BS EN 62606:2013

BSI Standards Publication

General requirements for arc fault detection devices

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National foreword

This British Standard is the UK implementation of EN 62606:2013. It was derived from IEC 62606:2013.

The CENELEC common modifications have been implemented at the appropriate places in the text. The start and finish of each common modification is indicated in the text by [C› ‹C].

The UK participation in its preparation was entrusted by Technical Committee PEL/23, Electrical accessories, to Subcommittee PEL/23/1, Circuit breakers and similar equipment for household use.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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EUROPEAN STANDARD

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EN 62606

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English version

General requirements for arc fault detection devices
(IEC 62606:2013, modified)

Exigences générales des dispositifs pour la détection de défaut d'arcs (CEI 62606:2013, modifiée)

Allgemeine Anforderungen an Fehlerlichtbogen-Schutzeinrichtungen (IEC 62606:2013, modifiziert)

This European Standard was approved by CENELEC on 2013-08-13. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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CENELEC

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

CEN-CENELEC Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 23E/785/FDIS, future edition 1 of IEC 62606, prepared by SC 23E, "Circuit-breakers and similar equipment for household use", of IEC TC 23, "Electrical accessories", was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62606:2013.

A draft amendment, which covers common modifications to IEC 62606 (23E/785/FDIS), was prepared by CLC/TC 23E,"Circuit breakers and similar devices for household and similar applications" and approved by CENELEC.

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)	2014-08-13
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2016-08-13

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

In this standard, the following print types are used:
- compliance statements: in italic type.

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For the relationship with EU Directive(s) see informative Annex ZZ, which is an integral part of this document.

This standard covers the Principle Elements of the Safety Objectives for Electrical Equipment Designed for Use within Certain Voltage Limits (LVD - 2006/95/EC).

Endorsement notice

The text of the International Standard IEC 62606:2013 was approved by CENELEC as a European Standard with common modifications.

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

IEC 60060-2	NOTE Harmonized as EN 60060-2.
IEC 60112:2003	NOTE Harmonized as EN 60112:2003 (not modified).
IEC 60269-1:2006	NOTE Harmonized as EN 60269-1:2007 (not modified).
IEC 60664-3	NOTE Harmonized as EN 60664-3.
IEC 60664-5	NOTE Harmonized as EN 60664-5.
IEC 60695-2-11:2000	NOTE Harmonized as EN 60695-2-11:2001 (not modified).
IEC 61000-4-2	NOTE Harmonized as EN 61000-4-2.
IEC 61000-4-3	NOTE Harmonized as EN 61000-4-3.
IEC 61000-4-4	NOTE Harmonized as EN 61000-4-4.
IEC 61000-4-5:2005	NOTE Harmonized as EN 61000-4-5:2006 (not modified).

IEC 61000-4-6	NOTE Harmonized as EN 61000-4-6.
IEC 61000-4-16:1998	NOTE Harmonized as EN 61000-4-16:1998 (not modified).
+A1:2001 +A2:2009	+A1:2004 +A2:2011
IEC 61210	NOTE Harmonized as EN 61210.

Annex ZA
(normative)
Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60068-2-30	2005	Environmental testing - Part 2-30: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle)	EN 60068-2-30	2005
IEC 60068-3-4	2001	Environmental testing - Part 3-4: Supporting documentation and guidance - Damp heat tests	EN 60068-3-4	2002
IEC 60364	Series	Low-voltage electrical installations	HD 60364	Series
IEC 60364-4-44 (mod)	2007	Low-voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances	HD 60364-4-442	2012
IEC 60417	Data base	Graphical symbols for use on equipment	-	-
IEC 60479	Series	Effects of current on human beings and livestock	-	-
IEC 60529	-	Degrees of protection provided by enclosures (IP Code)	-	-
IEC 60664-1	2007	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests	EN 60664-1	2007
IEC 60695-2-10	2000	Fire hazard testing - Part 2-10: Glowing/hot-wire based test methods - Glow-wire apparatus and common test procedure	EN 60695-2-10[1)]	2001
IEC/TR 60755	-	General requirements for residual current operated protective devices	-	-
IEC 60898-1 (mod) - - -	2002 - - -	Electrical accessories - Circuit breakers for overcurrent protection for household and similar installations - Part 1: Circuit-breakers for a.c. operation	EN 60898-1 + corr. February + A11 + A12 + A13	2003 2004 2005 2008 2012
IEC 61008-1 (mod)	2010	Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCB's) - Part 1: General rules	EN 61008-1	2012
IEC 61009-1 (mod)	2010	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) - Part 1: General rules	EN 61009-1	2012

[1)] EN 60695-2-10 is superseded by EN 60695-2-10:2013, which is based on IEC 60695-2-10:2013.

Publication	Year	Title	EN/HD	Year
IEC 61543 + A1 (mod) + A2 -	1995 2004 2005 -	Residual current-operated protective devices (RCDs) for household and similar use - Electromagnetic compatibility	EN 61543 + corr. December + A11 + corr. May + A2 + A12	1995 1997 2003 2004 2006 2005
IEC 62423	-	Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses	EN 62423	-
CISPR 14-1 + A1	2005 2008	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission	EN 55014-1 + A1	2006 2009

Annex ZZ
(informative)

Coverage of Essential Requirements of EU Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers all relevant essential requirements as given in Article 1 of Annex I of the EU Directive 2004/108/EC.

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive(s) concerned.

WARNING: Other requirements and other EU Directives may be applicable to the products falling within the scope of this standard.

CONTENTS

INTRODUCTION

This International Standard aims to provide necessary requirements and testing procedures for devices to be installed by skilled people in households and similar uses to mitigate the risk of igniting an electrical fire downstream of the device.

Residual Current Devices (RCDs) are recognised as efficient to reduce the risk of fire by detection of leakage current and arcing to ground as a consequence of tracking currents within an electrical installation. However, RCDs as fuses or circuit-breakers are not able to reduce the risk of electrical fire due to series or parallel arcing between live conductors.

During a series arc fault, there is no leakage to ground therefore RCDs cannot detect such a fault. Moreover, the impedance of the series arc fault reduces the load current, which will keep the current below the tripping threshold of the circuit-breaker and the fuse. In the case of a parallel arc between phase and neutral conductor, the current is only limited by the impedance of the installation. In the worst cases of sporadic arcs, the conventional circuit breakers were not designed for that purpose.

Experience and information available confirmed that the r.m.s. current value of an earth fault current caused by an arcing fault, which is able to ignite a fire, is not limited to the rated power supply frequency of 50/60 Hz, but may contain a much higher frequency spectrum that is not taken into account for the testing of RCDs.

It has been recognised that the risk of igniting a fire within an electrical installation can also be a consequence of an overvoltage due to a broken neutral in a three phase installation.

This standard covers devices designed to be installed in a distribution board at the origin of one or several final circuits of a fixed installation.

GENERAL REQUIREMENTS FOR ARC FAULT DETECTION DEVICES

1 Scope

This International Standard applies to arc fault detection devices (AFDD) for household and similar uses in a.c. circuits.

note deleted

An AFDD is designed by the manufacturer:

– either as a single device having opening means able to open the protected circuit in specified conditions; or
– as a single device integrating a protective device; or
– as a separate unit, according to Annex D assembled on site with a declared protective device.

The integrated protection device is either a circuit-breaker in accordance with IEC 60898-1 or an RCD in accordance with IEC 61008-1, IEC 61009-1 or IEC 62423.

These devices are intended to mitigate the risk of fire in final circuits of a fixed installation due to the effect of arc fault currents that pose a risk of fire ignition under certain conditions if the arcing persists.

Protection against fire ignition due to overvoltage due to a broken neutral within a three phase installation to be included in this type of equipment as an additional option is under consideration in 9.22.

NOTE 1 Tracking current leads to arcing and therefore may ignite fire.

This International Standard applies to devices performing simultaneously the detection and discrimination of arcing current with regards to fire hazards and defines operating criteria under specified conditions for the opening of the circuit when the arcing current exceeds the limit values given in this standard.

AFDDs complying with this standard, with the exception of those with an uninterrupted neutral, are suitable for use in IT systems.

The maximum rated voltage is 240 V a.c. AFDDs, according to this standard, are supplied either between line and neutral or between two lines.

The maximum rated current (I_n) is 63 A a.c.

AFDDs energised from batteries or a circuit other than the protected circuit are not covered by this standard.

AFDDs provide isolation, they are intended to be operated by uninstructed persons and do not require maintenance.

Particular requirements may be necessary for:

– AFDDs incorporated in or intended only for association with plugs and socket-outlets or with appliance couplers for household or similar general purposes;
– AFDDs intended to be used at frequencies other than 50 Hz or 60 Hz.

