



BSI Standards Publication

Live working — Protective clothing against the thermal hazards of an electric arc

Part 1-1: Test methods — Method 1: Determination of the arc rating (ELIM, ATPV and/or EBT) of clothing materials and of protective clothing using an open arc

National foreword

This British Standard is the UK implementation of EN IEC 61482-1-1:2019. It is identical to IEC 61482-1-1:2019. It supersedes BS EN 61482-1-1:2009, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/78, Tools for live working.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Date	Text affected
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English Version

Live working - Protective clothing against the thermal hazards of
an electric arc - Part 1-1: Test methods - Method 1:
Determination of the arc rating (ELIM, ATPV and/or EBT) of
clothing materials and of protective clothing using an open arc
(IEC 61482-1-1:2019)

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 valeur
assignée d'arc (ELIM, ATPV et/ou EBT) des matériaux pour
vêtements et des vêtements de protection utilisant un arc
ouvert
(IEC 61482-1-1:2019)

Arbeiten unter Spannung - Schutzkleidung gegen
thermische Gefahren eines Lichtbogens - Teil 1-1:
Prüfverfahren - Verfahren 1: Bestimmung der Lichtbogen-
Kennwerte (ELIM, ATPV und/oder EBT) von
Bekleidungsstoffen und Schutzkleidung mithilfe eines
offenen Lichtbogens
(IEC 61482-1-1:2019)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

The text of document 78/1256/FDIS, future edition 2 of IEC 61482-1-1, prepared by IEC/TC 78 "Live working" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61482-1-1:2019.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2020-05-07
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2022-08-07

This document supersedes EN 61482-1-1:2009 and all of its amendments and corrigenda (if any).

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Endorsement notice

The text of the International Standard IEC 61482-1-1:2019 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60060-1	NOTE	Harmonized as EN 60060-1
IEC 61482-1-2:2014	NOTE	Harmonized as EN 61482-1-2:2014 (not modified)
ISO 3175-2	NOTE	Harmonized as EN ISO 3175-2
ISO 6330	NOTE	Harmonized as EN ISO 6330
ISO 9151	NOTE	Harmonized as EN ISO 9151
ISO 13688	NOTE	Harmonized as EN ISO 13688
ISO 15797	NOTE	Harmonized as EN ISO 15797

Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60584-1	-	Thermocouples - Part 1: EMF specifications and tolerances	EN 60584-1	-
IEC 61482-2	2018	Live working – Protective clothing against the thermal hazards of an electric arc – Part 2: Requirements	-	-
ISO/IEC 17025	2017	General requirements for the competence of testing and calibration laboratories	EN ISO/IEC 17025	2017
ISO/TR 11610	-	Protective clothing - Vocabulary	CEN ISO/TR 11610	-
ISO 11612	2015	Protective clothing – Clothing to protect against heat and flame – Minimum performance requirements	EN ISO 11612	2015

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**LIVE WORKING –
PROTECTIVE CLOTHING AGAINST
THE THERMAL HAZARDS OF AN ELECTRIC ARC –****Part 1-1: Test methods –
Method 1: Determination of the arc rating (ELIM, ATPV and/or EBT)
of clothing materials and of protective clothing using an open arc**

FOREWORD

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

This second edition cancels and replaces the first edition published in 2009. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- addition of the *Incident energy limit (ELIM)* as a further *arc rating* performance property value;
- replacement of char length requirement in the scope by indication that Procedure A is applicable for testing of *materials* meeting the limited flame spread requirements of IEC 61482-2;

- clarification of the definition and the meaning of the *Stoll curve*;
- modification of specification of positioning of *monitor sensors* with respect to the *electric arc* as function of intended high *incident energy* exposure of test specimens;
- modification of specifications of *monitor sensor* construction;
- specification of black paint;
- elimination of *calorimeters* from the chest of the mannequin;
- specification for possible positioning of mannequin(s) at a height different from the centre of the *electric arc* and possible turning in order to adequately expose all parts of the *garment* or clothing which would affect performance;
- more explicit description of requirements for data acquisition system;
- preconditioning of the samples;
- modification of requirements for apparatus and arc exposure verification by *bare shots*;
- more explicit description of test procedures A and B, in particular the subclauses dealing with “sequence of test”, “test parameter” and “test criteria”;
- addition of determination of *arc rating* values of *garments* and/or *garment* assemblies.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
78/1256/FDIS	78/1262/RVD

