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INTERNATIONAL STANDARD

NORME INTERNATIONALE

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 E_{BT50}) of flame resistant materials for clothing

Travaux sous tension – Vêtements de protection contre les dangers thermiques d'un arc électrique –
Partie 1-1: Méthodes d'essai – Méthode 1: Détermination de la caractéristique d'arc (ATPV ou E_{BT50}) de matériaux résistant à la flamme pour vêtements

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International Standard IEC 61482-1-1 has been prepared by IEC technical committee 78: Live working.

This standard cancels and replaces IEC 61482-1:2002. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC 61482-1:

– addition of a detailed analysis of the sensor response.

The text of this standard is based on the following documents:

FDIS	Report on voting
78/793/FDIS	78/805/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61482 series can be found, under the general title *Live working – Protective clothing against the thermal hazards of an electric arc*, on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition; or
- amended.

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 E_{BT50}) of flame resistant materials for clothing

1 Scope

This part of IEC 61482 specifies test methods to measure the arc thermal performance value of materials intended for use in heat- and flame-resistant clothing for workers exposed to the thermal effects of electric arcs and the function of garments using these materials. These test methods measure the arc thermal performance value of materials which meet the following requirements: less than 100 mm char length and less than 2 s afterflame after removal from flame, when tested in accordance with ISO 15025, procedure B (bottom-edge ignition) on the outer material, and the char length measured using a modified ISO method as described in Annex A.

These methods are used to measure and describe the properties of materials, products, assemblies or garments, in response to convective and radiant energy generated by an electric arc in open air under controlled laboratory conditions.

The materials used in these methods are in the form of flat specimens for method A and garments for method B.

Method A is used to determine the arc rating of materials and material assemblies when tested in a flat configuration.

Method B is used to measure garment response, not arc rating, to an arc exposure including all the garment findings, sewing thread, fastenings, fabrics and other accessories when tested on a male mannequin torso. Method B is also used for accident replication.

It is the responsibility of the user of this part of IEC 61482 to establish appropriate safety and health practices prior to use. For specific precautions, see Clause 7.

The test methods in this part of IEC 61482 are not directed to classify by protection classes. Methods determining protection classes are prescribed in IEC 61482-1-2.

2 Normative references

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

ISO 3175-2, *Textiles – Professional care, drycleaning and wetcleaning of fabrics and garments – Part 2: Procedure for testing performance when cleaning and finishing using tetrachloroethene*

ISO 6330, *Textiles – Domestic washing and drying procedures for textile testing*

ISO 9151, *Protective clothing against heat and flame – Determination of heat transmission on exposure to flame*

ISO 15025:2000, *Protective clothing – Protection against heat and flame – Method of test for limited flame spread*

3 Terms, definitions and symbols

For the purposes of this document, the following terms, definitions and symbols apply.

NOTE For definitions of other textile terms related to the topic, see ASTM D-123 [7] [1].

3.1 Terms and definitions

3.1.1
arc duration
time duration of the arc

NOTE Arc duration is expressed in s.

3.1.2
arc energy
W_{arc}
electrical energy supplied to the arc and converted in the arc; sum of the instantaneous arc voltage values multiplied by the instantaneous arc current values multiplied by the incremental time values during the arc duration

NOTE Arc energy is expressed in kJ or kW·s.

3.1.3
arc gap
distance between the arc electrodes

NOTE Arc gap is expressed in mm.

3.1.4
arc rating
value attributed to materials or material systems that describes their performance to exposure to an electrical arc discharge

NOTE The arc rating is expressed in kW·s/m² – or optionally in cal/cm² – and is derived from the determined value of ATPV or E_{BT50} (should a material or material system exhibit a breakopen response below the ATPV value).

3.1.5
arc thermal performance value (ATPV)
in arc testing, 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 curve, without breakopen

NOTE ATPV is expressed in kJ/m² or kW·s/m² (cal/cm²).

3.1.6
arc voltage
voltage across the arc

NOTE Arc voltage is expressed in V.

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[1] Figures in square brackets refer to the bibliography.

3.1.7
asymmetrical arc current
total arc current produced during closure; it includes a direct component and a symmetrical component

NOTE Asymmetrical arc current is expressed in A.

3.1.8
breakopen
in electric arc testing, material response evidenced by the formation of one or more openings in the material which may allow flame to pass through the material

NOTE 1 The specimen is considered to exhibit breakopen when any opening is at least 300 mm^2 in area or at least 25 mm in any dimension. A single thread across the opening does not reduce the size of the hole for the purposes of this part of IEC 61482.

NOTE 2 A multilayer specimen is considered to exhibit breakopen when all layers show formation of one or more openings.