[C] NOTE 2 [C] For AFDDs incorporated in, or intended only for socket-outlets the requirements of this standard can be used, as far as applicable, in conjunction with the requirements of IEC 60884-1 or the national requirements of the country where the product is placed on the market.

[C] NOTE 3 [C] In the UK, the plug part and the socket-outlet part(s) need not comply with any IEC 60884-1 requirements. In the UK, the plug part shall comply with BS 1363-1 and the socket-outlet part(s) shall comply with BS 1363-2.

Special precautions (e.g. surge protective devices) may be necessary when excessive overvoltages are likely to occur on the supply side.

The requirements of this standard apply for standard conditions of temperature and environment. They are applicable to AFDDs intended for use in an environment with pollution degree 2. Additional requirements may be necessary for devices used in locations having more severe environmental conditions.

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.

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 + 12 h cycle)*

IEC 60068-3-4:2001, *Environmental testing – Part 3-4: Supporting documentation and guidance – Damp heat tests*

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60417, *Graphical symbols for use on equipment*, available from: <http://www.graphical-symbols.info/equipment>

IEC 60479 (all parts), *Effects of current on human beings and livestock*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60695-2-10:2000, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC/TR 60755, *General requirements for residual current operated protective devices*

IEC 60898-1:2002, *Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations – Part 1: Circuit-breakers for a.c. operation*

IEC 61008-1:2010, *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules*

IEC 61009-1:2010, *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 1: General rules*

IEC 61543:1995, *Residual current-operated protective devices (RCDs) for household and similar use – Electromagnetic compatibility*
Amendment 1:2004
Amendment 2:2005

IEC 62423, *Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses*

CISPR 14-1:2009, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC/TR 60755, IEC 60898-1, IEC 61008-1, IEC 61009-1, IEC 62423 and the following apply.

NOTE Where the terms "voltage" or "current" are used, they imply r.m.s. values, unless otherwise specified.

3.1
arc
arcing
luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization of the electrodes

Note 1 to entry: A complete sinusoidal current half cycle is not considered to be an arcing half cycle.

3.2
arc fault
arcing fault
dangerous unintentional parallel or series arc between conductors

3.3
arc fault detection device
AFDD
device intended to mitigate the effects of arcing faults by disconnecting the circuit when an arc fault is detected

3.4
arc fault detection unit
AFD unit
part of the AFDD ensuring the function of detection and discrimination of dangerous earth, parallel and series arc faults and initiating the operation of the device to cause interruption of the current

Note 1 to entry: The interruption of the current can either be provided by opening means (see 4.1.1) or by a protective device integrating an AFD unit (see 4.1.2) or by a protective device assembled with an AFD unit see (4.1.3).

3.5
detection
function consisting in sensing the presence of an arc fault current

3.6
interruption
function consisting in bringing automatically the main contacts of the AFDD from the closed position into the open position, thereby interrupting the arc fault current(s) flowing through them

3.7
earth arc fault
arc fault where the current is flowing from active conductor to the earth

Note 1 to entry: The earth arc current may have a value close to the parallel arc current in some installations (e.g. TN installation).

3.8
parallel arc fault
arc fault where the arc current is flowing between active conductors in parallel with the load of the circuit.

3.9
series arc fault
arc fault where the current is flowing through the load(s) of the final circuit protected by an AFDD

3.10
closed position
position in which the predetermined continuity of the main circuit of the AFDD is secured

3.11
open position
position in which the predetermined clearance between open contacts in the main circuit of the AFDD is secured

3.12
pole
that part of an AFDD associated exclusively with one electrically separated conducting path of its main circuit provided with contacts intended to connect and disconnect the main circuit itself and excluding those portions which provide a means for mounting and operating the poles together

3.13
switched neutral pole
pole only intended to switch the neutral and not intended to have a short-circuit capacity

3.14
isolation
isolating function
function intended to cut off the supply from the whole installation or a discrete section of it by separating it from every source of electrical energy for reasons of safety

[SOURCE: IEC 60947-1:2007, 2.1.19]

3.15
isolating distance
clearance between open contacts, meeting the safety requirements specified for isolation purposes

[SOURCE: IEC 60050-441:1984, 441-17-35, modified – "disconnectors" has been replaced by "isolation purposes".]

3.16
making capacity
value of the a.c. component of a prospective current that an AFDD is capable of making at a stated voltage under prescribed conditions of use and behaviour

3.17
breaking capacity
value of the a.c. component of a prospective current that an AFDD is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

3.18
conditional short-circuit current
I_{nc}
value of the a.c. component of a prospective current, which an AFDD, protected by a suitable short-circuit protective device (SCPD) in series can withstand under specified conditions of use and behaviour

3.19
prospective current
current that would flow in the circuit, if each main current path of the AFDD were replaced by a conductor of negligible impedance

Note 1 to entry: The prospective current may be qualified in the same manner as an actual current, for example: prospective breaking current, prospective peak current, etc.

3.20
maximum prospective peak current (of an a.c. circuit)
prospective peak current, when the initiation of the current takes place at the instant which leads to the highest possible value

3.21
short-circuit (making and breaking) capacity
alternating component of the prospective current, expressed by its r.m.s. value, which the AFDD is designed to make, to carry for its opening time and to break under specified conditions

3.22
thread forming tapping screw
tapping screw having an uninterrupted thread

Note 1 to entry: It is not a function of this thread to remove material from the hole.

Note 2 to entry: An example of a thread forming tapping screw is shown in Figure 1.

3.23
thread cutting tapping screw
tapping screw having an interrupted thread

Note 1 to entry: It is a function of this thread to remove material from the hole.

Note 2 to entry: An example of a thread cutting tapping screw is shown in Figure 2.

4 Classification

4.1 According to the method of construction

4.1.1 AFDD as one single device, comprising an AFD unit and opening means and intended to be connected in series with a suitable short circuit protective device declared by the manufacturer complying with one or more of the following standards IEC 60898-1, IEC 61009-1 or IEC 60269 series

4.1.2 AFDD as one single device, comprising an AFD unit integrated in a protective device complying with one or more of the following standards IEC 60898-1, IEC 61008-1, IEC 61009-1 or IEC 62423.

4.1.3 AFDD according to Annex D, comprised of an AFD unit and a declared protective device, intended to be assembled on site.

4.2 According to the method of mounting and connection

Panel board type AFDDs, also referred to as distribution board types, can be connected as follows:

a) AFDDs the connections of which are not associated with the mechanical mounting;

b) AFDDs the connections of which are associated with the mechanical mounting, for example:

   1) plug-in type;

   2) bolt-on type.

NOTE Some AFDDs of the plug-in type or bolt-on type on the line side only, the load terminals being usually suitable for wiring connection.

4.3 According to the number of poles and current paths

[C) *text deleted* (C]

– Two-pole AFDD.

NOTE 1 Extension to three or four-pole AFDDs is under consideration.

NOTE 2 In China uninterrupted neutral AFDDs are not allowed.

4.4 AFDD providing monitoring information

AFDD providing monitoring information are under consideration

Under consideration.

5 Characteristics of AFDDs

5.1 Summary of characteristics and conditions to mitigate the risk of fire

An AFDD shall ensure detection for:

– earth arc fault (see 3.7); and

– parallel arc fault (see 3.8); and

– series arc fault (see 3.9).

The characteristics of an AFDD shall be stated in the following terms:

– rated current I_n (see 5.2.2);

– rated voltage U_n (see 5.2.1);

– rated frequency (see 5.2.3);
– rated making and breaking capacity I_m (see 5.2.4);
– rated making and breaking capacity on one pole I_{m1} (see 5.2.5);
– degree of protection (see IEC 60529);
– rated conditional short-circuit current I_{nc} (see 5.3.6 and 5.5.2);
– rated conditional short-circuit current on one pole I_{nc1} (see 5.3.6 and 5.5.2);
– method of connection (see 4.2).

5.2 Rated quantities and other characteristics

5.2.1 Rated voltage

5.2.1.1 Rated operational voltage (U_n)

The rated operational voltage (hereafter referred to as "rated voltage") of an AFDD is the value of voltage, assigned by the manufacturer, to which its performance is referred.

The same AFDD may be assigned for a number of rated voltages.

5.2.1.2 Rated insulation voltage (U_i)

The rated insulation voltage of an AFDD is the value of voltage, assigned by the manufacturer, to which dielectric test voltages and creepage distances are referred.

Unless otherwise stated, the rated insulation voltage is the value of the maximum rated voltage of the AFDD. In no case shall the maximum rated voltage exceed the rated insulation voltage.

5.2.1.3 Rated impulse withstand voltage (U_{imp})

The rated impulse withstand voltage of an AFDD shall be equal to or higher than the standard values of rated impulse withstand voltage according to Table F.1 of IEC 60664-1:2007 and Table 4 of this standard.

5.2.2 Rated current (I_n)

The value of current, assigned to the AFDD by the manufacturer, which the AFDD can carry in uninterrupted duty.

