IEC 61482-1-2

Edition 2.0 2014-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Live working – Protective clothing against the thermal hazards of an electric arc –
Part 1-2: Test methods – Method 2: Determination of arc protection class of material and clothing by using a constrained and directed arc (box test)

Travaux sous tension – Vêtements de protection contre les dangers thermiques d'un arc électrique –
Partie 1-2: Méthodes d'essai – Méthode 2: Détermination de la classe de protection contre l'arc de matériaux et de vêtements au moyen d'un arc dirigé et contraint (enceinte d'essai)

IEC 61482-1-2:2014-10(en-fr)

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International Standard IEC 61482-1-2 has been prepared by IEC technical committee 78: Live working.

This second edition cancels and replaces the first edition, published in 2007. This edition constitutes a technical revision.

It includes the following significant technical changes with regard to the previous edition:

- new mean values of main control parameters *arc energy* and *incident energy* based on an extended statistical database consisting of parameter values measured in four laboratories;
- reduction of validity check ranges of main control parameters;

- determination of the *incident energy* by averaging the two *sensor* values of a test (instead of considering each single *sensor* value);
- determination of the heat curves of transmitted *incident energy* and an amendment to the *heat flux* acceptance criterion;
- information on precision (repeatability and reproducibility) of the test method;
- clarification of the scope;
- selection of the *arc protection classes* (test classes) by the amount of the *arc energy* and *incident energy* instead of the short-circuit current;
- permitting electrode design without bores;
- recommendations of the heat resistance *materials* to be used for the box and for the test plate;
- clarification of the conditions for cleaning and replacing the box;
- requirement for including in the test report the differences ΔE_i of the *transmitted energy* values to the Stoll limit value at t_{max} and the information if the heat curves of transmitted *incident energy* exceed the *Stoll curve* during the *exposure time*;
- preconditioning of the samples according to manufacturer's instruction.

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

FDIS	Report on voting
78/1053/FDIS	78/1089/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.

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 publication will remain unchanged until the stability 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 1-2: Test methods – Method 2: Determination of arc protection class of material and clothing by using a constrained and directed arc (box test)

1 Scope

This part of IEC 61482 specifies procedures to test *material* and *garments* intended for use in heat and flame-resistant *clothing* for workers if there is an electric arc hazard. A directed and constrained *electric arc* in a test circuit is used to classify *material* and *clothing* in two defined *arc protection classes*.

This International Standard is not dedicated toward measuring the arc rating values (ATPV[1], ELIM[2] or EBT[3]). Procedures determining these arc rating values are prescribed in IEC 61482-1-1, using an open arc for testing.

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 standard.

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

2 Normative references

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

ISO 9151:1995, *Protective clothing against heat and flame – Determination of heat transmission on exposure to flame*

3 Terms, definitions and symbols

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

3.1 Terms and definitions

3.1.1
arc current
I_{arc}
current actually flowing in the electric test circuit during *arc duration* (through the arc)

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1 ATPV = *arc thermal performance value*.

2 ELIM= incident *energy limit*

3 EBT= breakopen *energy threshold*

Note 1 to entry: *Arc current* is expressed in kA rms.

Note 2 to entry: The *arc current* flowing during *arc duration* fluctuates due to the non-linear arc impedance stochastically varying with time.

3.1.2
arc duration
time duration of the arc

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

3.1.3
arc energy
$W_{\mathbf{arc}}$
electrical energy supplied to the arc and converted in the arc

Note 1 to entry: *Arc energy* is 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 kJ or kW·s.

3.1.4
arc gap
distance between the arc electrodes

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

3.1.5
arc protection class
category of *arc thermal protection* of *material* and *protective clothing* tested in the box test (class 1 or class 2)

Note 1 to entry: The *arc protection class* is characterized by the test energy level of arc exposure (*arc energy* and *incident energy*).

Note 2 to entry: Tested *material* and *protective clothing* show *arc thermal protection* at minimum up to the class energy level. In general the actual exposure energy limit up to which the *material* and *protective clothing* provide protection is higher.

3.1.6
arc thermal protection
degree of thermal protection offered against *electric arc* under specific arc testing conditions

Note 1 to entry: For *materials*, the arc thermal performance is obtained from the measurement of the *transmitted energy* and by evaluation of other thermal parameters (*burning time*, *hole formation*, *melting*).

Note 2 to entry: For *garment*s, the arc thermal performance is obtained by evaluation of thermal parameters (*burning time*, *hole formation*, *melting*) and of the functioning of fasteners and accessories.

3.1.7
arc voltage
voltage across the arc

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

3.1.8
burning time
after flame 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 s.