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

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

In this standard terms defined in Clause 3 appear in *italics*.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

LIVE WORKING – PROTECTIVE CLOTHING AGAINST THE THERMAL HAZARDS OF AN ELECTRIC ARC –

Part 1-1: Test methods – Method 1: Determination of the arc rating (ELIM, ATPV and/or EBT) of clothing materials and of protective clothing using an open arc

1 Scope

This part of IEC 61482 specifies test method procedures to determine the *arc rating of flame resistant clothing materials and garments or assemblies of garments* intended for use in clothing for workers if there is an *electric arc* hazard.

An *open arc* under controlled laboratory conditions is used to determine the values of *ELIM*, *ATPV* or *EBT* of *materials*, *garments* or assemblies of *garments*.

NOTE 1 The user can, if he desires, classify the arc protective performance into *arc rating* protection levels based on *ELIM*, *ATPV* and/or *EBT* values which correspond best to the different hazard and risks levels that can result from the user's risk analysis.

NOTE 2 This document is not dedicated to classifying the arc protective performance of the *material* and clothing into arc protection classes. Procedures determining these arc protection classes APC1 and APC2 are specified in IEC 61482-1-2, which uses a constrained arc for testing.

NOTE 3 This test method is not intended and not appropriate to evaluate whether *materials* or *garments* are *flame resistant* or not, as this is covered in IEC 61482-2.

Other effects than the thermal effects of an *electric arc* like noise, light emissions, pressure rise, hot oil, electric shock, the consequences of physical and mental shock or toxic influences are not covered by this document.

Protective clothing for work intentionally using an *electric arc*, e.g. arc welding, plasma torch, is not covered by this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 60584-1, *Thermocouples – Part 1: EMF specifications and tolerances*

IEC 61482-2:2018, *Live working – Protective clothing against the thermal hazards of an electric arc – Part 2: Requirements*

ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories*

ISO/TR 11610, *Protective clothing – Vocabulary*

ISO 11612:2015, *Protective clothing – Clothing to protect against heat and flame – Minimum performance requirements*

3 Terms, definitions, symbols and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 11610 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1.1

ablation

<electric arc testing> *material response* evidenced by formation of one or more openings in one or several outer layers, but not in all layers of a *material assembly specimen*

Note 1 to entry: for the use of this document the opening is defined as follows:

- a) with an opening in the layer of at least 1 600 mm² in area or at least 80 mm in any planar direction,
- b) with one or several individual threads across an opening not reducing the size of the opening.

3.1.2

arc duration

time duration of the arc

Note 1 to entry: *Arc duration* is expressed in milliseconds (ms).

3.1.3

arc energy

W_{arc}

<electric arc testing> electrical energy supplied to the arc and converted in the arc

Note 1 to entry: *Arc energy* is calculated as the 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 2 to entry: *Arc energy* is expressed in kilojoules (kJ).

3.1.4

arc gap

distance between the arc electrodes

Note 1 to entry: *Arc gap* is expressed in millimetres (mm).

3.1.5

arc rating

<electric arc testing> numerical value attributed to a product, that describes its protective performance when tested in accordance with the *open arc test*

Note 1 to entry: The arc rating can be the arc thermal performance value (*ATPV*), the breakopen threshold energy (*EBT*) or the incident energy limit (*ELIM*).

Note 2 to entry: The arc rating values are expressed in kJ/m² (cal/cm²).

3.1.6

arc thermal performance value

ATPV

<electric arc testing> numerical value of *incident energy* attributed to a product that describes its thermal properties of attenuating (reducing) a *heat flux* generated by an *electric arc*

Note 1 to entry: The *ATPV* of a *material* or *material assembly* is calculated using logistic regression analysis applied to the data points obtained from testing a set of test specimens. It is the value of *incident energy* at which the heat transfer through the test specimens is enough to reach the Stoll criteria with 50 % probability.

Note 2 to entry: The *ATPV* attributed to a *garment* or *garment assembly* is either equal to or lower than the *ATPV* of the *material* or *material assembly* of which it is made, depending on whether the tested specimen(s) fulfil also additional visual design and performance assessment criteria.