5.2.3 Rated frequency

The rated frequency of an AFDD is the power frequency for which the AFDD is designed and to which the values of the other characteristics correspond.

The same AFDD may be assigned a number of rated frequencies.

5.2.4 Rated making and breaking capacity (I_m)

The r.m.s. value of the a.c. component of prospective current, assigned by the manufacturer, which an AFDD can make, carry and break under specified conditions.

The conditions are those specified in 9.11.2 for AFDDs classified according to 4.1.1 and in the standard of the declared protective device (e.g. IEC 60898-1, IEC 61008-1, IEC 61009-1, IEC 62423) for AFDDs classified according to 4.1.2 and 4.1.3.

5.2.5 Rated making and breaking capacity on one pole (I_{m1})

The r.m.s. value of the a.c. component of prospective current, assigned by the manufacturer, which an AFDD can make, carry and break with one pole, under specified conditions.

5.3 Standard and preferred values

5.3.1 Preferred values of rated voltage (U_n)

Preferred values of rated voltage are as follows

– 230 V: wherever in this standard there is a reference to 230 V they may be read as 220 V or 240 V respectively;

[C〉 *text deleted* 〈C]

5.3.2 Preferred values of rated current (I_n)

Preferred values of rated current are:

6 – 8 – 10 – 13 – 16 – 20 – 25 – 32 – 40 – 50 – 63 A.

5.3.3 Preferred values of rated frequency

[C〉 Preferred values of rated frequency is 50 Hz. 〈C]

If another value is used, the rated frequency shall be marked on the device and the tests carried out at this frequency.

5.3.4 Minimum value of the rated making and breaking capacity (I_m)

The minimum value of the rated making and breaking capacity I_m is 10 I_n or 500 A, whichever is the greater.

The associated power factors are given in 9.11.2 for AFDDs classified according to 4.1.1 and in the standard of the declared protective device for AFDDs classified according to 4.1.2 and 4.1.3.

5.3.5 Minimum value of the rated making and breaking capacity on one pole (I_{m1})

The minimum value of the rated making and breaking capacity on one pole I_{m1} is 10 I_n or 500 A, whichever is the greater.

The associated power factors are given in 9.11.2 for AFDDs classified according to 4.1.1 and in the standard of the declared protective device for AFDDs classified according to 4.1.2 and 4.1.3.

5.3.6 Standard and preferred values of the rated conditional short-circuit current (I_{nc}) and standard and preferred values of the rated conditional short circuit current for one pole (I_{nc1})

5.3.6.1 General

The standard and preferred values of the rated conditional short-circuit current I_{nc} and I_{nc1} are specified as follows:

5.3.6.2 Values up to and including 10 000 A

Up to and including 10 000 A, the standard values of the rated conditional short-circuit current I_{nc} and I_{nc1} are:

3 000 – 4 500 – 6 000 – 10 000 A.

The associated power factors are given in 9.11.2 for AFDDs classified according to 4.1.1 and in the standard of the declared protective device for AFDDs classified according to 4.1.2 and 4.1.3.

[C] *note deleted* [C]

5.3.6.3 Values above 10 000 A

For values above 10 000 A up to and including 25 000 A, a preferred value is 20 000 A.

The associated power factors are given in 9.11.2 for AFDDs classified according to 4.1.1 and in the standard of the declared protective device for AFDDs classified according to 4.1.2 and 4.1.3.

Values above 25 000 A are not considered in this standard.

5.3.7 Limiting values of operating criteria for AFDDs for low and high arc currents

5.3.7.1 Limit values of operating criteria for AFDDs at low arc currents up to 63 A

Table 1 – Limit values of break time for U_n = 230 V AFDDs

Test arc current (r.m.s. values)	2,5 A	5 A	10 A	16 A	32 A	63 A
Maximum break time	1 s	0,5 s	0,25 s	0,15 s	0,12s	0,12 s

NOTE Low arc currents can occur due to insulation faults phase to earth or series arcing

[C] *table deleted* [C]

When the test current to which the AFDD is exposed is not one of the values in Tables 1 or 2, the allowable break time shall be determined by linear interpolation between the break time values above and below the actual test current.

5.3.7.2 Limit values of operating criteria for AFDDs at high arc currents above 63 A

Table 3 – Maximum allowed number of arcing half-cycles within 0,5 s for U_n 230 V AFDDs [C] *text deleted* [C]

Test arc current [a] (r.m.s. values)	75 A	100 A	150 A	200 A	300 A	500 A
N [b]	12	10	8	8	8	8

[a] This test current is the prospective current before arcing in the testing circuit.

[b] N is the number of half cycles at the rated frequency.

NOTE High arc currents can occur due to insulation faults phase to earth or parallel arcing.

5.4 Standard value of rated impulse withstand voltage (U_{imp})

Table 4 gives the standard value of rated impulse withstand voltages as a function of the nominal voltage of the installation.

Table 4 – Rated impulse withstand voltage as a function of the nominal voltage of the installation

Rated impulse withstand voltage U_{imp} kV	Nominal voltage of the installation	
	Three-phase systems V	Single-phase system with mid-point earthed V
2,5[a]		Ⓒ *text deleted* Ⓒ [b]
4[a]	230/400	Ⓒ *text deleted* Ⓒ 240[c]

NOTE 1 For test voltages to check the insulation, see Table 15.

NOTE 2 For test voltages to check the isolation distance across open contacts, see Table 16.

[a] The values 3 kV and 5 kV respectively are used for verifying the isolating distances across open contacts at the altitude of 2 000 m (see Table 16).

[b] For installation practice in Japan.

[c] For installation practice in North American countries.

In case an AFDD is intended to be connected (see 4.1.1) or integrated (see 4.1.2) or assembled (see 4.1.3) with one or several declared protective devices whose standard values of rated impulse withstand voltage are more severe than those mentioned in Table 4, the standard conditions for operation in service and for installation of the most severe protective device standard shall apply.

5.5 Coordination with short-circuit protective devices (SCPDs)

5.5.1 General

AFDDs shall be protected against short-circuits by means of circuit-breakers or fuses complying with their relevant standards according to the installation rules of the IEC 60364 series.

Coordination between AFDDs and the SCPD shall be verified under the general conditions of 9.11 to verify that there is an adequate protection of the AFDDs against short-circuit currents up to the conditional short-circuit current I_{nc}.

5.5.2 Rated conditional short-circuit current (I_{nc}) and rated conditional short-circuit on one pole (I_{nc1})

The r.m.s. value of prospective current, assigned by the manufacturer, which an AFDD, protected by a SCPD, can withstand under specified conditions without undergoing alterations impairing its functions.

The conditions are those specified in 9.11.

5.5.3 Operating characteristics of opening means for AFDDs according to 4.1.1

5.5.3.1 General

Opening means shall meet all applicable requirements of this standard.

The following acronyms I_{m1} and I_{nc1} are used for testing on one pole only.

5.5.3.2 Rated making and breaking capacity (I_m and I_{m1})

The conditions for the rated making and breaking capacity (I_m and I_{m1}) in 5.2.4 and 5.2.5 are those specified in 9.11.2.3 and in 9.11.2.4.

The associated power factors for the minimum value of the rated making and breaking (I_m and I_{m1}) given in 5.3.4 and 5.3.5 are specified in Table 19 of 9.11.2.2.

5.5.3.3 Rated conditional short-circuit capacity (I_{nc} and I_{nc1})

The conditions for the rated conditional short circuit capacity (I_{nc} and I_{nc1}) in 5.3.6 are those specified in 9.11.2.5.

The associated power factors are specified in Table 19 of 9.11.2.2.

6 Marking and other product information

6.1 Marking

Each AFDD shall be marked in a durable manner with all or, for small apparatus, part of the following data:

Table 5 – Marking and position of marking

	Marking or Information item	Position of the marking or information		
		Visible on product when installed	On the product	In a Leaflet
a	the manufacturer's name or trade mark;		X	X
b	type designation, catalogue number or serial number		X	X
c	rated voltage(s)	X		X
d	rated frequency; AFDDs with more than one rated frequency (e.g. 50/60 Hz) shall be marked accordingly		X	X
e	rated current	X		X
f	rated making and breaking capacity		X	X
g	the position of use, if necessary			X
h	the degree of protection (only if different from IP20);			X
i	wiring diagram		X	X
j	standard reference		X	X

The marking shall be on the AFDD itself or on a nameplate or nameplates attached to the AFDD and shall be located so that it is legible when the AFDD is installed.

The suitability for isolation, which is provided by all AFDDs of this standard, may be indicated by the symbol  (IEC 60617-7:2001-07) on the device. When affixed, this marking may be included in a wiring diagram, where it may be combined with symbols of other functions.

NOTE In Australia this marking is mandatory but is not required to be visible after installation.

