



# Testing standards for arc rated garments Part 3

Information from JAS Consulting

Electrical arc flash safety is achieved through safe working practices, engineering interventions, training and lastly personal protective equipment (PPE).

Although it is recommended that these steps be followed in chronological order, electrical arc flash safety is largely not part of the original design, but rather a retrofit. This results in a reversal of the safety steps and PPE becomes the first item on the electrical arc flash safety program. The recently published South African standard aims at regulating the arc rated clothing market in South Africa. A previous article dealt with fabric specification standards. This article introduces arc test methods which are required by the arc rated fabric specifications.

## Terminology

Fabric in a single layer or multiple layers forms material. Material is used to construct garments. Garments are defined as single items of clothing such as trousers, shirts, jackets and one piece overalls or boiler suits. An assembly of garments will constitute personal protective clothing (PPC). Hoods, gloves, face shields, shoes, hearing protection, balaclavas and socks are referred to as personal protective equipment (PPE) for the purposes of this article.

## Definitions

Arc rating is the value given to materials which describes their performance in an electrical arc. Arc rating may be expressed in terms of ATPV or EBT.

ATPV or arc thermal performance value is the 50% probability value that sufficient heat will pass through the material to cause second degree burns without breaking open. A material exhibits break open when at least a 1,6 cm<sup>2</sup> hole or a 2,5 cm opening is recorded. The energy break open threshold, EBT, is the 50% probability value that sufficient heat will pass through the material to cause second degree burns. It is a common misconception to state that ATPV rating is superior to EBT or vice versa. This is not true since both designations yield an arc rating.

## Summary of legislation and standards

Standards used for arc rated garments come from IEC (International Electrotechnical Commission), ASTM (American Society for Testing and Materials) and SANS (South African National Standard).

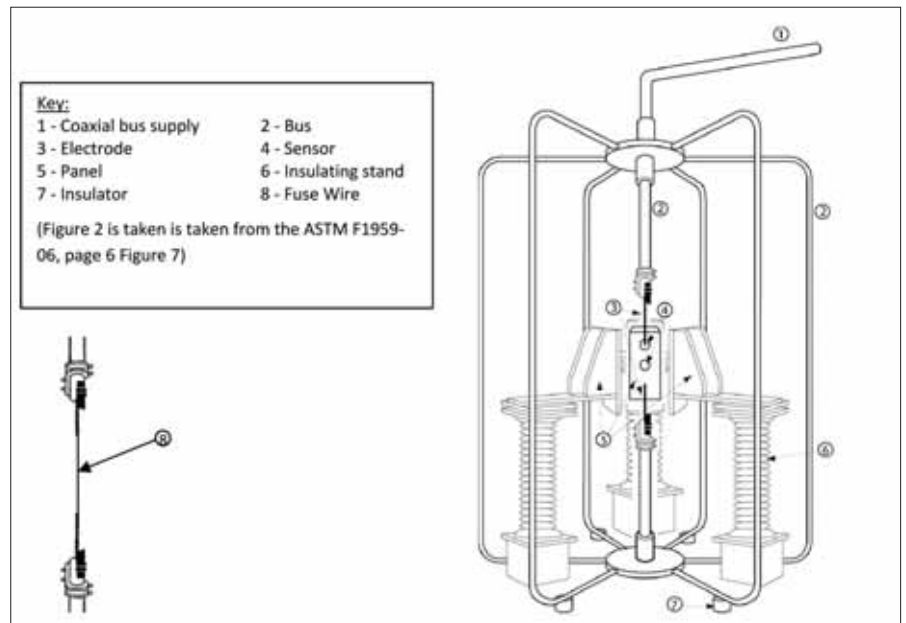


Fig. 1: Arc generating setup.

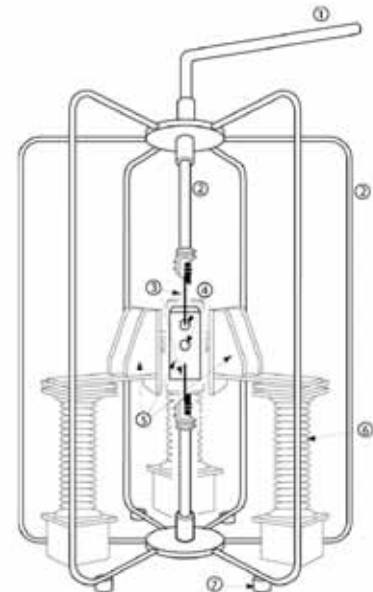


Fig. 2: Panel test setup.

