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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



78/1366/CD

COMMITTEE DRAFT (CD)

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IEC TC 78 : LIVE WORKING	
SECRETARIAT: France	SECRETARY: Mrs Sophie Chabin
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	

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TITLE:

Live working – Hand protective devices 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 hand protective devices using an open arc

NOTE FROM TC/SC OFFICERS:

This document has been prepared by PT 63232.

The CD of Part 1-2 and the NP for IEC 63232-2 LIVE WORKING – HAND PROTECTIVE DEVICES AGAINST THE THERMAL HAZARDS OF AN ELECTRIC ARC - Part 2: Requirements are circulating in parallel.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**LIVE WORKING –
HAND PROTECTIVE DEVICES 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 hand protective devices using an open arc**

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- IEC 63232-1-1 has been prepared by the project team PT 63232: Electric arc performance of hand protection equipment – test standard of IEC technical committee 78: LIVE WORKING. It is an International Standard.
- This is the first edition.

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

Draft	Report on voting
XX/XX/NP	XX/XX/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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**LIVE WORKING –
HAND PROTECTIVE DEVICES 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
hand protective devices using an open arc**

1 Scope

This part of IEC 63232-1-1 specifies test method procedures to determine the *arc rating* of hand protective devices or assemblies of *hand protective devices* for workers if there is an *electric arc* hazard.

An *open arc* under controlled laboratory conditions is used to determine the *arc rating values ELIM, ATPV or EBT* of *hand protective devices*.

This document is not dedicated to classifying the arc protective performance of the *hand protective devices* into arc protection classes. Procedures determining these arc protection classes are specified in IEC 63232-1-2, which uses a constrained arc for testing.

NOTE: The user can 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.

This test method is not intended and not appropriate to evaluate whether *hand protective devices* are *flame resistant* or not, as this will be covered in a future standard IEC 63232-2.

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

This test method does not make any statement on the dielectric properties of the hand protective devices before, during or after the arc. Use other standards to determine those properties.

NOTE: One glove may be insufficient to provide adequate protection, in such cases glove systems may need to be used in order to give complete protection to the hands for the intended use.

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.

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 60060-1: 2010, High-voltage test techniques – Part 1: General definitions and test requirements

IEC 60584-1: 2013, 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

IEC 61482-1-1: 2019 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 62475: 2010, High-current test techniques - Definitions and requirements for test currents and measuring systems

3 Terms, definitions, and symbols

For the purposes of this document, the terms and definitions given in IEC 60050-651 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>

NOTE For definitions of other terms related to *protective clothing*, see ISO/TR 11610 and ISO 13688.

3.1 Terms and definitions

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 multilayer assembly,

a) with an opening in the layer of at least 1600 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 current

I_{arc}

current actually flowing in the electric test circuit during arc duration (through the arc)

Note 1 to entry: *Arc current* is expressed in kiloamperes (kA).

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

3.1.3

arc duration

time duration of the arc

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

3.1.4

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).

3.1.5

arc gap

distance between the arc electrodes

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

3.1.6

arc rating

<electric arc testing> numerical value attributed to product, that describes its protective performance to exposure to an electric arc

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)

3.1.7**arc thermal performance value****ATPV**

<electric arc testing> numerical value of *incident energy* attributed to 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 hand protective device or hand protective device 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 hand protective device or hand protective device assembly is either equal to or lower than the ATPV of the hand protective device or hand protective device assembly, depending on whether tested specimen(s) also fulfil additional visual design and performance assessment criteria.

Note 3 to entry: ATPV is expressed in kJ/m² (cal/cm²).

3.1.8**arc voltage****voltage across the arc**

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

3.1.9**bare shot**

<electric arc testing> electric arc event during which test stands are bare, e.g. they are not covered by test specimens

3.1.10**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*.

3.1.11**breakopen threshold energy****EBT**

<electric arc testing> numerical value of *incident energy* attributed to product that describes its *breakopen* properties when exposed to heatflux of *electric arc*.

