored near energized equipment. Specifically, this test method is used to determine the arc protective blanket's *(1)* resistance to breakopen, *(2)* mechanical strength, and *(3)* ability to self-extinguish flames following a controlled arc exposure.

1.2 This method is used to determine the performance of arc protective blankets in terms of: maximum arc current level expressed in kA and BTP (BTP) expressed as the product of arc current in kA and arc duration in number of cycles to cause breakopen (kA*cycles). Cycles are on the basis of 60 Hz.

1.3 Blanket test specimens used in this test method are test size blankets of 152 ± 5 cm (60 ± 2 in.) by 122 ± 5 cm (48 ± 2 in.). The test specimen size is for testing purposes only. Commercially available arc protective blankets either larger or smaller than the test specimen size are covered by this standard.

1.4 The arc protective blankets described in this test method are made of flame-resistant materials and are available in varying sizes and configurations based on the application.

1.5 This test method shall be used to measure and describe the properties of materials, products, or assemblies in response to incident thermal (convective and radiant) and pressure energies generated by an electric arc under controlled laboratory conditions.

1.6 The values stated in SI units shall be regarded as standard. The values given in parentheses are mathematical conversion to inch-pound or other units commonly used for arc testing.

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

F819 Terminology Relating to Electrical Protective Equipment for Workers

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

3.1.3 *arc protective blanket, n*—a flat assembly of fabric(s) with locations for attachment used to protect workers from the effects of arc flash and arc blast.

3.1.4 *arc protective blanket maximum arc current $I_{max}$, n*—maximum value of RMS arc current that blanket can withstand without breakopen for no less than ten cycles of 60 Hz.

3.1.4.1 *Discussion*—Standard values of the maximum arc current for this test method are 15 kA, 25 kA, or 40 kA.

3.1.5 *arc protective blanket breakopen threshold performance (BTP) , n*—the product of the arc current *I*, kA and arc duration in cycles required for breakopen to occur at this same arc current level.

[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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[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.

3.1.6 *breakopen, n—in electrical 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.

3.1.6.1 *Discussion*—The instant of breakopen will only be visible with a high-speed (HS) camera. The size of the breakopen will quickly expand as the arc blows through the blanket and burns back the edges of the materials. The final size of the breakopen hole is not significant, as it will depend to a great extent on the duration of the arc once the breakopen point is reached. The important measure using the HS camera is the time from arc initiation to the first evidence of arc plasma through the blanket.

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

3.1.8 *directional arc, n—in arc protective blanket testing,* an arc expanding in direction of the blanket perpendicular to and centered to the blanket plane.

3.1.9 *dripping, n—in arc testing,* a material response evidenced by flowing of a specimen's material of composition and droplets separation from the material.

3.1.10 *embrittlement, n*—the formation of a brittle residue as the result of pyrolysis or incomplete combustion.

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

3.1.12 *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.

3.1.13 *mechanical strength, n—for an arc protective blanket,* the ability to remain attached to its support(s) in essentially its original configuration.

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

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

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

3.1.17 *shrinkage, n*—a decrease in one or more dimensions of an object or material.

3.2 For definitions of other terms see Terminologies D4391 or F819.

## 4. Summary of Test Method

4.1 This test method determines resistance to breakopen and mechanical strength under directional arc exposure, ability to self-extinguish flames and the afterflame time of the exposed arc protective blankets. This test method simulates a condition in a vault or substation or energy center where arc protective blanket may be attached to provide protection from the thermal effects and the pressure wave experienced during an electrical arc fault. This test method replicates most severe conditions when the arc is directed and focused on the blanket.

4.2 This test method determines two ratings for arc protective blanket: Maximum Arc Current, $I_{max}$, and BTP.

4.3 Three nominal values of $I_{max}$ are established in this test method: 15 kA, 25 kA and 40 kA. In this test method each arc protective blanket test specimen is intentionally forced to break open. To be considered arc rated, blanket shall withstand three times at least one of the nominal values of $I_{max}$ without breakopen during at least 10 cycles.

NOTE 1—Additional testing at a higher $I_{max}$ than 40 kA is permitted but the arc protective blanket shall be rated at one of the three nominal values of $I_{max}$ which shall be the official rating.

4.4 BTP is determined as the product of arc current and arc duration causing breakopen. Arc duration is the number of 60 Hz cycles between arc initiation and breakopen of the blanket.