3.1.9
breakopen threshold energy
E_{BT50}
incident energy on a fabric or material that results in a 50 % probability that sufficient heat transfer through the tested specimen is predicted to cause the tested specimen to break open

NOTE The breakopen threshold energy is expressed in kJ/m^2 or kW s/m^2 (cal/cm^2).

3.1.10
burning time
time for which a flame is visible after exposure to arc

NOTE Burning time is expressed in s.

3.1.11
calorimeter
device for measuring the heat flux and incident energy

3.1.12
charring
formation of carbonaceous residue as the result of pyrolysis or incomplete combustion

3.1.13
closure
point on supply current waveform where the arc is initiated

3.1.14
clothing
assembly of garments worn by workers

3.1.15
delta peak temperature
ΔT_{p}
difference between the maximum temperature and the initial temperature of the sensor during the test exposure time

NOTE Delta peak temperature is expressed in °C.

3.1.16
dripping
material response evidenced by flowing of the fibre polymer

3.1.17
electric arc
self-maintained gas conduction for which most of the charge carriers are electrons supplied by primary-electron emission

[IEV 121-13-12]

NOTE During live working, the electric arc is generated by gas ionisation arising from an unintentional electrical conducting connection or breakdown between live parts or a live part and the earth path of an electrical installation or an electrical device. During testing, the electric arc is initiated by the blowing of a fuse wire.

3.1.18
embrittlement
formation of a brittle residue as the result of pyrolysis or incomplete combustion

3.1.19
exposure time
shortly before, during and for 30 s after an arc thermal exposure has been initiated

3.1.20
garment
single item of clothing which may consists of single or multiple layers

3.1.21
heat attenuation factor (HAF)
per cent of the incident energy which is blocked by a material at an incident energy level equal to ATPV

3.1.22
heat flux
q
thermal intensity of an electric arc indicated by the amount of energy transmitted per unit surface area and time

NOTE Heat flux is expressed in kW/m^2.

3.1.23
ignition
initiation of combustion

3.1.24
incident energy
E_i
heat energy (total heat) received at a unit surface area as a result of an electric arc

NOTE 1 The heat energy is measured as a proportional peak temperature rise ΔT_p of a calorimeter sensor.

NOTE 2 Incident energy is expressed in kJ/m^2 or $kW \cdot s/m^2$ (cal/cm^2).

NOTE 3 In an arc test, incident energy for a specimen is determined from the average temperature-rise response of the two monitoring sensors adjacent to the test specimen.

3.1.25
material
fabric or other substances of which the garment is made, this may consist of single or multiple layers

3.1.26
material response
subjective observation of the reaction of the material to an electric arc indicated by the following characteristics: burning time (after flame, ignition), breakopen, melting, dripping, charring, embrittlement, shrinkage

3.1.27
melting
material response evidenced by softening and deformation of the fibre polymer

3.1.28
mix zone
range of incident energies, which can result in either a positive or negative outcome for predicted second-degree burn injury, breakopen or underlayer ignition

NOTE 1 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.

NOTE 2 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
monitoring sensor
monitor sensor
sensor mounted on each side of the panel or mannequin, using the calorimeters not covered by test specimen and used to measure incident energy

3.1.30
peak arc current
maximum value of the a.c. arc current

NOTE Peak arc current is expressed in A.

3.1.31
protective clothing
clothing which covers or replaces personal clothing, and which is designed to provide protection against one or more hazards

[Definition 3.4 of ISO 13688 [6]]

3.1.32
r.m.s. arc current
root mean square of the a.c. arc current

NOTE RMS arc current is expressed in A.

3.1.33
sensor
assembly with a calorimeter and a non-conductive heat-resistant material in which the calorimeter is mounted

3.1.34
shrinkage
material response evidenced by reduction in specimen size

3.1.35
Stoll curve
curve of thermal energy and time produced from data on human tissue tolerance to heat and used to predict the onset of second-degree burn injury

NOTE See Table 1 and Equation (5).

3.1.36
time to delta peak temperature
t_{max}
time from beginning of the initiation of the arc to the time the delta peak temperature is reached

NOTE Time to delta peak temperature is expressed in s.

3.1.37
***X/R* ratio**
ratio of system inductive reactance to resistance

NOTE The *X*/*R* ratio is proportional to the *L*/*R* ratio of time constant, and is, therefore, indicative of the rate of decay of any d.c. offset. A large *X*/*R* ratio corresponds to a large time constant and a slow rate of decay.