3.1.7

arc voltage

voltage across the arc

Note 1 to entry: *Arc voltage* is expressed in volts (V).

3.1.8

bare shot

<electric arc testing> *electric arc* event during which panels or mannequins are bare, i.e. they are not covered by test specimens

3.1.9

breakopen

<electric arc testing> *material response* evidenced by the formation of an opening in the *material* specimen

Note 1 to entry: For the use of this document the opening is defined as follows:

- a) with a size of at least 300 mm² in area or at least 25 mm in any planar direction,
- b) with one or several individual threads across an opening not reducing the size of the opening.

Note 2 to entry: A *material assembly* specimen is considered to exhibit *breakopen* when all layers show formation of one or more openings.

Note 3 to entry: *Shrink-open* is considered as a particular form of *breakopen*.

3.1.10

breakopen threshold energy

EBT

<electric arc testing> numerical value of *incident energy* attributed to product (*material* or clothing) that describes its *breakopen* properties when exposed to *heat energy* generated by an *electric arc*

Note 1 to entry: The *EBT* of a *material* or *material assembly* is calculated using logistic regression analysis applied to the data points obtained from testing a set of test specimens. It is the value of *incident energy* at which *breakopen* occurs with 50 % probability.

Note 2 to entry: The *EBT* attributed to a *garment* or *garment assembly* is either equal to or lower than the *EBT* of the *material* or *material assembly* of which it is made, depending on whether the tested specimen(s) fulfil also additional visual design and performance assessment criteria.

3.1.11

burning time

afterflame time

time for which a flaming of the test specimen is visible after the end of the *electric arc duration*

Note 1 to entry: *Burning time* is expressed in seconds (s).

3.1.12

calorimeter

assembly of a copper disc with attached thermocouple, used for measuring the *heat energy* and *incident energy*

3.1.13
calorimetric sensor
sensor

assembly of a *calorimeter* and a non-conductive heat resistant *material*, in which the *calorimeter* is mounted

Note 1 to entry: The term *sensor* is used in this document to mean *calorimetric sensor*.

3.1.14
charring

material response evidenced by formation of carbonaceous residue as the result of pyrolysis or incomplete combustion

3.1.15
dripping

material response evidenced by formation of polymer droplets that fall from the *material* or *garment*

3.1.16
electric arc

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

Note 1 to entry: During live working, the *electric arc* is generated by gas ionization 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.

[SOURCE: IEC 60050-121:1998, 121-13-12, modified – Note 1 to entry has been added to refer specifically to live working and arc testing.]

3.1.17
embrittlement

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

3.1.18
flame resistant

<*electric arc* testing> property evidenced by clothing *materials* which meet the limited flame spread requirements of IEC 61482-2

3.1.19
garment

single item of clothing which may consist of single or multiple layers of *materials*

3.1.20
garment assembly
assembly of garments

clothing consisting of two or more *garments* worn together, which may individually cover different parts of the wearer's body and/or which may be worn fully or partially on top of each other

Note 1 to entry: For example, *garment assembly* can be a combination of jacket and trousers, combination of shirt, trousers and jacket or overcoat which have been designed in such a way as to fit together.

3.1.21
heat flux

q
<*electric arc* testing> thermal intensity transmitted by an *electric arc* indicated by the amount of heat energy transfer per unit surface area and time

3.1.22**ignition**

initiation of flaming and combustion

3.1.23**incident energy**

E_i

<electric arc testing> heat energy Q resulting from an *electric arc*, received at a unit surface area at a specified distance from the *electric arc*

3.1.24**incident energy limit**

ELIM

<electric arc testing> numerical value of *incident energy* attributed to a product (*material* or clothing), below which value all product responses are below the *Stoll curve* and without *breakopen*

Note 1 to entry: The *ELIM* of a *material* or *material assembly* is calculated from data points obtained from testing a set of test specimens, which are also used for the determination of the *ATPV* and/or *EBT*.

Note 2 to entry: The *ELIM* attributed to a *garment* or *garment assembly* is either equal to or lower than the *ELIM* of the *material* or *material assembly* of which it is made, depending on whether the tested specimen(s) fulfil also additional visual design and performance assessment criteria.