When the symbol is used on its own (i.e. not in a wiring diagram), combination with symbols of other functions is not allowed.

If a degree of protection higher than IP20 according to IEC 60529 is marked on the device, it shall comply with it, whichever the method of installation. If the higher degree of protection is obtained only by a specific method of installation, and/or with the use of specific accessories (e.g. terminal covers, enclosures, etc.), this shall be specified in the manufacturer's literature.

If, for small devices, the space available does not allow all the above data to be marked, at least the information under c & e shall be marked and visible when the device is installed. The information under a, b, d, f & i may be marked on the side or on the back of the device and be visible only before the device is installed. Alternatively the information under h may be on the inside of any cover which has to be removed in order to connect the supply wires. Any remaining information not marked shall be given in the manufacturer's catalogues.

The open position shall be indicated by the symbol "O" (IEC 60417-5008:2002-10) and the closed position by the symbol "|" (a short straight vertical line, IEC 60417-5007:2002-10). Additional national symbols for this indication are allowed. Provisionally the use of national indications only is allowed. These indications shall be readily visible when the AFDD is installed.

Alternatively, a button remaining in its depressed position is sufficient to indicate the closed position. On the other hand, if the button does not remain depressed, an additional means indicating the position of the contacts shall be provided.

If it is necessary to distinguish between the supply and the load terminals, they shall be clearly marked (e.g. by "line" and "load" placed near the corresponding terminals or by arrows indicating the direction of power flow).

Terminals exclusively intended for the connection of the neutral circuit shall be indicated by the letter N.

Terminals intended for the protective conductor, if any, shall be indicated by the symbol ⏚ (IEC 60417-5019:2006-08).

The marking shall be indelible, easily legible and not be placed on screws, washers or other removable parts.

The terminal shall be suitable for all types of conductors: rigid (solid or stranded) and unless otherwise specified by the manufacturer also for flexible.

For universal terminals (for rigid-solid, rigid-stranded and flexible conductors):

– no marking.

For non-universal terminals:

– terminals declared for rigid-solid conductors only shall be marked by the letters "s" or "sol";
– terminals declared for rigid (solid and stranded) only conductors shall be marked by the letter "r";

The markings should appear on the AFDD or, if the space available is not sufficient, on the smallest package unit or in technical information.

For devices according to 4.1.2, the marking required in Clause 6 of IEC 60898-1:2002 or IEC 61008-1:2010 or IEC 61009-1:2010 shall be indicated, as applicable.

Compliance is checked by inspection and by the test of 9.3, according to the testing procedure given in 9.1.1

6.2 Additional marking for AFDDs according to 4.1.1

6.2.1 Marking of AFDDs

AFDDs shall be marked with:

- Maximum rated current of the main protective device with which it may be connected (e.g. 32 A max.) for short-circuit protection. If this value depends on the declared protective devices the lowest value is marked;
- Rated making and breaking capacity on one pole (I_{m1});
- Rated conditional short circuit current (I_{nc});
- Rated conditional short-circuit current on one pole (I_{nc1}).

It is recommended that the references of the main protective device with which the AFDD can be connected in series be marked.

The manufacturer shall state the Joule integral I^2t and the peak current I_p withstand capabilities of the AFDD. Where these are not stated, minimum values as given in Table 18.

For AFDDs intended to be wired with several protective devices the highest values of I^2t and I peak of the protective devices declared by the manufacturer is applied.

Compliance is checked by inspection and by the tests of 9.3 of this standard.

6.2.2 Instructions for wiring and operation

The AFDD manufacturer's data sheet and catalogue shall mention with which declared and standardised protective device according to IEC 60898-1 and/or IEC 61009-1 and/or IEC 62423 and/or IEC 60269 it can be connected with.

The manufacturer shall provide adequate instructions with the AFDD.

These instructions shall cover at least the following:

- reference to the type(s) and catalogue number(s), covering current and voltage ratings etc. of the declared protective device(s) with which the AFDD is designed to be wired with;
- derating factor(s), if any.

7 Standard conditions for operation in service and for installation

7.1 Standard conditions

AFDDs complying with this standard shall be capable of operating under the following standard conditions shown in Table 6.

Table 6 – Standard conditions for operation in service

Influencing quantity	Standard range of application	Reference value	Test tolerances [f]
Ambient temperature [a g]	–5 °C to +40 °C [b]	20 °C	± 5 °C
Altitude	Not exceeding 2 000 m		
Relative humidity maximum value 40 °C	50 % [c]		
External magnetic field	Not exceeding 5 times the earth's magnetic field in any direction	Earth's magnetic field	[d]
Position	As stated by the manufacturer, with a tolerance of 2° in any direction [e]	As stated by the manufacturer	2 ° in any direction
Frequency	Reference value ± 5 % [f]	Rated value	± 2 %
Sinusoidal wave distortion	Not exceeding 5 %	Zero	5 %

[a] The maximum value of the mean daily temperature is +35 °C.

[b] Values outside the range are admissible where more severe climatic conditions prevail, subject to agreement between manufacturer and user.

[c] Higher relative humidities are admitted at lower temperature (for example 90 % at 20 °C).

[d] When an AFDD is installed in proximity of a strong magnetic field, supplementary requirements may be necessary.

[e] The device shall be fixed without causing deformation liable to impair its functions.

[f] The tolerances given apply unless otherwise specified in the relevant test.

[g] Extreme limits of -20 °C and +60 °C are admissible during storage and transportation, and should be taken into account in the design of the device.

In case an AFDD is connected (see 4.1.1) or integrated (see 4.1.2) or assembled (see 4.1.3) with one or several associated declared protective devices whose standard conditions for operation in service and for installation are more severe than those mentioned in Table 6, the standard conditions for operation in service and for installation of the most severe protective device standard shall apply.

7.2 Conditions of installation

AFDDs shall be installed in accordance with the manufacturer's instructions.

7.3 Pollution degree

AFDDs complying with this standard are intended for environment with pollution degree 2, i.e. normally, only non-conductive pollution occurs; occasionally, however, a temporary conductivity caused by condensation may be expected

8 Requirements for construction and operation

8.1 General

The AFD unit shall not reduce the main operating characteristics of the declared protective device. The AFD unit within an AFDD according to 4.1.3 and the protective device shall be from the same manufacturer or being affixed with the same trade mark.

As a consequence, the manufacturer shall declare both with which protective device the AFD unit can be associated and which AFD unit is suitable with the protective device.

An AFDD shall not be designed in such a way that the AFD unit provides a current between a phase and the neutral or protective conductor within the installation having the purpose to trip another device.

AFDDs shall be so designed and constructed that, in normal use, their performance is safe, reliable and without danger to the user or the environment.

AFDDs shall comply with this standard in accordance with the scope and the relevant classifications.

AFDDs classified according to 4.1.1 shall comply with the requirements and tests given in this standard (in particular see 6.2, 9.11.2 and 9.18.1).

In the case of AFDDs intended to be wired with several protective devices, a selection of the most stringent tests among all applicable protective device standards shall be applied.

The degree of protection of AFDDs according to 4.1.1 shall not be less than the degree of protection of the declared protective device which it is to be wired with.

Where an AFDD can be wired with several declared protective devices, the highest degree of protection of all applicable standards including this one applies.

AFDDs classified according to 4.1.2 shall comply with the relevant standard of the protective device with which it is integrated (IEC 60898-1, IEC 61008-1, IEC 61009-1, or IEC 62423 as applicable) and additionally to the requirements and tests given in this standard.

Where tests included in this standard are also included in IEC 60898-1, IEC 61008-1, IEC 61009-1, or IEC 62423, a selection of the most stringent requirements and tests among all applicable standards shall be applied only once.

AFDDs classified according to 4.1.3 shall comply with the requirements given in this standard and additionally to the requirements and tests given in Annex D as applicable.

In case of AFDDs intended to be assembled with several protective devices, a selection of the most stringent tests among all applicable standards shall be applied.

8.2 Mechanical design

8.2.1 General

The arcing current detection and release with regards to fire hazard shall be located between the incoming and outgoing terminals of the AFDD.

It shall not be possible to alter the operating characteristics of the AFDD by means of external interventions.

It shall not be possible to disable or inhibit the AFDD function by any means.

The instructions shall state that it is not allowed to wire a circuit-breaker or an overcurrent protective device of a given rated short-circuit capacity with an AFDD according to 4.1.1 so as to result in a lower short-circuit performance.

Compliance is checked by the documentation.

8.2.2 Mechanism

The moving contacts of all poles of multipole AFDDs shall be so mechanically coupled that all poles except the switched neutral, if any, make and break substantially together, whether operated manually or automatically.

A switched neutral pole of a four pole AFDD shall not close after and shall not open before the other pole(s).

AFDDs shall have a trip-free mechanism.

It shall be possible to switch the AFDD on and off by hand.