Note 1 to entry: The EBT of a hand protective device or hand protective device 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 *hand protective device or hand protective device assembly* is either equal to or lower than the EBT of the *hand protective device or hand protective device assembly*, determined by the fulfillment of only the Stoll criteria, depending on whether tested specimen(s) fulfil also additional visual design and performance assessment criteria

Note 3 to entry: EBT is expressed in kJ/m² (cal/cm²).

3.1.12**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).

3.1.13**calorimeter**

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

3.1.14**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 the document as *calorimetric sensor*

3.1.15**charring**

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

3.1.16**dripping**

material response evidenced by formation of droplets that fall from the material of the product.

3.1.17**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.]

3.1.18**flame resistant**

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

[SOURCE: IEC 61482-1-1:2018, modified from “clothing” to “materials”.]

3.1.19**hand protective device
protective glove**

item of personal protective equipment (PPE), e.g. protective gloves, that protects the hand or a part of the hand against injury, and is worn to supplement other protective equipment (e.g. protective clothing, face shield, etc.) and can also be used to protect the forearm or the entire arm

3.1.20**hand protective device assembly**

a *hand protective device* consisting of two or more *hand protective devices* worn together, which may individually cover different parts of the wearer's hands and forearms and/or which may be worn fully or partially on top of each other (e.g. combination of a liner glove, a rubber electrical insulating glove and a protector glove, etc.) and which have been designed in such a way as to fit together

Note 1 to entry: The arc rating of a hand protective device assembly cannot be determined from the arc rating of the individual devices but can only be determined by testing of hand protective device assembly specimens.

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

Note 1 to entry: *Heat flux* is expressed in kW/m².

3.1.22**ignition**

initiation of flaming and combustion

3.1.23**ignition threshold**

<electric arc testing> an energy limit at which the product does not melt and drip or continue to burn

3.1.24**incident energy**

E_i

<electric arc testing> *heat energy* Q (total heat) received at a unit surface area at a specified distance from the *electric arc*, as a result of the *electric arc*

Note 1 to entry: *Incident energy* is expressed in kJ/m^2 or $\text{kW}\cdot\text{s/m}^2$ (cal/cm^2).

3.1.25**incident energy limit****ELIM**

<electric arc testing> numerical value of *incident energy* attributed to a product, below which there is no data point with the amount of heat transmitted through the product reaching the Stoll criteria or with the product exhibiting *breakopen*

Note 1 to entry: The ELIM of a *hand protective device* or hand protective device 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 *hand protective device* or *hand protective device assembly* is either equal to or lower than the ELIM of the *hand protective device* or *hand protective device assembly*, determined by the fulfillment of only the Stoll and breakopen criteria, depending on whether tested specimen(s) fulfil additional visual design and performance assessment criteria.

Note 3 to entry: ELIM is expressed in kJ/m^2 (cal/cm^2).

3.1.26**material**

product consisting of single or multiple layers of fabric or of other planiform substances of which a *hand protective device* is made

Note 1 to entry: For example, textile fabric or a multilayer fabric assembly.

[SOURCE: IEC 61482-1-1: 2019, 3.1.25, modified by “hand protective device” substituted for “garment”.]

3.1.27**material response**

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

3.1.28**melting**

material response evidenced by softening and deformation

Note 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 (e.g., 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 clause 11.1.3.1 and clause 12.2.

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

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

Note 5 to entry: In the very rare case that at the boundaries of the mixed zone there are two or more data points with the same incident energy but with a binary response 1 and a binary response 0 among them. All these data points are considered to be inside the mixed zone.

3.1.30

monitor sensor

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

3.1.31

open arc

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/CDV:2015, 3.1.5]

3.1.32

test stand sensor

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

3.1.33

hand protective device

a *glove, mitten or other device* which covers the hand or another hand protective device, and which is designed to provide protection against one or more hazards

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 dislodges exposing any part of the calorimeter of the test stand.

