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Performance requirements of personal arc protective equipment

个人电弧防护用品通用技术要求

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Performance requirements of personal arc protective equipment

1 Scope

This Standard specifies the technical requirements, test methods, selection methods, quality inspection rules, use and maintenance as well as marking, instructions for use, storage and transportation of personal arc protective equipment in electrical workplaces.

This Standard applies to the production, acceptance and use of personal arc protective equipment in the electric power trade.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the dated version applies to this document. For undated references, the latest edition (including all amendments) applies to this document.

GB/T 2912.1, Textiles - Determination of formaldehyde - Part 1: Free and hydrolyzed formaldehyde (water extraction method)

GB/T 3609.1-2008, Occupational eye and face protection - Welding protection - Part 1: Welding protector

GB/T 3917.3, Textiles - Tear properties of fabrics - Part 3: Determination of tear force of trapezoid-shaped test specimens

GB/T 3920, Textiles - Tests for colour fastness - Colour fastness to rubbing

GB/T 3922, Textiles - Tests for colour fastness - Colour fastness to perspiration

GB/T 3923.2, Textiles - Tensile properties of fabrics - Part 2: Determination of maximum force using the grab method

GB/T 4669-2008, Textiles - Woven fabrics - Determination of mass per unit length and mass per unit area

GB/T 5455, Textiles - Burning behaviour - Determination of damaged length, afterglow time and afterflame time of vertically oriented specimens

GB/T 5713, Textiles - Tests for colour fastness - Colour fastness to water

3.3

arc burn

Compound burns to the human body – caused by the powerful arc light generated when electric current passes through the air medium or the circuit is short-circuited – within its injuring distance. Thermal burn caused by arc flash and electrical burn caused when electric current breaks down and enters the human body are included. See Appendix A for grading of burn severity. This Standard applies to the prevention of thermal burn.

3.4

arc protection

Protection which is taken – when an arc occurs, by blocking the incident arc hazard energy – to reduce the possible harm of the arc to the human body, so that the residual energy is not enough to cause second-degree or above burns to the human body.

3.5

arc thermal performance value; ATPV

Value characterized by 50% chance that the energy incident on the arc protection material will cause heat energy to penetrate the material and cause second-degree burns (judged based on the Stohr curve). When the external incident energy is less than this value, the material can effectively block and reduce the transmitted energy to avoid causing second-degree and above burns to the human body.

3.6

breakopen threshold energy

E_{bt}

Value characterized by that the energy incident on a single-layer or multi-layer arc protection fabric has a 50% chance of causing the fabric to rupture. During the arc protection performance test, where the total area of holes produced in the arc protection fabric exceeds 160 mm^2 or the length of a single hole is greater than 25 mm, it is a rupture. For multi-layer arc protection fabrics, holes shall penetrate all layers of fabrics.

3.7

inherent flame resistant

Flame retardant and heat insulation property – formed relying on the molecular structure of the protective material itself – whose corresponding property does not decline as conditions change.

3.8

after-finishing flame resistant

Certain flame retardant and heat insulation property of the material – obtained through dyeing and finishing methods using a certain dose of chemicals – whose corresponding property decreases or disappears as conditions change.

3.9

personal arc protective equipment

Protective equipment used to protect the persons who may be exposed to arc-related thermal hazards, including arc protective garment, arc protective face shield, arc protective hood, arc protective gloves, and arc protective shoes cover.

3.10

arc protective garment

Protective equipment used to protect the torso, arms, and legs of persons who may be exposed to arc-related thermal hazards.

3.11

arc protective face shield

Protective equipment used to protect the eyes and face of persons who may be exposed to arc-related thermal hazards.

3.12

arc protective hood

Protective equipment used to protect the head and neck of persons who may be exposed to arc-related thermal hazards.

3.13

arc protective gloves

Protective equipment used to protect the hands of persons who may be exposed to arc-related thermal hazards.

3.14

arc protective shoes cover

Protective equipment used to protect the feet of persons who may be exposed to arc-related thermal hazards.

a) Vertical burning behaviour. The vertical burning behaviour of the single layer or each layer of the multi-layer fabrics shall be tested according to the method specified in GB/T 5455. During the test, the fabric shall not melt and drop, the damaged length shall not be greater than 100 mm, and the afterflame time shall not be greater than 2 s.

b) Flame retardant durability performance. The flame-retardant durability of the single layer or each layer of the multi-layer fabrics shall be tested by washing 100 times according to the washing method specified in GB/T 17595 (temperature 40 °C), and the method specified in GB/T 5455. During the test, the fabric shall not melt and drop, the damaged length shall not be greater than 100 mm, and the afterflame time shall not be greater than 2 s.