AFDDs shall be so constructed that the moving contacts can come to rest only in the closed position or in the open position, even when the operating means is released in an intermediate position.

AFDDs shall provide in the open position an isolation distance in accordance with the requirements necessary to satisfy the isolating function.

Indication of the position of the main contacts shall be provided by one or both of the following means:

- the position of the actuator (this being preferred), or
- a separate mechanical indicator.

If a separate mechanical indicator is used to indicate the position of the main contacts, this shall show the colour red for the closed position and the colour green for the open position.

NOTE In the USA, the colours red and green are not used for contact position indication.

The means of indication of the contact position shall be reliable.

AFDDs shall be designed so that the actuator, front plate or cover can only be fitted in a manner which ensures correct indication of the contact position.

When means are provided or specified by the manufacturer to lock the operating means in the open position, locking in that position shall only be possible when the main contacts are in the open position.

Locking of the operating means in the closed position is permitted for particular applications.

Where the operating means is used to indicate the position of the contacts, the operating means, when released, shall automatically take up the position corresponding to that of the moving contacts; in this case, the operating means shall have two distinct rest positions corresponding to the position of the contacts, but, for automatic opening, a third distinct position of the operating means may be provided, in which case it shall be necessary to reset the AFDD manually before reclosing is possible.

The action of the mechanism shall not be influenced by the position of enclosures or covers and shall be independent of any removable part.

A cover sealed in position by the manufacturer is considered to be a non-removable part.

If the cover is used as a guiding means for push-buttons, it shall not be possible to remove the buttons from the outside of the AFDD.

Operating means shall be securely fixed on their shafts and it shall not be possible to remove them without the aid of a tool.

Operating means directly fixed to covers are allowed. If the operating means has an "up-down" movement, when the AFDD is mounted as in normal use, the contacts shall be closed by the up movement.

Compliance with the above requirements is checked by inspection, by manual test and, for the trip-free mechanism, by the tests of 9.11 and 9.15 according to the testing procedure given in 9.1.1.

8.2.3 Clearances and creepage distances (see Annex B)

The minimum required clearances and creepage distances are given in Table 7 which is based on the AFDD being designed for operating in an environment with pollution degree 2.

Compliance for item 1 in Table 7 is checked by measurement and by the tests of 9.7.7.4.1and 9.7.7.4.2. The test is carried out with samples not submitted to the humidity treatment described in 9.7.2.

The clearances of items 2 and 4 may be reduced provided that the measured clearances are not shorter than the minimum allowed in IEC 60664-1:2007 for homogenous field conditions; in which case, after the humidity treatment described in 9.7.2, compliance for items 2 and 4 and arrangements of 9.7.2 items b), c), d) and e) is checked in the following order:

- tests according to 9.7.2 to 9.7.5 as applicable;
- tests according to 9.7.7.2 is applied with test voltages given in Table 15 with test arrangements of 9.7.3 items b), c), d), e).

If measurement does not show any reduced clearance, test 9.7.7.2 is not applied.

Compliance for item 3 in Table 7 is checked by measurement.

NOTE 1 All measurements required in 8.2.3 are carried out in test sequence A on 1 sample and the tests according to 9.7.6 are carried out on 3 samples of test sequence B.

Parts of PCBs connected to the live parts protected against pollution by the use of a type 2 protection according to IEC 60664-3 are exempt from this verification.

The insulating materials are classified into material groups on the basis of their comparative tracking index (CTI) according to 4.8.1 of IEC 60664-1:2007.

Table 7 – Minimum clearances and creepage distances *(1 of 2)*

	Minimum clearances mm			Minimum creepage distances [e, f] mm											
				Group IIIa [h] (175 V ≤ CTI < 400 V)[d]				Group II (400 V ≤ CTI < 600 V)[d]				Group I (600 V ≤ CTI) [d]			
	Rated voltage V			Working voltage [e] V											
	U_{imp}														
	2,5 kV	4 kV	4 kV												
Description	Ⓒ *text deleted* Ⓒ	Ⓒ *text deleted* Ⓒ 240	230/400 230 400	> 25 ≤ 50[i]	Ⓒ *text deleted* Ⓒ	250	400	> 25 ≤ 50[i]	Ⓒ *text deleted* Ⓒ	250	400	> 25 ≤ 50[i]	Ⓒ *text deleted* Ⓒ	250	400
1. between live parts which are separated when the main contacts are in the open position [a]	2,0	4,0	4,0	1,20	2,00	4,0	4,0	0,90	2,00	4,0	4,0	0,60	2,00	4,0	4,0
2. between live parts of different polarity [a]	1,5	3,0	3,0	1,20	1,50	3,0	4,0	0,90	1,50	3,0	3,0	0,60	1,50	3,0	3,0
3. between circuits supplied from different sources, one of which being PELV or SELV [g]	3,0	6,0	8,0		3,0	6,0	8,0		3,0	6,0	8,0		3,0	6,0	8,0
				Rated voltage V											
				Ⓒ *text deleted* Ⓒ		230 / 400		Ⓒ *text deleted* Ⓒ		230 / 400		Ⓒ *text deleted* Ⓒ		230 / 400	
4. between live parts and – accessible surfaces of operating means – screws or other means for fixing covers which have to be removed when mounting the AFDD – surface on which the AFDD is mounted [b] – screws or other means for fixing the AFDD [b] – metal covers or boxes [b] – other accessible metal parts [c] – metal frames supporting flush-type AFDDs	1,50	3,0	3,0	1,50		4,0		1,50		3,0		1,50		3,0	

NOTE 1 The values given for 400 V are also valid for 440 V.

NOTE 2 The parts of the neutral path, if any, are considered to be live parts.

NOTE 3 Care should be taken to provide adequate clearances and creepage distances between live parts of different polarity of AFDDs, e.g. of the plug-in type mounted close to one another. If the clearance and creepage distances requirements are not fulfilled to all the surfaces adjacent to the AFDD, appropriate information will be provided for installation purposes.

Table 7 *(2 of 2)*

[a] For auxiliary and control contacts the values are given in the relevant standard.

[b] The values are doubled if clearances and creepage distances between live parts of the device and the metallic screen or the surface on which the AFDD is mounted are not dependent on the design of the AFDD only, so that they can be reduced when the AFDD is mounted in the most unfavourable condition.

[c] Including a metal foil in contact with the surfaces of insulating material which are accessible after installation for normal use. The foil is pushed into corners, grooves, etc., by means of a straight unjointed test finger according to 9.6 (see Figure 3).

[d] See IEC 60112:2003.

[e] Interpolation is allowed in determining creepage distances corresponding to voltage values intermediate to those listed as working voltage. When interpolating, linear interpolation shall be used and values shall be rounded to the same number of digits as the values picked up from the tables. For determination of creepage distances, see Annex B.

[f] Creepage distances cannot be less than the associated clearances.

[g] To cover all different voltages including ELV in an auxiliary contact.

[h] For material group IIIb (100 V ≤ CTI < 175 V), the values for material group IIIa multiplied by 1,6 apply.

[i] For working voltages up to and including 25 V, reference may be made to IEC 60664-1:2007.

NOTE 2 Information on the requirements for design of solid insulation and appropriate testing is provided in IEC 60664-1:2007, 5.3 and 6.1.3.

NOTE 3 For clearances on printed wiring material, the following Note 3 Table F.2 in IEC 60664-1:2007 can be used: "For printed wiring material, the values for pollution degree 1 apply except that the value shall not be less than 0,04 mm, as specified in Table F.4." For creepage distances on printed wiring material, distances in Table F.4 in IEC 60664-1:2007 can be used if protected with a coating meeting IEC 60664-3 requirements and tests.

NOTE 4 The dimensioning of clearances and creepage distances for spacings equal to or less than 2 mm for printed wiring board can be optimised under certain conditions in case of use of IEC 60664-5. Only humidity levels HL 2 and HL3 are considered.

8.2.4 Screws, current-carrying parts and connections

8.2.4.1 Connections, whether electrical or mechanical, shall withstand the mechanical stresses occurring in normal use.

Screws operated when mounting the AFDD during installation shall not be of the thread-cutting type.

NOTE 1 Screws (or nuts) which are operated when mounting the AFDD include screws for fixing covers or cover-plates, but not connecting means for screwed conduits and for fixing the base of an AFDD.

Compliance is checked by the test of 9.4 according to the testing procedure given in 9.1.1.

NOTE 2 Screwed connections are considered as checked by the tests of 9.8, 9.11, 9.12, and 9.20.

8.2.4.2 For screws in engagement with a thread of insulating material and which are operated when mounting the AFDD during installation, correct introduction of the screw into the screw hole or nut shall be ensured.

Compliance is checked by inspection and by manual test.

NOTE The requirement with regard to correct introduction is met if introduction of the screw in a slanting manner is prevented, for example, by guiding the screw by the part to be fixed by a recess in the female thread or by the use of a screw with the leading thread removed.