4.5 BTP is determined for at least three different arc current levels. A minimum value of BTP is assigned as arc rating to an arc protective blanket.

4.6 In this test method the arc electrodes configuration is designed so that the arc blast projects directionally towards the test specimen.

4.7 This test method involves observing HS video recordings to determine test specimen breakopen and afterflame time. Each trial is recorded with a HS video camera.

## 5. Significance and Use

5.1 This test method determines the effectiveness of arc protective blankets in suprressing the combined effects of an arc flash and arc blast.

5.2 The arc exposure energy is produced from controlled phase-to-ground arc fault. The resulting arc flash and blast energy are intentionally directed onto the test specimen to simulate worst case conditions.

5.3 Test results will describe the maximum arc current and product of arc current and cycles at which test specimens block the energy without breakopen, ability to self-extinguish afterflaming, afterflame time and the detection of mechanical attachment failures during testing. Mechanical attachment failure and afterflame time are obtained from visual observations and video recording after each arc exposure.

5.4 This test method maintains the arc protective blanket in a vertical position and does not involve movement except that resulting from the arc exposure.

5.5 In this test method, test specimens are exposed at three arc current levels to determine the test specimen's performance.

NOTE 2—In experimental testing, some blankets increase in protection (in value of kA*cycles to cause breakopen) as the arc current increases and some decrease as shown in Fig. 1. This test method is designed to recognize this behavior and to specify testing over the range of arc current levels including lower levels of 5 kA or 10 kA, or both.

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

NOTE 3—In addition to the standard set of exposure conditions, it is permitted to test using other conditions representative of the expected hazard, reported all non-standard test conditions that are used.

## 6. Apparatus

6.1 *General Arrangement for Testing of Arc Protective Blankets*—The test apparatus shall consist of a vault containing

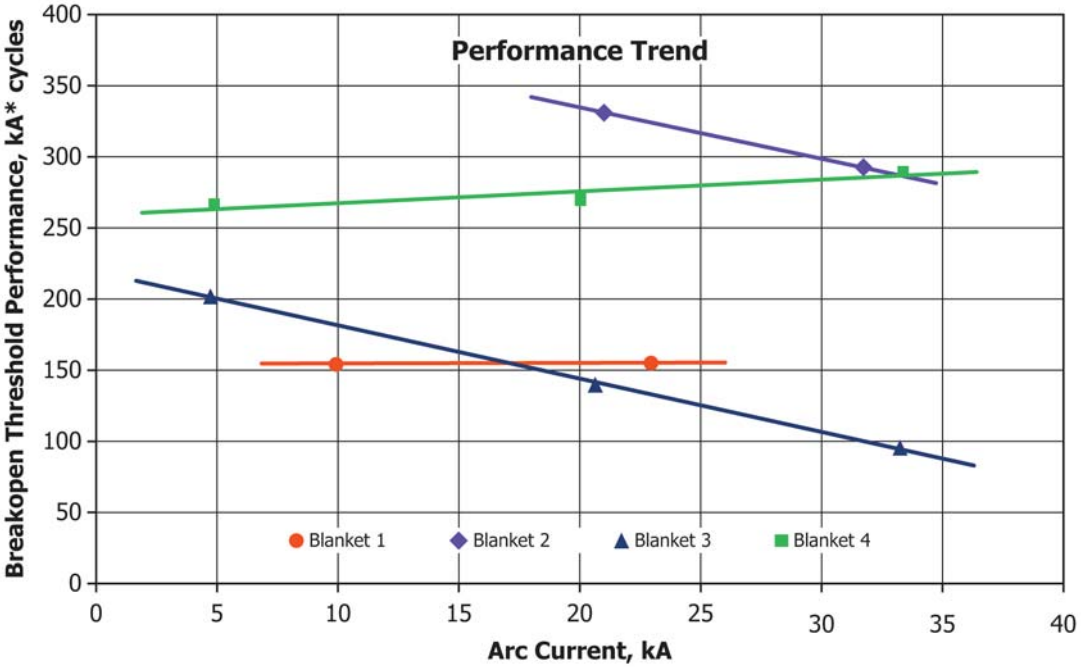


**FIG. 1 Example of Performance Trend for Different Blankets**

an electrode system and a blanket test specimen holding structure and a HS camera positioned outside the vault. A top view of the test apparatus in Fig. 2 shows the suggested electrode mounting supports.