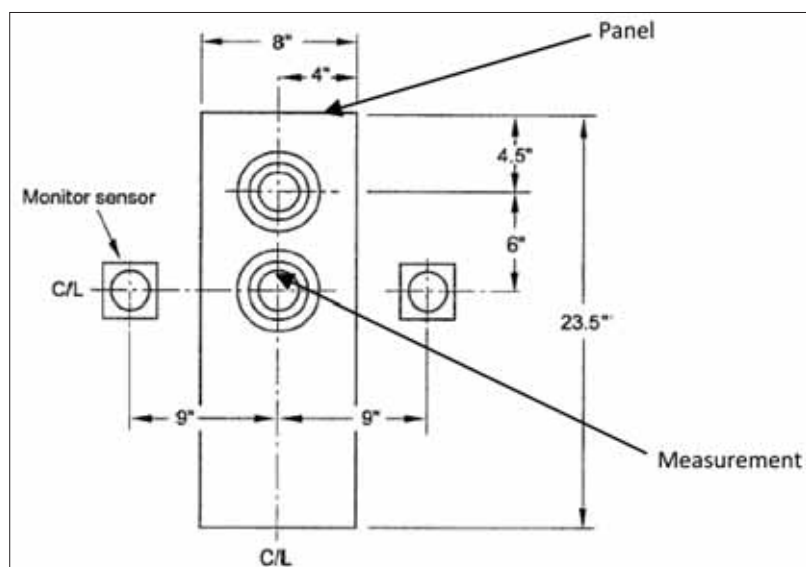


Fig. 3: Two sensor panel (Face view) showing the monitor sensors as taken from the ASTM F1959-06.

## Specifications and test methods

A textile specification stipulates a pass/fail criterion. Looking at the ASTM model as an example, ASTM F1506 requires mechanical tests and arc tests. The test results will indicate whether a fabric passes or fails the textile specification – ASTM F1506.

ASTM F1506 requires an ASTM F1959 arc test. ASTM F1959 does not have a pass/fail criterion, it merely discusses the details around the equipment required for the test, acceptable ways for performing the test, accuracy and repeatability of data, capture and interpretation of data and

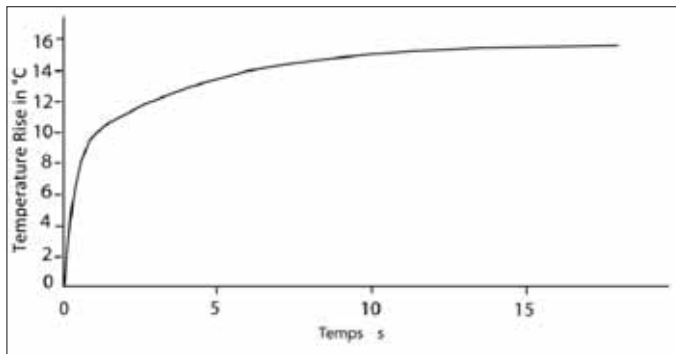


Fig. 4: Measurement sensor temperature rise versus time.

finally safety when testing. The results from the ASTM F1959 arc test are measured against the requirements of ASTM F1506 .

Test methods ASTM F1959 and IEC 61482-1-1

This section will discuss the principles of the test method and reference ASTM examples in order to streamline the contents. An identical philosophy exists for the IEC standards.

#### Sample preparation

Sample preparation is important as this aims at removing any treatment used to facilitate ease of stitching or handling. Such treatments may result in deviations from the actual arc rating. Mills often include sizing (use of starch or lubricants) in the fabrics before supplying a client. Sizing will facilitate ease of sewing and handling, but could possibly reduce the arc rating on materials. As a result test methods require pre-laundering of fabrics. An important learning point is that arc rated garments should preferably be washed before use. However, if not laundered, the lower arc rating is marginal and within the standard deviation of the test method.