4.1.1.3 Physical and chemical safety performance

Protective fabrics shall be provided with the following physical and chemical safety properties:

a) Conductive loops shall not be formed on the fabrics.

b) The formaldehyde content of fabrics – measured according to the method specified in GB/T 2912.1 – shall meet the requirements of Table 2.

c) The pH value of fabrics – measured according to the method specified in GB/T 7573 – shall meet the requirements of Table 2.

d) The colour fastness to water of fabrics – tested according to the method specified in GB/T 5713 – shall meet the requirements of Table 2.

e) The color fastness to acid and alkali perspiration of fabrics – tested according to the method specified in GB/T 3922 – shall meet the requirements of Table 2.

f) The color fastness to dry rubbing of fabrics – tested according to the method specified in GB/T 3920 – shall meet the requirements of Table 2.

g) When the color fastness to household and commercial laundering of the single layer and outer shell material of the multi-layer fabrics is tested according to the method specified in GB/T 12490, where the test condition is 50 °C water temperature for 45 minutes, the color change grade of the fabrics shall meet the requirements of Table 2.

h) The odor detection of fabrics – tested according to the method specified in 6.7 of GB 18401-2010 – shall meet the requirements of Table 2.

i) The decomposable aromatic amine dyes of fabrics – tested according to the methods specified in GB/T 17592 and GB/T 23344 – shall meet the requirements of Table 2.

The design and performance of arc protective gloves (referred to as gloves) and arc protective shoes cover (referred to as shoes cover) shall comply with the requirements in Table 7.

5 Test methods

5.1 Fabric arc protection performance test

5.1.1 Test sample and preparation

5.1.1.1 Requirements for test sample

Before testing the arc protection performance of fabrics, ensure that the fabrics pass the flame-retardant property test.

5.1.1.2 Preparation steps

The fabric sample to be tested shall be washed and dried three times. The washing water temperature shall be 50 °C and the sample shall be tumble dried. The size of the test sample shall be 30 cm × 66 cm. Take enough samples and the number shall not be less than 33 pieces. Multi-layer fabric samples shall be arranged in order and the upper ends of the multi-layer fabrics shall be sewn or stapled into a whole before testing. Place the prepared samples in groups of 3 vertically on the corresponding 3 sample racks. Each sample rack shall have two monitoring sensors located on both sides of the sample rack; the three sample racks shall be evenly distributed on a circle at 120° intervals. The upper and lower electrodes under test are located at the center of the circle, and the distance between the upper and lower electrodes is 30.5 cm. The test arc peak current is 8 kA ± 1 kA.

5.1.2 Test process

5.1.2.1 Requirements for the number of samples and valid data points

For ATPV testing of fabric samples, at least 7 groups of samples shall be used. During the test, different incident energies are obtained by adjusting the arc duration. During

the ATPV calculation, the number of valid data points for incident energy shall not be less than 21.

5.1.2.2 Requirements for the placement of data points

Among at least 21 data points, at least 15% of the data points shall fall in the first area, where the incident energy value shall make the energy received by the sensor corresponding to the sample reach second-degree burn[1)]; in addition, at least 15% of the data points shall fall in the second area, where the incident energy value shall make the energy received by the sensor corresponding to the sample not reach second-degree burn[1)]; in addition, at least 50% of the data points shall fall in the third area, where some of the incident energy values shall reach second-degree burns[1)], and some shall not reach second-degree burns. These values are distributed within the range of ±20% of the sample ATPV.

5.1.3 Data processing

The ATPV shall be determined by regression analysis calculations from all measured data points.

5.2 Face shield arc protection performance test

5.2.1 Face shield material arc protection performance test

The face shield material arc protection performance test shall be carried out on at least 24 material samples. During the test, a group of 3 samples to be tested is placed on the corresponding 3 standard prosthetic heads; each standard prosthetic head has 4 built-in sensors, located respectively in the eyes, mouth and chin; on both sides of each prosthetic head there is a monitoring sensor; three standard prosthetic heads are evenly distributed on a circle at 120°. The upper and lower electrodes under test are located at the center of the circle, and the distance between the upper and lower electrodes is 30.5 cm. The arc peak current required for the test is 8 kA ± 1 kA. Its testing process and data processing methods are consistent with 5.1.

5.2.2 Evaluation and verification of overall protection performance of head shield and hood

The evaluation and verification of the overall protection performance of face shield and hood shall be carried out on products manufactured with the face shield that meets the requirements of Table 3. Take 3 samples from each group and determine them in turn according to the method in 5.2.1. If no less than 2 samples in each group of samples are qualified, the group shall be considered as passed; otherwise, another group of samples shall be taken, up to 8 groups of samples. The overall protection performance of the face shield and hood shall not be lower than the arc protection performance value of the face shield.

[1)] According to Stohr curve.

c) Dirt shall be removed from personal arc protective equipment in a timely manner after use.

8.3 Instructions for forbidden

Instructions for forbidden are as follows:

a) Personal arc protective equipment which is damaged and cannot be repaired shall be prohibited from use;

b) Personal arc protective equipment after arc burns shall be prohibited from use.

9 Marking, instructions for use, storage and transportation

9.1 Marking

The marking shall include the following:

a) name;

b) implementation standard number;

c) ATPV, E_{bt} and mass per unit area of fabrics;

d) name, trademark, address and contact number of the manufacturer or supplier;

e) model specifications;

f) date of delivery;

g) storage conditions or corresponding illustrations.

