IEC 61482-1-1

Edition 2.0 2019-07

INTERNATIONAL STANDARD

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colour inside

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

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 61482-1-1:2019-07(en-fr)

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CONTENTS

FOREWORD 5
1 Scope 7
2 Normative references 7
3 Terms, definitions, symbols and units 8
3.1 Terms and definitions 8
3.2 Symbols and units 13
4 Principle of test procedures A and B 13
4.1 Procedure A – *Material open arc* test procedure 13
4.2 Procedure B – *Garment open arc* test procedure 14
5 Significance and use of the test procedures A and B 14
5.1 General 14
5.2 Procedure A – *Material open arc* test procedure 15
5.3 Procedure B – *Garment open arc* test procedure 15
6 Test apparatus 15
6.1 General 15
6.2 Calorimetric *sensors* 15
6.2.1 *Calorimeter* construction 15
6.2.2 Panel *sensor* construction 17
6.2.3 Monitor *sensor* construction and positioning 19
6.3 Panel construction 20
6.4 Mannequin construction 22
6.5 Arrangement of panels and monitor *sensors* for testing according to Procedure A 23
6.6 Arrangement of mannequin(s) and monitor *sensors* for testing according to Procedure B 24
6.7 Supply bus and electrodes 28
6.7.1 General 28
6.7.2 Structural cage arrangement 28
6.7.3 Electrodes 30
6.7.4 Fuse wire 30
6.8 Electric supply 30
6.9 Test-circuit control 31
6.10 Data acquisition and data processing system 31
6.10.1 General 31
6.10.2 Data acquisition 31
6.10.3 Signal synchronization 32
7 Operator safety 32
8 Specimen preparation 33
8.1 Description of the test specimens 33
8.1.1 Test specimens for Procedure A 33
8.1.2 Test specimens for Procedure B 33
8.2 Pre-treatment of test specimens by cleaning 34
8.3 Pre-conditioning of the test specimens 34
9 Calibration and verification 34
9.1 Data acquisition system pre-calibration 34
9.2 Verification of *calorimeters* 34

9.3 Arc exposure and apparatus verification for the two-*sensor* panels and the monitoring *sensor*s 35
9.3.1 Set-up of electrodes and fuse wire 35
9.3.2 Positioning of the two-*sensor* panels, mannequins and monitor *sensor*s 35
9.3.3 Verification *bare shot* 35
9.3.4 Verification *bare shot* test protocol 36
10 Test apparatus care and maintenance 36
10.1 Surface reconditioning 36
10.2 Care of panels, mannequins and *sensor*s 37
10.3 Care of electrodes 37
11 Test procedures 37
11.1 Procedure A – testing with panels 37
11.1.1 Test parameter and settings 37
11.1.2 Sequence of tests with test specimens of *material* or *material assembly* 37
11.1.3 Criteria for set of data obtained from iterative process of *test shot*s 38
11.2 Procedure B – testing with mannequins 39
11.2.1 Test parameters and settings 39
11.2.2 Single test or sequence of tests with test specimen(s) of *garment* or *garment assembly* 39
11.3 Air ventilation and initial temperature of *sensor*s 40
11.4 Specimen mounting 40
11.4.1 Procedure A – testing with panels 40
11.4.2 Procedure B – testing with mannequins 40
11.5 Specimen description 42
11.6 Test protocol 42
12 Test results 43
12.1 Heat calculation 43
12.1.1 General 43
12.1.2 Copper heat capacity 43
12.1.3 Incident and transmitted energy 43
12.1.4 Panel *sensor* response (transmitted energy (E_t) comparison with *Stoll curve*) 44
12.1.5 Monitor *sensor* responses (*incident energy* (E_i)) 45
12.2 Determination of *arc thermal performance value* ($ATPV$) 46
12.3 Determination of *breakopen threshold energy* (EBT) 46
12.4 Determination of the *incident energy limit* ($ELIM$) 47
12.5 Visual inspection 47
12.6 *Arc rating* 49
12.6.1 *Arc rating* of a *material* or *material assembly* 49
12.6.2 *Arc rating* of a *garment* or *garment assembly* 49
13 Test report 50
13.1 Reporting requirements common for tests according to Procedures A and B 50
13.2 Reporting requirements specific for tests according to Procedure A 51
13.3 Reporting requirements specific for tests according to Procedure B 52
Annex A (informative) Logistic regression technique 54
Annex B (informative) 95 % confidence intervals of $ATPV$ and EBT 56
Annex C (informative) Iterative process of *test shot*s of Procedure A 60
Annex D (informative) Example *material*s for insulating and mounting boards 61