3.1.9
calorimeter
assembly of a copper disc with attached thermocouple used for measuring the heat flux and incident energy

3.1.10
charring
formation of carbonaceous residue as the result of pyrolysis or incomplete combustion

3.1.11
clothing
assembly of *garments* worn by workers

3.1.12
delta peak temperature
ΔT_p
difference between the maximum temperature and the initial temperature of the *sensor* during the test *exposure time*

Note 1 to entry: *Delta peak temperature* is expressed in °C.

Note 2 to entry: The symbol ΔT_p is used without index when testing with *material*; an additional index "0" is used when testing without *material* for calibration (ΔT_{p0}).

3.1.13
direct exposure incident energy
E_{i0}
heat energy or *incident energy* emitted by the *electric arc* and received at a *calorimeter* directly exposed to the arc without *material* influence

Note 1 to entry: *Direct exposure incident energy* is used for calibration.

Note 2 to entry: *Direct exposure incident energy* is expressed in kJ/m^2 or kW·s/m^2 (cal/cm^2)[4].

3.1.14
dripping
material response evidenced by flowing of the fibre polymer

3.1.15
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 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.

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

3.1.16
embrittlement
formation of a brittle residue as the result of pyrolysis or incomplete combustion

3.1.17
exposure time
total test time interval of observation and measurement

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4 Correlation: 1 cal/cm^2 = 41,868 kJ/m^2; 1 kJ/m^2 = 0,023 885 cal/cm^2.

Note 1 to entry: *Exposure time* is expressed in s.

3.1.18
garment
single item of *clothing* which may consist of single or multiple layers

3.1.19
heat flux
thermal intensity of an *electric arc* indicated by the amount of energy transmitted per unit area and time

Note 1 to entry: *Heat flux* is expressed in kW/m^2.

3.1.20
hole formation
existence of openings in the test specimen *material* with minimum 5 mm in any direction

3.1.21
ignition
initiation of flaming and combustion

3.1.22
incident energy
E_i
heat energy (total heat) received at a unit surface area as a result of an electric arc

Note 1 to entry: *Incident energy* is measured as a proportional peak temperature rise ΔT_p of a *calorimeter sensor.*

Note 2 to entry: *Incident energy* is expressed in kJ/m^2 or kW·s/m^2 (cal/cm^2).

3.1.23
material
fabric or other substances of which the *garment* is made

Note 1 to entry: The *material* may consist of single or multiple layers.

3.1.24
material response
reaction of the *material* to an *electric arc* characterized by *burning time* (after flame), *ignition*, *hole formation*, *melting*, *dripping*, *charring*, *embrittlement*, *shrinkage* and *transmitted energy*

3.1.25
melting
material response evidenced by softening and deformation

Note 1 to entry: *Materials* which melt are normally polymer(s).

3.1.26
prospective short-circuit current
predicted current flowing when the arc electrodes are connected by a conductor of negligible impedance (short-circuit of supply)

Note 1 to entry: *Prospective short-circuit current* is expressed in kA rms.

Note 2 to entry: There is in general a difference between the actual *arc current* I_{arc} and the *test current* I_{class} as defined. The actual *arc current* flowing during the *arc duration* is smaller and fluctuates due to the non-linear arc impedance stochastically varying with time. Reproducible test conditions may only be defined by means of the *prospective short-circuit current* to be expected in case of impedance-less connected arc electrodes. This *prospective short-circuit current* is, by the way, also a parameter which describes the practically interesting points in the electrical systems or installations where arc exposure has to be considered.

3.1.27
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 it by removing the unclear term “protector”]

3.1.28
sensor
assembly with a *calorimeter* and a non-conductive heat-resistant *material* in which the *calorimeter* is mounted

3.1.29
shrinkage
material response evidenced by the reduction in specimen size

3.1.30
Stoll curve
an empirical predicted second-degree skin burn injury model defining a relationship between the amount of thermal energy transferred to human tissue and the time of exposure

3.1.31
test current
I_{class}
prospective short-circuit current of the electric test circuit (predicted current)

Note 1 to entry: *Test current* is expressed in kA rms (symmetrical a.c. component).

3.1.32
test voltage
no-load a.c. voltage of the test circuit source at 50 Hz or 60 Hz

Note 1 to entry: *Test voltage* is expressed in V rms.

3.1.33
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 1 to entry: *Time to delta peak temperature* is expressed in s.

3.1.34
transmitted energy
E_{it}
incident energy received at a *calorimeter* when testing *material* or *clothing*

Note 1 to entry: *Transmitted energy* is the fraction of the emitted *incident energy* which is transmitted through the specimen.

Note 2 to entry: *Transmitted energy* is expressed in kJ/m^2 or kW·s/m^2 (cal/cm^2).