ASTM test method requires three washes as per AATCC 135. After three cycles of warm washes in a standard front loading machine, the garment is tumbled dried. The IEC test method, although similar, requires five washes, originating from the already established test requirements for compliance.

Fabric test specimens should be cut into 60 x 30 cm pieces and a minimum of 20 fabric test specimens should be tested.

#### Test setup

The arc is achieved by a single phase supply, two electrodes and a thin copper fuse wire as shown in Fig.1 and Fig. 2.

The full test setup shown in Fig. 2 shows the panels (5) each with two measurement sensors (4). The fabric test specimens are placed over the panels (5).

Fig. 3 shows the mounting of monitor sensors in line with the measurement sensors (4).

#### Arc exposure and Arc energy

The electrical switch is closed resulting in the thin fuse wire disintegrating and creating an arc between the two electrodes. The current and voltage are fixed. Altering the exposure time changes the arc energy between exposures or shots. The test method requires that at least 20 fabric test specimens be exposed to various arc energies i.e. minimum of seven shots exposing three fabric test specimens per shot.

The fabric test specimens are placed over the panel (5 of Fig. 2). The measurement sensor thus measures the energy through the fabric test specimen. The monitor sensors are not covered and are directly exposed to the arc, thus measuring the energy of the arc.

The measurement sensors are copper "slug" calorimeters. The temperature increase of the copper mass is continuously (and instantaneously) measured two seconds before the arc is initiated until 30 seconds after. A thermocouple is attached to each copper mass to determine the change in temperature of the copper mass using Eqn. (1).

$$S(\text{specific heat}) = \frac{\text{energy (joules or calories)}}{\text{mass} \times \Delta T (\text{change in temperature})}$$

Specific heat of copper is 0,385 J/g°C, while each copper mass is 18 g. The change in temperature(ΔT) is captured via high speed data acquisition units. The energy of the arc and the energy through the fabric test specimen are thus determined.

#### Arc rating methodology

Manipulating equation (1) together with the electrical system data, the sensor temperature rise versus time graph may be plotted as shown in Fig. 4. The stall curve displays temperature rise versus time which will result in the onset of a second degree burn on human tissue. It appears similar to Fig. 4 and any point above this curve will result in a burn and any point below will result in no burn. The stall curve and measurement sensor curves are superimposed. Where the measurement sensor curve lies below the Stoll curve

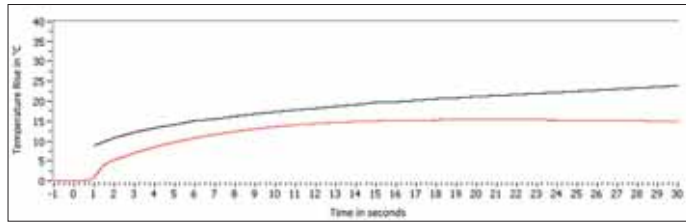


Fig. 5: Stoll Curve (black) and measurement sensor curve (red) on a specimen showing no burns.

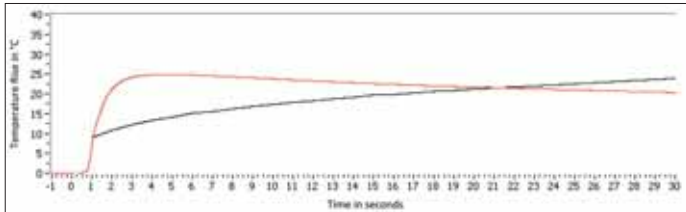


Fig. 6: Stoll curve (black) and measurement sensor curve (red) on a specimen showing burns.

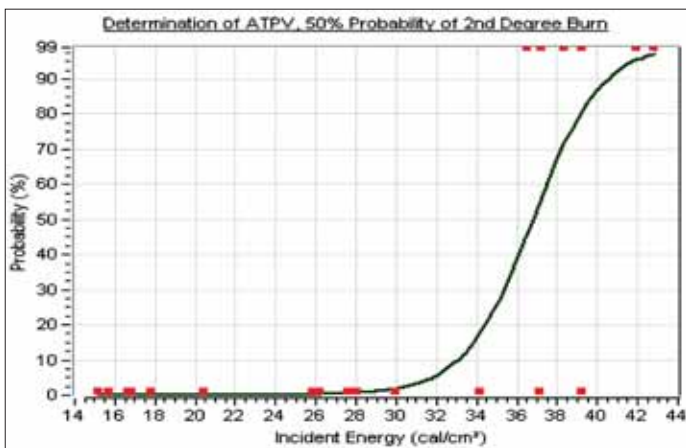


Fig. 7: Statistical probability used to determine the arc ratings.