3.2 Symbols and units

ATPV	arc thermal performance value	$kW \cdot s/m^2$ (see incident energy)
C_p	heat capacity	J/g °C
E_{BT50}	breakopen threshold energy	$kW \cdot s/m^2$ (see incident energy)
E_i	incident energy	kJ/m^2 or $kW \cdot s/m^2$
$E_{transmitted}$	transmitted energy	kJ/m^2 or $kW \cdot s/m^2$
HAF	heat attenuation factor	
haf	HAF data point	
Q	Heat energy	J/cm^2
q	heat flux	kW/m^2
T	measured temperature	°C
t	time	s
W_{arc}	arc energy	kJ, kW·s

NOTE
1 J/g °K = 4,186 8 cal/g °K
1 kJ/m^2 = 1 $kW.s/m^2$ = 0,1 J/cm^2 = 0,023 885 cal/cm^2
1 cal/cm^2 = 41,868 kJ/m^2 = 41,868 $kW.s/m^2$ = 4,186 8 J/cm^2

4 Principle of the test methods

4.1 Test method A

The test method A specified in this standard determines the incident energy which would predict a second-degree burn injury when the material(s) is (are) exposed to heat energy from an electric arc.

During the tests, the amount of heat energy transferred by the material(s) is measured during and after exposure to an electric arc.

The heat flux of the exposure and that transferred by the test specimen(s) are both measured with copper slug calorimeter sensors. 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.

Material performance for this procedure is determined from the amount of heat transferred by the specimen(s).

Heat transfer data is used to predict the onset of a second-degree burn using the Stoll curve.

The procedures incorporate incident-energy monitoring sensors.

Material response shall be further described by recording the observed effects of the electric arc exposure on the specimens and using the terms given in 3.1.26.

4.2 Test method B

The test method B specified in this standard is used for evaluation of protective clothing design or accident replication. Garments shall be evaluated with findings, pockets and closures positioned as manufactured, but no arc rating can be reported due to the impact of garment design such as pocketing and multilayer closures on the heat transfer to the sensors.

5 Significance and use of the test methods

The test method A measures the arc thermal performance value of materials intended for use in flame-resistant clothing for workers exposed to electric arcs. The test method is intended for the determination of the thermal performance value of a material by itself or in comparison with other materials.

Because of the variability of the arc exposure, different heat transmission values may result for individual sensors. The results of each sensor shall be evaluated in accordance with Clause 12.

The test method B specified in this standard is used for evaluation of protective clothing design. Garments made of materials or material systems previously tested according to method A, shall be first tested as panels following method A. Then the garment using materials previously tested are tested following method B.

The test methods maintain the specimen in a static vertical position and do not involve movement, except that resulting from the exposure.

The test methods specify a standard set of exposure conditions. Different exposure conditions may produce different results. In addition to the standard set of exposure conditions, other conditions representative of the expected hazard may be used.

6 Test apparatus

6.1 General

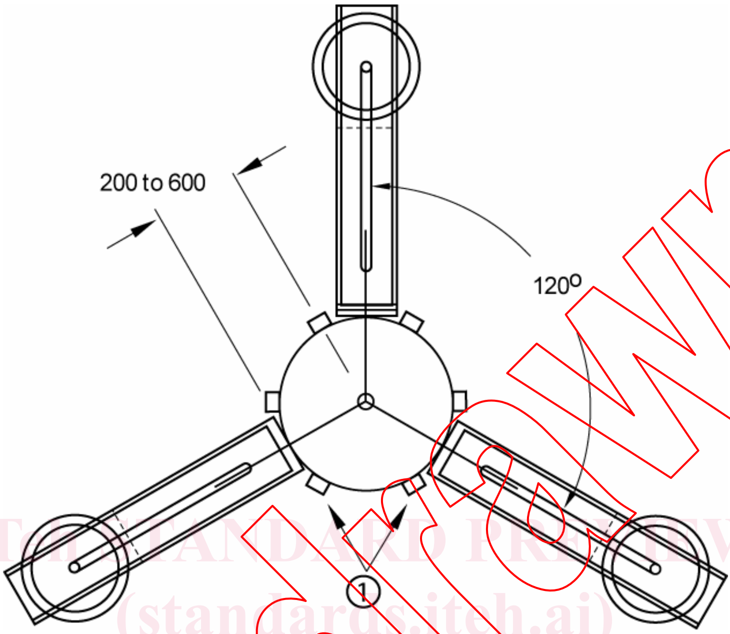
The test apparatus shall consist of the following elements:

- supply bus;
- arc controller;
- recorder or data acquisition system;
- arc electrodes;
- three two-sensor panels (method A) or one to three four-sensor mannequins (method B);
- monitoring sensors for each panel or mannequin.

6.2 Method A – Arrangement of the two-sensor panels

Three two-sensor panels shall be used for each test and spaced at 120° as shown in Figure 1. In addition, 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 Figure 2.

Dimensions in millimetres



Key

1 Monitoring sensor

Figure 1 – Method A – Arrangement of three two-sensor panels with monitoring sensors (plan view)