3.1.25**material**

substances, excluding hardware, of which an item of clothing is made

3.1.26**material assembly**

assembly of *materials*, which is representative for the build-up of layers of a *garment* or *garment assembly*

Note 1 to entry: The *arc rating* of a *material assembly* of which an *assembly of garments* worn on top of each other is made, cannot be determined from the *arc rating* of each *material*, of which the individual *garments* are made but can only be determined by testing of *material assembly* specimens representative for the *garment assembly*.

3.1.27**material response**

reaction of the *material* to an *electric arc* characterised by *ignition*, *burning time (afterflame time)*, *breakopen*, *melting*, *dripping*, *shrinkage*, etc.

3.1.28**melting**

material response evidenced by softening and deformation

Note 1 to entry: *Materials* which melt are normally polymers.

3.1.29**mix zone**

<electric arc testing> range of measured *incident energies* (the independent variable X), in which a binary response (i.e. either the value "0" or "1") (the dependent variable Y) is attributed to a studied parameter of the measured *material response* or to a combination of several studied parameters

Note 1 to entry: A *mix zone* of a data point distribution is established when the highest *incident energy* with binary response "0" is greater than the lowest *incident energy* with binary response "1". The *mix zone* of a data point distribution is empty when the highest *incident energy* with a binary response "0" is lower than the lowest *incident energy* with a binary response "1".

Note 2 to entry: For the *material response* parameters studied for the determination of the *ATPV*, see 11.1.3.1 and 12.2.

Note 3 to entry: For the *material response* parameters studied for the determination of the *EBT*, see 11.1.3.2 and 12.3.

Note 4 to entry: For the *material response* parameters studied for the determination of the *ELIM*, see 11.1.3.3 and 12.4.

3.1.30

monitor sensor

<electric arc testing> *calorimetric sensor* mounted on each side of the panel or mannequin, not covered by a test specimen and used to measure *incident energy* at a specified distance from the *electric arc*

3.1.31

open arc

<electric arc testing> *electric arc* between two vertically opposing electrodes intended to provide an equal distribution of emitted energy around the centreline formed by the electrodes and where the emitted energy is not directed by means of any physical constraints (e.g. enclosure, wall)

[SOURCE: IEC 61482-2:2018, 3.1.13]

3.1.32

panel sensor

<electric arc testing> *calorimetric sensor* mounted in the panel, which, when covered by test specimen, is used to measure energy transmitted through a test specimen

3.1.33

protective clothing

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

[SOURCE: ISO 13688:2013, 3.5, modified – The definition has been modified to clarify by removing the unclear term “protector”.]

3.1.34

shrinkage

material response evidenced by reduction in specimen size

3.1.35

shrink-open

<electric arc testing> *material response* caused by excessive *shrinkage* with the result that the test specimen dislodging from the clamping and exposing the panel

Note 1 to entry: *Shrink-open* is considered as a particular form of *breakopen*.

3.1.36

Stoll curve

empirical predicted second-degree skin burn-injury model

Note 1 to entry: *Stoll curve* defines a relationship between the absorbed energy rate and the human skin tolerance time.

Note 2 to entry: See Stoll, A.M. and Chianta, M.A. Method and rating system for evaluation of thermal protection.

3.1.37

test shot

<electric arc testing> *electric arc* event during which one or more test specimens are mounted on the specimen support(s) of the test apparatus, with the specimen(s) covering some or all *sensors* except *monitor sensors* and being exposed to the effects of the *electric arc*

3.1.38***X/R ratio***

ratio of system inductive reactance to resistance

Note 1 to entry: 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 DC offset. A large *X/R ratio* corresponds to a large time constant and a slow rate of decay.

3.2 Symbols and units

<i>ATPV</i>	<i>arc thermal performance value</i>	kJ/m^2 (cal/cm^2)
C_p	heat capacity	$\text{J/g } ^\circ\text{C}$
<i>EBT</i>	<i>breakopen threshold energy</i>	kJ/m^2 (cal/cm^2)
E_i	<i>incident energy</i>	kJ/m^2
E_t	transmitted energy	kJ/m^2
<i>ELIM</i>	<i>incident energy limit</i>	kJ/m^2 (cal/cm^2)
Q	heat energy	kJ/m^2
q	<i>heat flux</i>	kW/m^2
T	temperature	K
t	time	s
t_0	arc initiation time	s