9.2 Instructions for use

Instructions for use shall at least include correct use, care and maintenance methods.

9.3 Storage

The product shall be stored in a dry and ventilated place, away from direct sunlight, and must not be mixed with corrosive items.

9.4 Transportation

The product shall be kept clean during transportation and must not be damaged in packaging, stressed, damaged, damp or exposed to direct sunlight.

Appendix A

(Informative)

Arc burn

A.1 Classification of arc burns

The severity of arc burns depends on the scope and depth of the injured tissue. The depth of burns is divided into first-degree, second-degree (superficial partial-thickness burns and deep partial-thickness burns) and third-degree burns according to the internationally accepted rule of three degrees and four levels.

A.2 First-degree burns

First-degree burns are limited to the epidermis, with skin congestion and mild local swelling and pain. The basal cell layer is not damaged, and is of active regeneration ability; no scars are left after healing; it is not included in the burn area.

A.3 Second-degree burns

Second-degree burns are classified into superficial partial-thickness burns and deep partial thickness burns. Superficial partial-thickness burns include damage to the entire thickness of the epidermis and the papillary layer of the dermis, while retaining the hair follicles, sebaceous glands and sweat glands, and leaving the reticular layer intact. Blisters are formed between the epidermis and the dermis. The base is red and moist, the peripheral nerves are injured, and the pain is severe. There is generally no scar left after healing, and sometimes there is pigmentation. Deep partial-thickness burns have involved the reticular layer of the dermis, but the deep hair follicles are intact; there is dull sensation, but there is hair-pulling pain; the base is slightly moist, and the wound surface is pale or white with red, red and white alternately; healing takes a long time, but the adnexal epithelium can proliferate, leaving scars if granulation tissue grows during the healing period.

A.4 Third-degree burns

Third-degree burns damage the entire thickness of the skin and may also involve subcutaneous tissue, muscles, bones, etc. The local symptoms are pale, tan or burnt black; the skin loses elasticity, and is as hard as leather to the touch; the surface is dry; the pain disappears, and there is no hair-pulling pain. Smaller wounds are healed by the crawling of edge epithelial cells, but there are severe scars; larger wounds must be repaired by skin grafting and transfer of skin flaps.

Appendix D

(Normative)

Risk assessment of arc hazard

D.1 Assessment significance

Arc hazard risk assessment is the study of the risk of arc injury when a circuit (including its protective devices) is short-circuited. The study results of circuit short circuit are used to determine the short circuit fault current. The study results of the short-circuit protective device are used to determine the arcing time. The study results coordinating circuit short circuits and their protective devices provide the information needed for risk assessment of arc hazards. The results of arc hazard risk assessment are used to identify arc protection interfaces (risk characterization) and incident energy (risk estimation) within specified operating distances at any location or level throughout the generation, transmission, distribution, or consumption system.

The arc protection interface and incident energy, once calculated, can be used as a reference for selecting the level of personal arc protective equipment, cutting off power for work or using arc-proof switching equipment, and other necessary engineering measures or work practices.

D.2 Assessment steps

The risk assessment steps of arc hazards are as follows:

a) Collect system and equipment parameter data. Collect system circuit diagrams, including parameters of transformers, transmission lines, loop distribution, protective devices, capacitors, circuit breakers with protective devices, voltage levels and each component, etc.

b) Determine the operating mode of system. In addition to the system parameters, the short-circuit fault current is also affected by the way the system is operated, for example, the system containing one or more branch lines, the standby busbar circuit breaker switching status, the generator in use or on standby, etc.

c) Calculate the short circuit fault current. Based on the system wiring diagram, calculate the short-circuit fault current.

d) Calculate the arc current. According to the corresponding conditions, select the calculation formula including the one introduced in Appendix E to calculate the arc current.

Appendix E

(Informative)

Arc hazard energy calculation methods and examples

E.1 Overview

Calculate the estimated possible arc hazard energy based on known system voltage, fault current, arc duration, and operating distance in a typical work area.

E.2 Arc hazard energy calculation methods

E.2.1 Empirical calculation model

E.2.1.1 Overview

The empirical calculation model is suitable for situations where the frequency is 50 Hz, the system voltage is 380 V ~ 15 kV, the short-circuit fault current is 700 A ~ 106 000 A, and the conductor gap is 13 mm ~ 152 mm. The calculation steps are:

a) Calculate the arc current I_a;

b) Calculate the typical accident energy E_n;

c) Calculate the accident energy E.

E.2.1.2 Calculate the arc current I_a

The arc current is calculated using Formula (E.1):

$$\lg I_a = K + 0.662 \lg I_k + 0.096\,6U + 0.000\,526G + 0.558U \lg I_k - 0.003\,04G \lg I_k \quad (E.1)$$

Where:

I_a – arc current, kA;

K – constant, which is 0.153 for open structure, and 0.097 for closed structure;

I_k – short circuit fault current, kA;

U – system voltage, kV;

G – conductor gap, mm, see Table E.1.

The system arc current of 1 kV and above is calculated using Formula (E.2):

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