6.2 *Arrangement of the Vault:*

6.2.1 Internal dimensions of the vault shall be 2.2 ± 0.3 m (7 ± 1 ft) wide, 2.2 ± 0.3 m (7 ± 1 ft) high and 2.2 ± 0.3 m (7 ± 1 ft) deep.

6.2.2 The vault shall have three solid walls (back and two sides), floor and roof and be capable of withstanding the entire range of test conditions.

6.2.3 The front is open for access to electrode system and blanket-holding structure and for providing a view for the HS camera.

6.2.4 The roof, floor and walls of the vault shall have no opening.

6.2.5 The vault may be constructed of concrete or framed plywood finished with non-conductive heat-resistant material.

6.3 *Arrangement of Arc Electrodes and Supply Bus* —Arc electrodes shall be arranged pointing at the center of the test specimen.

6.3.1 Two arc electrodes shall penetrate into the vault through a side wall.

6.3.2 Material and diameter of the arc electrodes shall be stainless steel rod with 18-mm (0.75-in.) diameter.

6.3.3 The arc electrodes shall be positioned horizontally, parallel to each other, equidistant from the floor and the roof in vertical plane and equidistant from back wall and front opening in horizontal plane.

NOTE 4—Electromagnetic forces generated by arc current can bend or move parallel electrodes. In order to keep electrodes parallel, it is recommended to use spacers made of insulating materials.

6.3.4 The spacing between parallel arc electrodes shall be 10 ± 0.6 cm (4 ± 0.25 in.). This spacing is equal to arc gap in this test method.

6.3.5 The arc electrodes shall protrude into the vault for the distance of approximately 30 cm (12 in.) and be terminated to a supply bus outside the vault. The electrode distance to the blanket is 6 in.; this requires to be adjusted before every test.

6.3.6 Care must be taken in the position and configuration of the supply bus or feeding cables to the arc electrodes as not to adversely affect the direction or motion of the arc. For testing purposes, the arc is directed towards the blanket test specimen providing a controlled test exposure. The general arrangement of supply buses and arc electrodes is shown in Fig. 2.

6.4 *Arrangement of Blanket Test Specimen*—The test specimen of the arc protective blanket shall be arranged perpendicular to arc electrodes and at the distance of 15 ± 1 cm (6 ± 0.5 in.), from the tips of the arc electrodes.

6.4.1 The test specimen shall be attached to the blanket holding structure.

6.4.2 The blanket holding structure shall have the dimensions of 183 ± 2.5 cm (72 ± 1 in.) by 152 ± 2.5 cm (60±1 in.).

6.4.3 The blanket holding structure shall be mounded vertically and parallel to the side wall of the vault and at the distance of 46 cm (18 in.) from the side wall.

6.4.4 The blanket holding structure shall be equidistant from the floor and the roof in a vertical plane and equidistant from back wall and front opening in a horizontal plane.