8.2.4.3 Electrical connections shall be so designed that contact pressure is not transmitted through insulating material other than ceramic, pure mica or other material with characteristics no less suitable, unless there is sufficient resilience in the metallic parts to compensate for any possible shrinkage or yielding of the insulating material.

Compliance is checked by inspection.

NOTE The suitability of the material is considered in respect of the stability of the dimensions.

8.2.4.4 Current-carrying parts including parts intended for protective conductors, if any, shall be made of a metal having, under the conditions occurring in the equipment, mechanical strength, electrical conductivity and resistance to corrosion adequate for their intended use.

Examples of suitable materials are given below:

– copper;
– an alloy containing at least 58 % copper for parts worked cold, or at least 50 % copper for other parts;
– other metal or suitably coated metal, no less resistant to corrosion than copper and having mechanical properties no less suitable.

In case of using ferrous alloys or suitably coated ferrous alloys, compliance to resistance to corrosion is checked by a test of resistance to rusting (see 9.16).

The requirements of this subclause 8.2.4.4 do not apply to contacts, magnetic circuits, heater elements, bimetals, shunts, parts of electronic devices or to screws, nuts, washers, clamping plates, similar parts of terminals and parts of the test circuit.

8.2.5 Terminals for external conductors

8.2.5.1 Terminals for external conductors shall be such that the conductors may be connected so as to ensure that the necessary contact pressure is maintained permanently.

Connection arrangements intended for busbar connection are admissible, provided they are not used for the connection of cables.

Such arrangements may be either of the plug-in or of the bolt-on type.

The terminals shall be readily accessible under the intended conditions of use.

Compliance is checked by the test of 9.5 according to the testing procedure given in 9.1.1.

8.2.5.2 AFDDs shall be provided with terminals which shall allow the connection of copper conductors having nominal cross-sectional areas as shown in Table 8.

NOTE Examples of possible designs of terminals are given in Annex IB.

The terminals of the AFDD according to 4.1.1 shall be able to clamp the range of nominal cross-sections of conductors specified in the standard of all declared protective devices for the rated currents of the declared protective devices with which it is designed to be wired.

Compliance is checked by inspection, by measurement and by fitting in turn one conductor of the smallest and one of the largest cross-sectional area as specified.

Table 8 – Connectable cross-sections of copper conductors for screw-type terminals

Rated current [b] A		Range of nominal cross-section to be clamped [a] mm^2	
Greater than	**Up to and including**	**Rigid (solid or stranded) conductors**	**Flexible conductors**
–	13	1 to 2,5	1 to 2,5
13	16	1 to 4	1 to 4
16	25	1,5 to 6	1,5 to 6
25	32	2,5 to 10	2,5 to 6
32	50	4 to 16	4 to 10
50	80	10 to 25	10 to 16

NOTE For AWG cross-sections, see Annex IC.

[a] It is required that, for current ratings up to and including 50 A, terminals be designed to clamp solid conductors as well as rigid stranded conductors. Nevertheless, it is permitted that terminals for conductors having cross-sections from 1 mm^2 up to 6 mm^2 be designed to clamp solid conductors only.

[b] A range of AFDDs having the same fundamental design and construction of terminals, the terminals are fitted with copper conductors of the smallest cross-section for the minimum rated current and largest cross-section for the maximum rated current, as specified, solid and stranded, as applicable.

8.2.5.3 The means for clamping the conductors in the terminals shall not serve to fix any other component, although they may hold the terminals in place or prevent them from turning.

Compliance is checked by inspection and the test of 9.5 according to the testing procedure given in 9.1.1.

8.2.5.4 Terminals for rated currents up to and including 32 A shall allow the conductors to be connected without special preparation.

Compliance is checked by inspection.

NOTE The term "special preparation" covers soldering of wire of the conductor, use of cable lugs, formation of eyelets, etc., but not the reshaping of the conductor before its introduction into the terminal or the twisting of a flexible conductor to consolidate the end.

8.2.5.5 Terminals shall have adequate mechanical strength.

Screws and nuts for clamping the conductors shall have a metric ISO thread or a thread comparable in pitch and mechanical strength.

Compliance is checked by inspection and by the tests of 9.4 and 9.5.1 according to the testing procedure given in 9.1.1.

8.2.5.6 Terminals shall be so designed that they clamp the conductor without undue damage to the conductor.

Compliance is checked by inspection and by the test of 9.5.2 according to the testing procedure given in 9.1.1.

8.2.5.7 Terminals shall be so designed that they clamp the conductor reliably and between metal surfaces.

Compliance is checked by inspection and by the tests of 9.4 and 9.5.1 according to the testing procedure given in 9.1.1.

8.2.5.8 Terminals shall be so designed or positioned that neither a rigid solid conductor nor a wire of a stranded conductor can slip out while the clamping screws or nuts are tightened.

This requirement does not apply to lug terminals.

Compliance is checked by the test of 9.5.3 according to the testing procedure given in 9.1.1.

8.2.5.9 Terminals shall be so fixed or located that, when the clamping screws or nuts are tightened or loosened, their fixings do not become loose.

These requirements do not imply that the terminals shall be so designed that their rotation or displacement is prevented, but any movement shall be sufficiently limited so as to prevent non-compliance with the requirements of this standard.

The use of sealing compound or resin is considered to be sufficient for preventing a terminal from working loose, provided that:

– the sealing compound or resin is not subject to stress during normal use;
– the effectiveness of the sealing compound or resin is not impaired by temperatures attained by the terminal under the most unfavourable conditions specified in this standard.

Compliance is checked by inspection, by measurement and by the test of 9.4 according to the testing procedure given in 9.1.1.

8.2.5.10 Clamping screws or nuts of terminals intended for the connection of protective conductors shall be adequately secured against accidental loosening and it shall not be possible to unclamp them without a tool.

Compliance is checked by manual test.

In general, the designs of terminals of which examples are shown in Annex IB provide sufficient resilience to comply with this requirement; for other designs special provisions, such as the use of an adequately resilient part which is not likely to be removed inadvertently, may be necessary.

8.2.5.11 Screws and nuts of terminals intended for the connection of external conductors shall be in engagement with a metal thread and the screws shall not be of the tapping screw type.

8.3 Protection against electric shock

AFDDs shall be so designed that, when they are mounted and wired as for normal use, live parts are not accessible.

NOTE The term "normal use" implies that AFDDs be installed according to the manufacturer's instructions.

A part is considered to be "accessible" if it can be touched by the standard test finger (see 9.6).

For AFDDs other than those of the plug-in type, external parts, other than screws or other means for fixing covers and labels, which are accessible when AFDDs are mounted and wired as in normal conditions of use, shall either be of insulating material, or be lined throughout with insulating material, unless the live parts are within an internal enclosure of insulating material.

Linings shall be fixed in such a way that they are not likely to be lost during installation of AFDDs. They shall have adequate thickness and mechanical strength and shall provide adequate protection at places where sharp edges occur.

Inlet openings for cables or conduits shall either be of insulating material or be provided with bushings or similar devices of insulating material. Such devices shall be reliably fixed and shall have adequate mechanical strength.

For plug-in AFDDs external parts other than screws or other means for fixing covers, which are accessible for normal use, shall be of insulating material.

Metallic operating means shall be insulated from live parts and their conductive parts, which otherwise would be "exposed conductive parts", shall be covered by insulating material, with the exception of means for coupling insulated operating means of several poles.

Metal parts of the mechanism shall not be accessible. In addition, they shall be insulated from accessible metal parts, from metal frames supporting the base of flush-type AFDDs, from screws or other means for fixing the base to its support and from metal plates used as support.

It shall be possible to replace plug-in AFDDs easily without touching live parts.

Lacquer and enamel are not considered to provide adequate insulation for the purpose of this subclause.

Compliance is checked by inspection and by the test of 9.6 according to the testing procedure given in 9.1.1.

8.4 Dielectric properties and isolating capability

AFDDs shall have adequate dielectric properties and shall ensure isolation.

Control circuits connected to the main circuit shall not be damaged by high d.c. voltage due to insulation measurements which are normally carried out after AFDDs are installed.

Compliance is checked by the tests of 9.7 according to the testing procedure given in 9.1.1.

8.5 Temperature rise

8.5.1 Temperature-rise limits

The temperature-rises of the parts of an AFDD specified in Table 9, measured under the conditions specified in 9.8.2, shall not exceed the limiting values stated in Table 9.

The AFDD shall not suffer damage impairing its functions and its safe use.