3.1.35
***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 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 used in this document

E_i	*incident energy*	kJ/m^2 or kW·s/m^2 (cal/cm^2) 1 cal/cm^2 = 41,868 kJ/m^2; 1 kJ/m^2 = 0,023885 cal/cm^2
E_{i0}	*direct exposure incident energy*	kJ/m^2 or kW·s/m^2 (cal/cm^2)
E_{it}	*transmitted energy*	kJ/m^2 or kW·s/m^2 (cal/cm^2)
I_{arc}	*arc current*	kA
I_{class}	*test current (prospective short-circuit current)*	kA
t_{max}	*time to delta peak temperature*	s
T_a	*ambient temperature*	°C
T_0	*initial sensor temperature*	°C
W_{arc}	*arc energy*	kJ, kW·s
ΔT_p	*delta peak temperature*	°C
ΔT_{p0}	*delta peak temperature by calibration*	°C

4 Principle of the test method

4.1 Material box test procedure

The box test method comprises two procedures: the *material* box test procedure and the *garment* box test procedure.

The *material* box test procedure covered by this standard determines the behaviour of *materials* when exposed to heat energy from *electric arcs* with specific characteristics.

With the *material* box test procedure the amount of heat energy transferred by the flat *material*(s) is measured during and after exposure to a specified *electric arc*.

Material performance for this procedure is determined from the amount of heat transmitted through the specimen(s) and other thermal parameters.

The *heat flux* of the exposure during the calibration shot and the *heat flux* transferred by the test specimen(s) during a test shot are measured with copper *calorimeters.* The degree to which the temperature of the *calorimeters* increases is a direct measure of the heat energy received.

Heat transfer data is used to assess the occurrence of a second-degree burn using the *Stoll curve*.

Material response shall be further described by recording the observed effects of the *electric arc* exposure on the specimens.

4.2 Garment box test procedure

The *garment* box test procedure covered by this standard determines the behaviour of *garments* when exposed to heat energy from *electric arcs* with specific characteristics.

Garment performance for this procedure is determined by evaluating the function of the *protective clothing* after exposure to a specified *electric arc*, including all the *garment* findings, sewing thread, fastenings and other accessories.

With the *garment* box test procedure, no *heat flux* will be measured.

5 Significance and use of the test method

This test method is for testing *material* and *garments* of *protective clothing* used for electrotechnical work if there is an electrical arc risk.

The test method permits to assess the arc thermal performance of *materials* (*material* box test procedure) and *garment*s (*garment* box test procedure) in terms of the energy level of the selected protection class. The protection class energy level is represented by the level of the *arc energy* and the corresponding level of the *direct exposure incident energy* according to the test conditions.

NOTE 1 There are two protection classes: Class 1 represents a basic protection level, class 2 an increased protection.

NOTE 2 In practice there can be situations with higher *arc energy* levels. Performing an electrical arc risk assessment, the potential *arc energy* of an arc flash is determined for the specific equipment and network conditions.

NOTE 3 This standard is for testing purposes. Guidance for the selection of the right *protective clothing* can be found in IEC 61482-2 and in an ISSA Guideline [1][5]. Furthermore, there is a preliminary work of TC78 on a technical report for correlating the results of arc test methods to electrotechnical applications in order to select the proper *electric arc* protective equipment.

NOTE 4 Work continues to evaluate higher energy exposures.

With the box test set-up it is possible to evaluate *materials* and *garments* based on the use of a directed and constrained *electric arc* under defined laboratory conditions. A practical scenario concerning test set-up and test conditions, electrical and constructional parameters is selected.

The heat energy transfer and impact of the test arc are due to radiation, convection by the hot plasma and gas cloud, direct contact with the plasma cloud or parts of it, and hot molten metal particles and splash.

The test box set-up is introduced to meet typical arc fault conditions and particularly to cover actual arc exposure conditions in electrical equipment and switchgear, mainly in opened compact equipment, e.g. service entrance boxes, cable distribution cabinets, distribution substations or comparable installations where the *electric arc* is directed to the front of a worker at the height of his breastbone.

NOTE 5 The test set-up configuration of this standard leads to high heat transmission. Other exposure conditions such as vertical electrodes open-arc conditions are also covered by the test set-up.

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

The test method specifies a standard set of exposure conditions. Different exposure conditions may produce more or less severe 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 Test apparatus and test box

The test apparatus shall consist of the following elements:

– test box for both procedures;

5 Numbers in square brackets refer to the Bibliography.

– two-*sensor* test plate for *material* box test procedure;
– mannequin for *garment* box test procedure;
– electric supply and electrode configuration;
– recorder;
– data acquisition system.

The test box arrangement (identical for both procedures) is shown in Figure 1.

The test box shall be of electrically and thermally non-conductive, heat resistant material.

If plaster is used, then plaster material which gives a smooth and solid surface shall be used.

NOTE Besides others, the use of Keraquick™6 moulding compound, a ceramic powder for relief casting, has shown suitable results.

6 Keraquick™ is the trade name of a product supplied by KnorrPrandell GmbH, 96215 Lichtenfels, Germany. This information is given for the convenience of users of this standard and does not constitute an endorsement by IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.