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

3.1.36

Stoll curve

empirical model used to predict the onset of second-degree skin burn injury from thermal energy exposure

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

Note 2 to entry: The Stoll curve is defined in the paper: A Method and Rating System for Evaluation of Thermal Protection. Aerospace Medicine, 1969, Vol. 40, pp. 1232-1238 by A.M. Stoll and M.A. Chianta.¹

3.1.37

Stoll curve differential

SCD

the maximum or minimum difference between a curve of transmitted energy and the Stoll curve in the time interval from 1 s up to 30 s after the beginning of the arc (time zero); the SCD will be positive and its value will be the maximum difference between the two curves, if the curve

¹ A Method and Rating System for Evaluation of Thermal Protection. Aerospace Medicine, 1969, Vol. 40, pp. 1232-1238 by A.M. Stoll and M.A. Chianta.

of transmitted energy is at any moment during the 29 s equal or above the Stoll curve; the SCD will be negative and its absolute value will be the minimum difference between the two curves, if the curve of transmitted energy is always during the 29 s below the Stoll curve

Note to entry: Stoll curve differential is expressed in kJ/m^2 or $\text{kW}\cdot\text{s/m}^2$ (cal/cm^2).

3.1.38

test shot

<electric arc testing> electric arc event during which test stands are covered by test specimens

3.1.39

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

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

NOTE

1 $\text{J/g } ^\circ\text{K} = 0.23885 \text{ cal/g } ^\circ\text{K}$

1 $\text{kJ/m}^2 = 1 \text{ kW}\cdot\text{s/m}^2 = 0,1 \text{ J/cm}^2 = 0,023 \text{ 9006 cal/cm}^2$

1 $\text{cal/cm}^2 = 41,840 \text{ kJ/m}^2 = 41,840 \text{ kW}\cdot\text{s/m}^2 = 4,1840 \text{ J/cm}^2$

4 Principle of the test procedure

The procedure specified in this standard determines the *incident energy* up to which the *heat energy* transmitted through the *material(s)* does not exceed the *Stoll curve* criteria when the *material* is exposed to *heat energy* from an *open arc*.

The test specimens used in this procedure are in the form of the basic finished product or multi product protective assemblies (one type of glove or multiple types of gloves over one another to create a protective assembly). Additional components such as impact protection or extra layers on the dorsal side of the glove shall not be included in the specimens used for the determination of the arc rating. Additional specimens with all features or accessories shall be evaluated for the ignition threshold.

During the tests, the amount of *heat energy* transmitted by the *hand protective device* is measured during and after exposure to an *electric arc*.

During each single arc exposure test (e.g., single “test shot”), 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.

The protective performance of the *hand protective device*, expressed in the form of *arc rating values*, is determined from the amount of heat transmitted by the specimen(s) and the eventual observation of *breakopen* when exposed to various levels of incident-energy measured by the *monitor 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 3.1.27

5 Significance and use of the test procedure

The test method procedure for the determination of the *arc rating* of *hand protective devices* used for electrotechnical work if there is risk of an electric arc.

NOTE 1 This test method and its procedures are not intended and not appropriate to evaluate whether hand protective devices are flame resistant or not.

The procedure specified in this standard is used for the determination of the *arc rating values*, e.g., *incident energy limit (ELIM)*, the *arc thermal performance value (ATPV)* and/or the *breakopen threshold energy (EBT)*, of a *hand protective device* or assembly.

Because of the variability of the arc exposure, different heat transmission values may be measured by the *sensors* positioned at the back of 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) are statistically analysed in accordance with Clause 12.

The *arc rating* of the *hand protective device* or of the total assemblage of *hand protective devices* can be attributed to the *assembly* as its *arc rating*, if all the visual performance evaluation criteria of clause 12.4 are fulfilled.

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

NOTE 2 The test method procedures specify a standard set of exposure conditions. Different exposure conditions may produce different results.

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;
- test stands placed around the centre line of the *electric arc*,
- which can be one to three two-sensors test stands or one to six single-sensor test stands in case of the testing arrangement according to 6.3 (shown in Figure 6)
- or
- which can be one to four single-sensor test stands in case of the testing arrangement according to 6.4 (shown in Figure 7);
- two *monitor sensors*, one to the left and one to the right side
- of each two-sensors test stand (or each pair of single-sensor test stands) in case of the testing arrangement according to 6.3 (shown in Figure 6)
- or
- of each single sensor test stand in case of the testing arrangement according to 6.4 (shown in Figure 7); three of the monitor sensors are shown to be shared by each one's two adjacent single sensor test stands.

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, e.g., 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.