NOTE

$$1 \text{ kJ/m}^2 = 1 \text{ kW} \cdot \text{s/m}^2 = 0,1 \text{ J/cm}^2 = 0,0239006 \text{ cal/cm}^2$$

$$1 \text{ cal/cm}^2 = 41,840 \text{ kJ/m}^2 = 41,840 \text{ kW} \cdot \text{s/m}^2$$

4 Principle of test procedures A and B**4.1 Procedure A – *Material open arc test procedure***

Procedure A specified in this document is used to determine the *arc rating* of a *material* or *material assembly*, expressed by the value of *ATPV* or *EBT*, whichever is the lower one, or expressed by the value of the *ELIM* if specified by the person requesting testing, that the *arc rating* shall be expressed by the *ELIM*. The *ATPV*, *EBT* and *ELIM* are determined by comparing the amount of heat transmitted through the specimen(s) with Stoll criteria and the possible observation of *breakopen* when exposed to various levels of *incident energy* measured by the *monitor sensors*.

The test specimens used in this procedure are in the form of flat specimens of *material* or of *material assembly*, mounted on test panels.

The *arc rating* of a *material assembly* of which an *assembly of garments* worn on top of each other is made cannot be determined from the *arc rating* of each *material* or *material assembly* of which the individual *garments* are made, but can only be determined by testing of a *material assembly* specimen representative of the *garment assembly*.

During the tests, the amount of heat energy transmitted through the *material* or *material assembly* is measured during and after exposure to an *electric arc*.

During each single arc exposure test (i.e. during each single *test shot*), the *heat energy* of the exposure and that transferred through the test specimen(s) are both measured with copper *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 response shall be further described by recording the observed effects of the *electric arc* exposure on the specimens and using the terms given in 3.1.27.

4.2 Procedure B – *Garment open arc test procedure*

Procedure B specified in this document is used to assign the *arc rating* to an item of clothing. The *arc rating* is based on the *arc rating* of the *garment material* as determined by Procedure A and assigned by evaluation of design and performance of the clothing (consisting of one *garment* or an *assembly of garments*). This procedure consists of exposing the clothing to an *open arc*, causing an *incident energy* onto the outer surface of the clothing approximately equal to or greater than (see 11.2) the *arc rating*, determined according to Procedure A, of the *material* or the total assembly of *materials* of which the clothing is made. The *garment* or *garment assembly* shall be evaluated with findings, pockets and closures positioned as manufactured and fastened according to the manufacturer's use instructions; the tested specimen of the *garment* or *garment assembly* shall fulfil the visual assessment criteria (see 12.6.2, Table 3). In this case, the *arc rating* of the *material* or *material assembly* can be attributed to the clothing as its *arc rating* (see 11.2.2).

If a specimen of *garment* or *garment assembly*, tested at a given level of *incident energy*, does not fulfil the visual criteria for the assessment of the design and performance (see 12.6.2, Table 3), this value of *incident energy* cannot be attributed to the clothing as its *arc rating*.

However, one may test one or several further specimens of the *garment* or *garment assembly* at reduced *incident energy/energies*. If a specimen of the *garment* or *garment assembly* tested at a reduced *incident energy* and also all specimens eventually tested at even lower *incident energies* fulfil the visual assessment criteria (see 12.6.2, Table 3), this value of reduced *incident energy* may be attributed to the *garment* or *garment assembly* as its *arc rating* (see 11.2.2).

The test ordering party may deliberately specify an *incident energy* value, which may be (considerably) lower than the *arc rating* of the *material* or *material assembly*, and may require that it be tested, to determine if this specified value can be attributed to the clothing as its *arc rating*. In this case, testing may deliberately be carried out only at incident exposure energy (considerably) lower than the *arc rating* of the *material* or *material assembly*.

The test specimens used in this procedure are in the form of *garments* or *assembly of garments* mounted on test mannequins.

5 Significance and use of the test procedures A and B

5.1 General

The test procedures A and B are used to determine the *arc rating* of *flame resistant* clothing *materials* and clothing used for electrotechnical work if there is an *electric arc*.

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

IMPORTANT – This test method and the procedures are not intended and not appropriate to evaluate whether *materials* or *garments* are *flame resistant*.

NOTE The test procedures specify standard exposure conditions. Different exposure conditions can produce different test results.