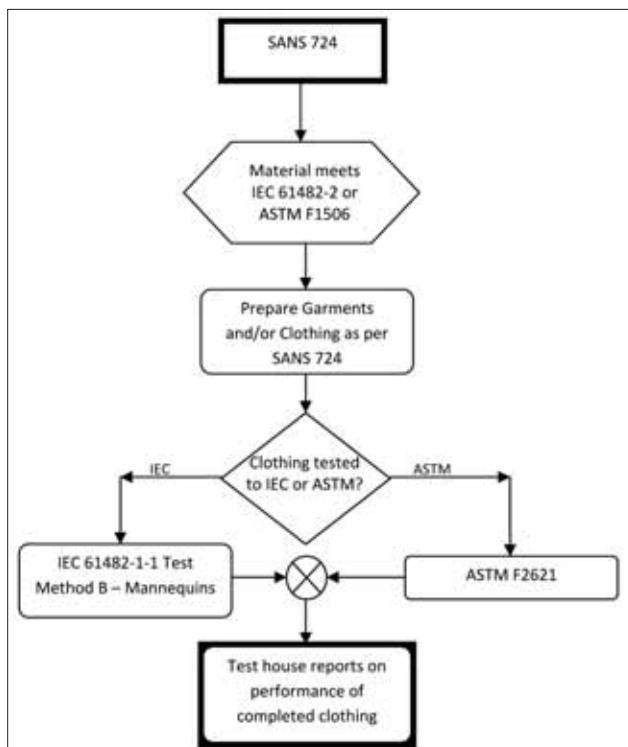


Fig. 8: Flowchart of post fabrication requirements of clothing based on SANS 724.

the fabric test specimen will protect the user against a second degree burn. The specimen is assigned a "zero percent probability of a second degree burn".

If at any point on the graph the measurement sensor curve lies above the Stoll curve, a user will receive second degree or third degree burns. The specimen is assigned a "hundred percent probability of a second degree burn".

Figs. 5 and 6 illustrates a burn and no burn result. The Stoll curve is shown in black and the measurement sensor curve is shown in red. After a minimum of 20 data points derived from graphs (or data) similar to Figs. 5 and 6, a statistical linear regression analysis may be performed.

At a known energy as verified by the monitor sensors, the fabric test specimen either received a zero percent probability of a burn or a hundred percent probability of a burn. This data is graphically represented in Fig. 7. In the example shown above the fabric received an arc rating of 36, 8 cal/cm<sup>2</sup>.

## SANS 724 and test methods

SANS 724 requires that the fabric specification be complied to and does not directly reference a test method. The standard further requires arc rated clothing only be constructed from fabric which meets the requirements of the textile specifications ASTM F1506 and/or IEC 61482-2. Upon completion of the garment, the entire garment should be tested as it is expected to be used. Fig. 8 describes the standards which were also mentioned earlier in this paper. IEC 61482-1-1 Test method B cannot be used to assign arc ratings to clothing. It is merely a test to observe the performance of a completed garment. This method is similar to the ASTM F2621 test. In the clothing tests, the clothing is exposed to the arc rating of the fabric. Post arc exposure, the lab reports on the maximum after flame and functionality of the garment.

## References

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- [4] ASTM F 1506, Standard performance specification for flame resistant textile materials for wearing apparel for use by electrical workers exposed to momentary electric arc and related thermal hazards.
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- [6] ASTM F 1959, Standard test method for determining the arc rating of materials for clothing.
- [7] SANS 61482-1-1/IEC 61482-1-1, Live working – Protective clothing against the thermal hazards of an electric arc – Part 1-1: Test methods – Method 1: Determination of the arc rating (ATPV or EBT50) of flame resistant materials for clothing.
- [8] SANS 724 Personal protective equipment and protective clothing against the thermal hazards of an electric arc.

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