Table 9 – Temperature-rise values

Parts [a, b]	Temperature-rise K
Terminals for external connections [c]	65
External parts liable to be touched during manual operation of the AFDD, including operating means of insulating material and metallic means for coupling insulated operating means of several poles	40
External metallic parts of operating means	25
Other external parts, including that face of the AFDD in direct contact with the mounting surface	60

[a] No value is specified for the contacts, since the design of most AFDDs is such that a direct measurement of the temperature of those parts cannot be made without the risk of causing alterations or displacement of parts likely to affect the reproducibility of the tests.

The test of reliability (see 9.19) is considered to be sufficient for checking indirectly the behaviour of the contacts with respect to undue temperature-rises in service.

[b] No value is specified for parts other than those listed, but no damage shall be caused to adjacent parts of insulating materials, and the operation of the AFDD shall not be impaired.

[c] For plug-in type AFDDs the terminals of the base on which they are installed.

In case an AFDD is wired (see 4.1.1) or integrated (see 4.1.2) or assembled (see 4.1.3) with one or several associated declared protective devices whose standard conditions for temperature rise are more severe than those mentioned in Table 9, the standard conditions for operation in service and for installation of the most severe protective device standard shall apply (IEC 60898, IEC 61008, IEC 61009 and IEC 62423).

8.5.2 Ambient air temperature

The temperature-rise limits given in Table 9 are applicable only if the ambient air temperature remains between the limits given in Table 6.

8.6 Operating characteristics

8.6.1 Operating characteristics of the protective device part

AFDDs classified according to 4.1.2 shall comply with the operating characteristics of the relevant standard of the protective device in which it is integrated (IEC 60898-1, IEC 61008-1, IEC 61009-1, or IEC 62423 as applicable).

Compliance is checked by carrying out all the relevant tests of the specified relevant standard.

AFDDs classified according to 4.1.3 shall comply with the operating characteristics of the relevant standard of the protective device to which it is assembled (IEC 60898, IEC 61008-1, IEC 61009-1, or IEC 62423 as applicable).

Compliance is checked by carrying out all the relevant tests provided in the specified relevant standard and in Annex D.

8.6.2 Operating characteristics

8.6.2.1 General

The operating characteristics of AFDDs shall comply with the following requirements.

Compliance of the following subclauses is checked by the tests given in 9.9.

8.6.2.2 Operation in case of a series arc fault

The operation of AFDDs to an arc fault current shall be in accordance with breaking time shown in Table 1 or 2 as applicable

Compliance is checked by the tests of 9.9.2.

8.6.2.3 Operation in case of a parallel arc fault

The operation of AFDDs in case of a parallel arc fault shall be in accordance with the number of arcing half cycles in Table 3.

Compliance is checked by the tests of 9.9.3.

8.7 Mechanical and electrical endurance

AFDDs shall be capable of performing an adequate number of mechanical and electrical operations.

Compliance is checked by the test of 9.10 according to the testing procedure given in 9.1.1.

8.8 Performance at short-circuits currents

AFDDs shall be capable of performing a specified number of short-circuit operations during which they shall neither endanger the operator nor initiate a flashover between live conductive parts or between live conductive parts and earth.

Compliance is checked by the tests of 9.11 according to the testing procedure given in 9.1.1.

8.9 Resistance to mechanical shock and impact

AFDDs shall have adequate mechanical behaviour so as to withstand the stresses imposed during installation and use.

Compliance is checked by the test of 9.12 according to the testing procedure given in 9.1.1.

8.10 Resistance to heat

AFDDs shall be sufficiently resistant to heat.

Compliance is checked by the test of 9.13 according to the testing procedure given in 9.1.1.

8.11 Resistance to abnormal heat and to fire

External parts of AFDDs made of insulating material shall not be liable to ignite and to spread fire if current-carrying parts in their vicinity, under fault or overload conditions, attain a high temperature. The resistance to abnormal heat and to fire of the other parts made of insulating material is considered as checked by the other tests of this standard.

Compliance is checked by the test of 9.14 according to the testing procedure given in 9.1.1.

8.12 Behaviour of AFDDs in case of overcurrents in the main circuit

AFDDs shall fulfil the specified conditions of overcurrents.

Compliance is checked by the test of 9.17 according to the testing procedure given in 9.1.1.

8.13 Behaviour of AFDDs in case of current surges caused by impulse voltages

AFDDs shall adequately withstand the current surges to earth due to the loading of the capacitances of the installation and the current surges to earth due to flashover in the installation.

Compliance is checked by the tests of 9.18 according to the testing procedure given in 9.1.1.

8.14 Reliability

AFDDs shall operate reliably even after long service, taking into account the ageing of their components.

Compliance is checked by the tests of 9.19 and 9.20 according to the testing procedure given in 9.1.1.

8.15 Electromagnetic compatibility (EMC)

AFDDs shall comply with relevant EMC requirements.

Compliance is checked by the tests of 9.21 according to the testing procedure given in 9.1.1.

8.16 Masking test for correct operation behaviour in presence of various appliances connected to the load side

AFDDs shall not be blinded and shall be able to continue to detect arc faults in case of various appliances connected to the load side

Compliance is checked by the tests of 9.9.4.

8.17 Performance of the AFD test device

An AFDD shall be provided with a manual or an automatically initiated test function or both that checks the arc detection circuit.

The automatic test function shall be performed at every switch on and at intervals not exceeding at least once a day.

During automatic testing, it is not required to open the contacts by performing the test.

NOTE 1 The mechanical parts of the mechanism are verified by the endurance tests and the contacts are verified by the short circuit tests. For that reason these parts are expected to be high reliable and need not to be included in a periodic test.

In case of manual test, the device shall trip.

NOTE 2 Additional requirements and testing procedure for testing the performance manually or automatically are under consideration.

In case a malfunction is detected during automatic testing, the AFDD shall trip and indicate the result.

AFDDs including an RCD function need a test device according to the relevant product standard.

The protective conductor of the installation shall not become live (the touch current and/or the touch voltage shall be limited below the dangerous levels according to IEC 60364 and IEC 60479 series of standards) is operated during the function test.

For verification, the manufacturer shall provide the necessary documentation of the test function circuit.

9 Testing procedure

9.1 General

9.1.1 General testing procedure for the different type of AFDDs

AFDDs classified according to 4.1.1 shall be connected in series with the declared protective device(s) which complies with IEC 60898-1 or IEC 61009-1 or IEC 62423 or IEC 60269, for the testing in 9.11.2.5.

For AFDDs intended to be wired with several protective devices, the testing procedure is applied with the highest values of I^2t and *I* peak of the protective devices declared by the manufacturer.

The declared protective device(s) shall comply with the type tests of:

– IEC 60898-1 for circuit-breakers;
– IEC 61009-1 or IEC 62423 for RCBOs;
– IEC 60269 series for fuses;

as applicable.

AFDDs classified according to 4.1.2 shall first be tested according to IEC 60898-1, IEC 61008-1, IEC 61009-1, or IEC 62423, as applicable.

After completion of the tests given either in IEC 60898-1, IEC 61008-1, IEC 61009-1, or IEC 62423, the additional tests given in this standard shall be applied in order to show conformity to this standard

In case tests included in this standard were also included in IEC 60898-1, IEC 61008-1, IEC 61009-1, or IEC 62423, the most severe tests among all applicable standards shall be applied only once but the acceptance criteria combines the acceptance criteria of all applicable standard

AFDDs classified according to 4.1.3 shall first be assembled as declared by the manufacturer with the declared protective device(s) (according to manufacturers' instructions) which complies/comply with IEC 60898-1, IEC 61008-1, IEC 61009-1, or IEC 62423, as applicable.

Afterward, the testing procedure given in this standard together with the additional requirements and test given in Annex D shall be applied.

In case of AFDDs intended to be assembled with several protective devices, the testing procedure has to be either repeated with each protective device declared by the manufacturer or the most stringent tests among all applicable standards shall be applied only once but the acceptance criteria combines the acceptance criteria of any applicable standard.

Annex A provides the test sequence and number of samples for testing the AFDDs.

9.1.2 The characteristics of AFDDs are checked by means of type tests

Type tests required by this standard are listed in Table 10:

Table 10 – List of type tests

Test	Subclause
– Indelibility of marking	9.3 [a]
– Reliability of screws, current-carrying parts and connections	9.4 [a]
– Reliability of terminals for external conductors	9.5 [a]
– Protection against electric shock	9.6 [a]
– Dielectric properties	9.7 [a]
– Temperature-rise	9.8
– Operating characteristics	9.9
– Mechanical and electrical endurance	9.10 [a]
– Behaviour under short-circuit conditions	9.11
– Resistance to mechanical shock and impact	9.12 [a]
– Resistance to heat	9.13 [a]
– Resistance to abnormal heat and to fire	9.14 [a]
– Verification of the trip-free mechanism	9.15
– Test of resistance to rusting	9.16
– Verification of limiting values of the non-operating current under overcurrent conditions	9.17
– Behaviour in case of surges caused by impulse voltage	9.18
– Verification of reliability	9.19
– Verification of ageing of electronic components	9.20
– Electromagnetic compatibility	9.21
– Verification of protection due to overvoltage due to a broken neutral in a three phase system	9.22
[a] For AFDDs classified according to 4.1.2, these tests are already covered by the tests according to the relevant standard for RCDs or circuit breakers and need not to be repeated here.	