5.2 Procedure A – *Material open arc test procedure*

Procedure A specified in this document is used for the determination of the *incident energy limit (ELIM)*, the *arc thermal performance value (ATPV)* and/or the *breakopen threshold energy (EBT)*, of a *material* or a *material assembly*.

Because of the variability of the arc exposure and fabric construction, different values of transferred heat energy may be measured by the *sensors* covered by test specimens when exposed to an *electric arc*. The heat transfer measurement results for a sufficiently large number of test specimens (at least 20 test specimens) is statistically analysed in accordance with Clause 12.

5.3 Procedure B – *Garment open arc test procedure*

Procedure B specified in this document is usually used for evaluation of *protective clothing* design and the determination of the *arc rating* of the clothing, when the *material* or *material assembly* of the clothing, i.e. of a *garment* or *assembly of garments*, has first been tested and its *arc rating* determined following Procedure A.

The *arc rating* of clothing is either equal to or lower than the *arc rating* of the *material* or of the total *material assembly*, or no *arc rating* can be attributed to the clothing, depending on whether the visual assessment criteria for *garments* and *garment assemblies* are fulfilled.

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 specimen supports around the centre line of the *electric arc*, of which one to three can be panels (used for Procedure A) or one to three can be mannequins (used for Procedure B). For Procedure A all three positions shall be occupied by a panel. For Procedure A it is not permissible to replace panels made of different shape or of different *materials* during a sequence of *test shots*, because such alterations may change the heat distribution;
- two *monitor sensors* for each panel or for each mannequin, one to the left and one to the right side of each panel or mannequin.

6.2 Calorimetric sensors

6.2.1 Calorimeter construction

The *calorimeters* shall be constructed from electrical grade copper with one thermocouple wire installed in the arrangement as shown in Figure 1 a).

An example of securing the thermocouple mechanically in the copper disc is shown in Figure 1 b). Soldering of the thermocouple into the disc is not allowed.

The copper discs and the filler, if used, shall be electrical grade copper with a purity greater than 99,90 %, IACS grade C110 (UNS11000). The copper discs shall have thickness of 1,6 mm $\pm$ 0,1 mm, a diameter of 40,0 mm $\pm$ 0,1 mm and a mass of 18 g $\pm$ 1 g. There shall be a hole in the centre of the copper disc, with a depth of 1,3 mm $\pm$ 0,1 mm and with a diameter of 1,2 mm $\pm$ 0,3 mm.

NOTE 1 The IACS (International Annealed Copper Standard) grade gives the level of the electrical conductivity of the copper.

The mass of each disc shall be determined to a precision of $\pm 0,05$ g and the diameter and thickness shall be determined to a precision of $\pm 0,03$ mm. For the calculations of each *sensor* response according to 12.1.2, Formula (3), the actual diameter (for the area calculation) and mass values of each individual disc shall be used. If average values for all *calorimeters* are used for calculations, their mass/area ratio shall be within $\pm 0,008$ g/cm² of their mean value.

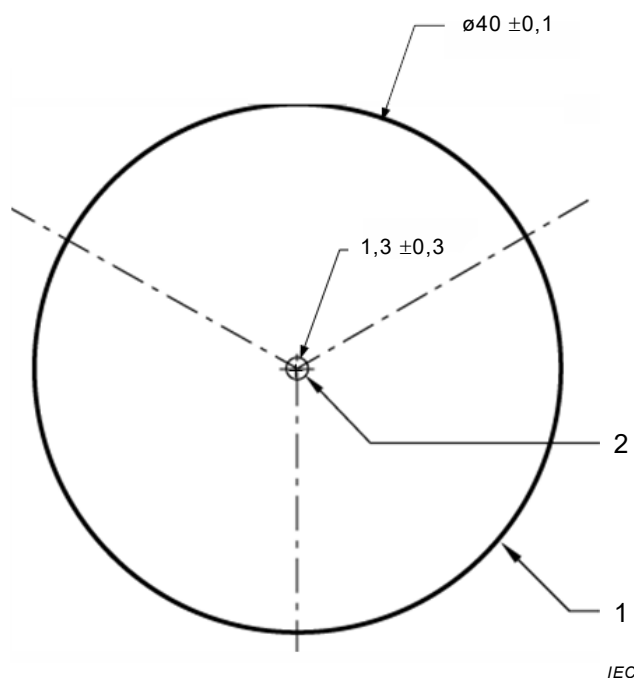
NOTE 2 Selecting copper discs for the *calorimeters* using the “average value” for the mass/area ratio [Formula (3)] can ease the operation and the replacement of *calorimeters*.