6.4.5 The center of the test specimen shall be aligned with the midpoint of the arc gap.

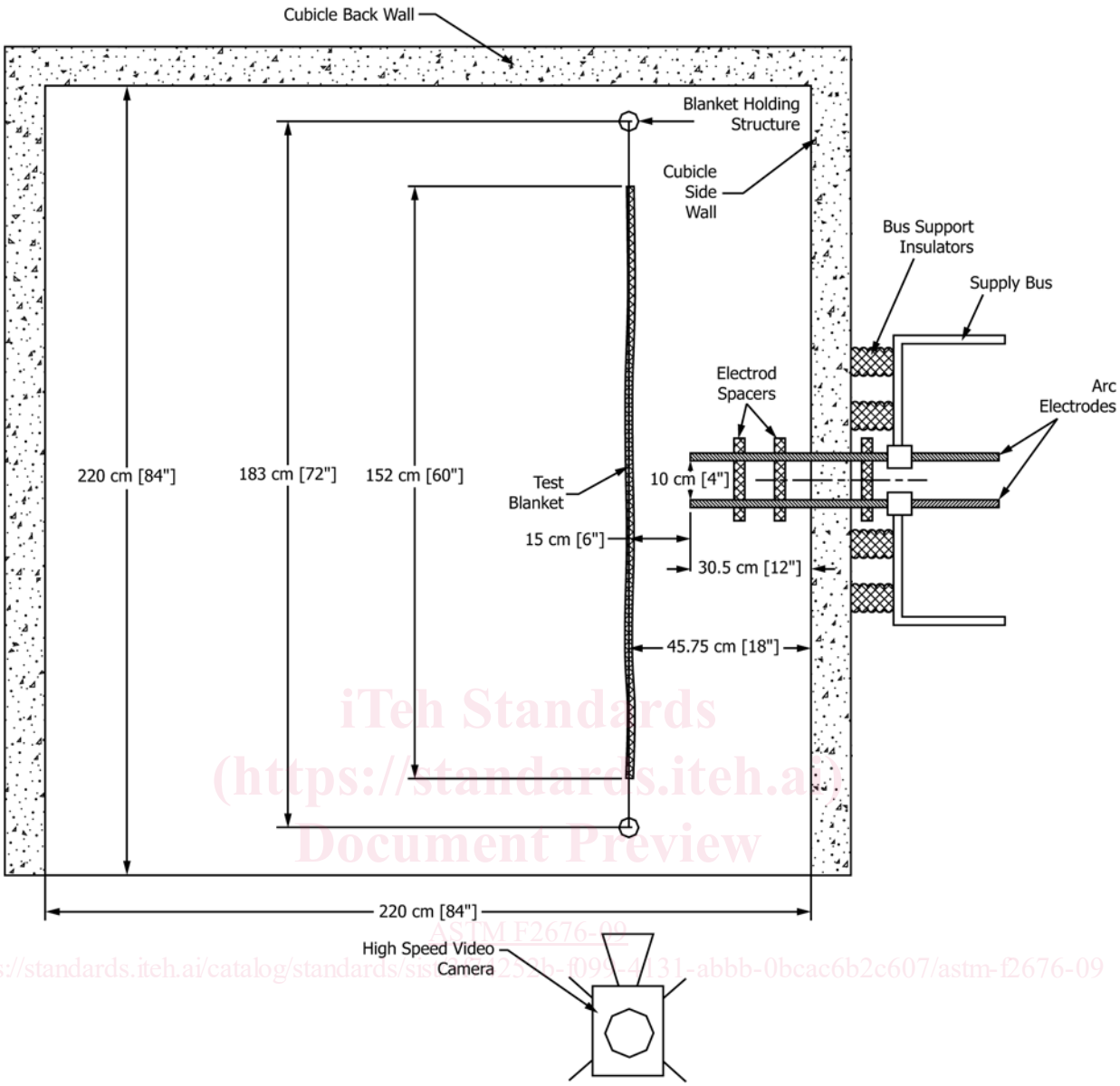


**FIG. 2 Test Cubicle Set Up**

6.5 *Fuse Wire*—A fuse wire, connecting the ends of electrodes tips, is used to initiate the arc. This wire is consumed during the test. The fuse wire shall be a copper 16 gauge wire.

6.6 *Electric Supply*—The electric supply shall be sufficient to allow for the discharge of an electric arc with a gap of up to 10 cm (4 in.), with alternating arc current from 5 kA up to 50 kA and with arc duration from 0.05 s (3 cycles at 60 Hz) up to 2.5 s (150 cycles at 60 Hz). The arc shall not self extinguish during the test. The X/R ratio fo 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 times the symmetrical RMS value.

6.7 *Test Circuit Control*—Repeat exposures of the arc currents shall be within the tolerance of the selected test level. The make switch shall be capable of point on wave closing within 0.2 cycles from test to test, such that the closing angle will produce maximum asymmetrical current with an X/R ratio of the test circuit as stated in 6.6. The arc current, arc duration, and arc voltage shall be measured. The arc current, duration, arc voltage and arc energy shall be displayed on a test control monitor in graph form and stored in digital format.

6.8 *Data Acquisition System*—The system shall be capable of recording voltage and current outputs with a resolution of 1 % of the applied voltage and current.

6.8.1 The current and voltage data shall be acquired at a minimum rate of 2000 samples per second.

6.8.2 The arc voltage shall be measured as close as practical to the electrodes.

6.9 *High-Speed (HS) Camera*—The camera shall have a speed of no less than 1000 frames per second. The analyzing software shall be capable of frame by frame steps with a time