D.1 General 61
D.2 *Material*s for use as thermally insulating mounting board (6.2) 61
D.3 *Material*s for use as mounting board, but not sufficiently thermally insulating for use as insulating board (6.3) 62
Annex E (informative) Recommended provisions for use of the test method for accident replication and for research 63
Bibliography 64

Figure 1 – Example of *calorimeter* construction 17
Figure 2 – Example of the panel *sensor* construction 18
Figure 3 – Example of monitor *sensor* construction, with optional cover plate 19
Figure 4 – Panel 21
Figure 5 – Example of *material* clamping assembly of a panel 22
Figure 6 – Arrangement of three two-*sensor* panels with monitoring *sensor*s (top view) for testing according to Procedure A 24
Figure 7 – Relative positioning of arc electrodes and of mannequin(s) and monitor *sensor*s for testing according to Procedure B 25
Figure 8 – Examples of mannequin configuration 27
Figure 9 – Example of cage arrangement (supply bus, bus tubes and arc electrodes) shown together with three panels for testing according to Procedure A (monitor *sensor*s are not shown) 29
Figure 10 – Relative positioning of cage arrangement (supply bus, bus tubes and arc electrodes) and of one torso mannequin and its monitor *sensor*s for testing according to Procedure B 30
Figure 11 – Typical average transmitted energy curves $Q_{t,avg}$ (i.e. average response of the two *sensor*s of same panel) for test specimens 45
Figure B.1 – Probability density function (PDF) 56
Figure B.2 – Cumulative density (CDF) 57
Figure B.3 – Graph with probability, lower and upper limits 59

Table 1 – Positioning of monitor *sensor*s depending on *incident energy* exposure 20
Table 2 – Reporting requirements and rating of visual inspection performance in case of testing clothing *material*(s) according to Procedure A and *garment*(s) or an assembly of *garment*s according to Procedure B 47
Table 3 – Visual assessment criteria in case of testing *garment(s)* or a *garment assembly* according to Procedure B 50
Table B.1 – Example of *incident energy* X and binary response Y (fulfillment of Stoll criteria) for 21 *test shot*s 58

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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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

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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 sensor*s 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 *calorimeter*s 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 shot*s;
- 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 *garment*s 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.

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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 *garment*s 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 *material*s, *garment*s or assemblies of *garment*s.

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 *material*s or *garment*s 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 1600 mm^2 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/m^2 (cal/cm^2).

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 mm^2 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 *material*s 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 *material*s

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: *Material*s 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 *sensor*s except monitor *sensor*s 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

ATPV	*arc thermal performance value*	kJ/m^2 (cal/cm^2)
C_p	heat capacity	J/g °C
EBT	*breakopen threshold energy*	kJ/m^2 (cal/cm^2)
E_i	*incident energy*	kJ/m^2
E_t	transmitted energy	kJ/m^2
ELIM	*incident energy limit*	kJ/m^2 (cal/cm^2)
Q	heat energy	kJ/m^2
q	*heat flux*	kW/m^2
T	temperature	K
t	time	s
t_0	arc initiation time	s

NOTE
1 kJ/m^2 = 1 kW·s/m^2 = 0,1 J/cm^2 = 0,023 9006 cal/cm^2
1 cal/cm^2 = 41,840 kJ/m^2 = 41,840 kW·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 sensor*s.

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