The thermocouples shall be an exposed bead Type K (NiCr – NiAl), having a cross-section area of 0,05 mm² (N° 30 AWG) but never larger, or equivalent, according to IEC 60584-1. The thermocouple wire shall be installed in the *calorimeter* as shown in Figure 1 b). Inside the hole of the copper disc, the thermocouple wires – having an outer diameter of 0,5 mm after removal of insulation, i.e. two times the single-wire diameter of 0,254 mm – shall be bare for the whole length inside the hole in the copper disc and the thermocouple wires shall be in full contact between themselves and with the surrounding copper disc, if necessary with the help of copper filler added into the hole. The thermocouple wires shall be separated (e.g. by help of fine tool) immediately upon exiting the copper disc.

NOTE 3 A visual magnifier can be used for verification that the copper wires are properly separated at the back of the copper disc and the wires have not been damaged.

NOTE 4 Each thermocouple wire exiting the copper disc is typically bare for some short distance after having exited the hole of the disc.

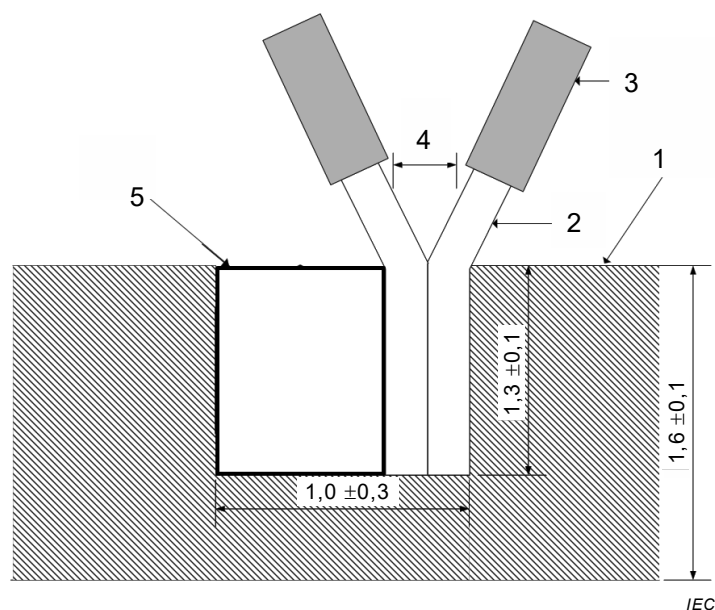
Dimensions in millimetres



Key

- 1 copper disc
- 2 thermocouple location

a) Position for installation of the thermocouple in the back side of copper disc



Key

- 1 copper disc
- 2 bare part of thermocouple wire
- 3 insulation of thermocouple wire
- 4 separation of thermocouple at the surface of the copper disc
- 5 filler to secure and maintain full contact of the thermocouple

b) Thermocouple wire installation – Details of hole and method of securing thermocouple

Figure 1 – Example of calorimeter construction

6.2.2 Panel sensor construction

The panel *sensor* is a *calorimetric sensor* constructed from a *calorimeter* mounted into a surrounding insulating board with specific physical properties (Figure 2). The insulating board shall surround the copper disc by at least 5 mm in all directions.

NOTE 1 In *calorimetric sensors* according to, for example, ISO 9151, the copper disc is surrounded by a ring of insulating board with an outer diameter of 89 mm. Another typical solution is to embed the copper disc into a quadratic insulating board of 130 mm × 130 mm.

The insulating board shall have the following physical properties.

- It shall be a piece of asbestos-free non-combustible heat insulating board.
- It shall have a permissible operating temperature of at least up to 760 °C.
- The thermal conductivity shall be less than or equal to 0,20 W/(m·K) at temperatures up to 500 °C.

For practical reasons, because of the brittle nature of insulating board, a thickness of at least 12 mm has been found sufficient for mechanical rigidity.

Alternatively, the copper disc of the *calorimeter* may be installed directly into the front board of the panel (see Figure 4), if the front board is made of an insulating *material* which meets the physical property requirements for the insulating board used for a *calorimetric sensor*.