9.1.3 For certification purposes, type tests are carried out in test sequences.

NOTE The term "certification" denotes either:

- the manufacturer's declaration of conformity; or
- third-party certification, for example by an independent certification body.

The test sequences and the number of samples to be submitted are stated in Annex A.

Unless otherwise specified, each test sequence is made on a new AFDD, the influencing quantities having their normal reference values (see Table 6).

9.1.4 Routine tests to be carried out by the manufacturer on each device

Routine tests of AFDDs are given in Annex E.

The routine test of the operating characteristics of declared protective devices for AFDDs classified 4.1.2 and 4.1.3 shall be tested according to declared protective device standards IEC 60898-1, IEC 61008-1, IEC 61009-1 or IEC 62423, as applicable.

9.2 Test conditions

The AFDD is mounted individually according to manufacturer's instructions and in free air, at an ambient temperature between 20 °C and 25 °C, unless otherwise specified, and is protected against undue external heating or cooling.

AFDDs designed for installation in individual enclosures are tested in the smallest of such enclosures specified by the manufacturer.

NOTE 1 An individual enclosure is an enclosure designed to accept one device only.

Unless otherwise specified due to the declared protective device, the AFDD is wired with the appropriate cable having the cross-section specified in Table 11 and is fixed on a dull black painted plywood board of not less than 20 mm, the method of fixing shall comply with the requirements relating to the indications of the manufacturer concerning mounting.

Table 11 – Test copper conductors corresponding to the rated currents

Rated current I_n A	$I_n \leq 6$	$6 < I_n \leq 13$	$13 < I_n \leq 20$	$20 < I_n \leq 25$	$25 < I_n \leq 32$	$32 < I_n \leq 50$	$50 < I_n \leq 63$
S mm^2	1	1,5	2,5	4	6	10	16

NOTE 2 For AWG copper conductors, see Annex IC.

Where tolerances are not specified, type tests are carried out at values not less severe than those specified in this standard. Unless otherwise specified, tests are carried out at the rated frequency ± 5 %.

During the tests no maintenance or dismantling of the samples are allowed.

For the tests of 9.8, 9.9, 9.19.3 and 9.20, the AFDD is connected as follows:

– the connections are made by means of single-core, PVC-insulated copper cables;
– the connections are in free air and spaced not less than the distance existing between the terminals;
– the minimum length of each temporary connection from terminal to terminal is:
  - 1 m for cross-sections ≤ 10 mm^2;
  - 2 m for cross-sections > 10 mm^2.

The tightening torques to be applied to the terminal screws are two-thirds of those specified in Table 12.

For AFDDs with dependent manual operation, an operating speed of 0,1 m/s ± 25 % shall be used during actuation for the tests of 9.10 and 9.11. The speed is measured at the extremity when and where the operating means of the test apparatus touches the actuating means of the AFDD under test. For rotary knobs, the angular velocity shall correspond substantially to the above conditions, referred to the speed of the operating means (at its extremities) of the AFDD under test.

9.3 Test of indelibility of marking

The test is made by rubbing the marking by hand for 15 s with a piece of cotton soaked with water and again for 15 s with a piece of cotton soaked with aliphatic solvent hexane (with a content of aromatics of maximum 0,1 % volume, a kauributanol value of 29, initial boiling point approximately 65 °C, dry point approximately 69 °C and specific gravity of 0,68 g/cm^3).

NOTE Aliphatic solvent hexane having both the main composition required by the standards and CAS No. 110-54-3 is acceptable.

Marking made by impressing, moulding or engraving is not subjected to this test.

After this test, the marking shall be easily legible. The marking shall also remain easily legible after all the tests of this standard.

It shall not be possible to easily remove labels and they shall show no curling.

9.4 Test of reliability of screws, current-carrying parts and connections

Compliance with the requirements of 8.2.4 is checked by inspection and, for screws and nuts which are operated when mounting and connecting the AFDD, by the following test.

The screws or nuts are tightened and loosened:

– 10 times for screws in engagement with a thread of insulating material;
– 5 times in all other cases.

Screws or nuts in engagement with a thread of insulating material are completely removed and reinserted each time.

The test is made by means of a suitable test screwdriver or spanner applying a torque as shown in Table 12.

The screws and nuts shall be tightened in one smooth and continuous motion.

The test is made with rigid conductors only, having the largest cross-sectional areas specified in Table 8, solid or stranded, whichever is the most unfavourable. The conductor is moved each time the screw or nut is loosened.

Table 12 – Screw thread diameters and applied torques

Nominal diameter of thread mm		Torque Nm		
Greater than	**Up to and including**	**I**	**II**	**III**
–	2,8	0,2	0,4	0,4
2,8	3,0	0,25	0,5	0,5
3,0	3,2	0,3	0,6	0,6
3,2	3,6	0,4	0,8	0,8
3,6	4,1	0,7	1,2	1,2
4,1	4,7	0,8	1,8	1,8
4,7	5,3	0,8	2,0	2,0
5,3	6,0	1,2	2,5	3,0
6,0	8,0	2,5	3,5	6,0
8,0	10,0	–	4,0	10,0

Column I applies to screws without heads if the screw, when tightened, does not protrude from the hole, and to other screws which cannot be tightened by means of a screwdriver with a blade wider than the diameter of the screw.

Column II applies to other screws which are tightened by means of a screwdriver.

Column III applies to screws and nuts which are tightened by means other than a screwdriver.

Where a screw has a hexagonal head with a slot for tightening with a screwdriver and the values in columns II and III are different, the test is carried out twice, first applying to the hexagonal head the torque specified in column III and then, on another sample, applying the torque specified in column II by means of a screwdriver. If the values in columns II and III are the same, only the test with the screwdriver is carried out.

During the test, the screwed connections shall not become loose and there shall be no damage, such as breakage of screws or deterioration to the head slots, threads, washers or stirrups, which will impair the further use of the AFDD.

Moreover, enclosures and covers shall not be damaged.

9.5 Test of reliability of terminals for external conductors

9.5.1 The terminals are fitted with copper conductors of the same type (solid, stranded or flexible) of the smallest and largest cross-sections specified in Table 8.

The terminal shall be suitable for all types of conductors: rigid (solid or stranded) and flexible, unless otherwise specified by the manufacturer.

Terminals shall be tested with the minimum and maximum cross-section of each type of conductors on new terminals as follows:

– Tests for solid conductors shall use conductors having cross-sections from 1 mm^2 up to 6 mm^2, as applicable;
– Tests for stranded conductors shall use conductors having cross-sections from 1,5 mm^2 up to 25 mm^2, as applicable;
– Tests for flexible conductors shall use conductors having cross-sections from 1 mm^2 up to 16 mm^2, as applicable.

The conductor is inserted into a new terminal for the minimum distance prescribed or, where no distance is prescribed, until it just projects from the far side, and in the position most likely to assist the wire to escape.

The clamping screws are then tightened with a torque equal to two-thirds of that shown in the appropriate column of Table 12.

Each conductor is then subjected to a pull of the value, in Newton, shown in Table 13, according to the relevant cross-section of the tested conductor.

The pull is applied without jerks, for 1 min, in the direction of the axis of the conductor space.

When it is necessary, the tested values, for the different cross-sections with the relevant pulling force, shall be clearly indicated in the test report.

Table 13 – Pulling forces

Cross-section of the conductor inserted in the terminal mm^2	**1 up to and including 4**	**Above 4 up to and including 6**	**Above 6 up to and including 10**	**Above 10 up to and including 16**	**Above 16 up to and including 50**
Pull N	50	60	80	90	100

During the test, the conductor shall not move noticeably in the terminal.

9.5.2 The terminals are fitted with copper conductors of the smallest and largest cross-sections specified in Table 8, solid or stranded, whichever is the more unfavourable, and the terminal screws are tightened with a torque equal to two-thirds of that shown in the appropriate column of Table 12.

The terminal screws are then loosened and the part of the conductor which may have been affected by the terminal is inspected.

The conductors shall show no undue damage or severed wires.

NOTE Conductors are considered to be unduly damaged if they show deep or sharp indentations.

During the test, terminals shall not become loose and there shall be no damage, such as breakage of screws or damage to the head slots, threads, washers or stirrups, which will impair the further use of the terminal.

9.5.3 The terminals are fitted with the largest cross-section area specified in Table 8, for stranded and/or flexible copper conductors.

Before insertion in the terminal, the strands of the conductor are suitably reshaped.

The conductor is inserted into the terminal until the conductor reaches the bottom of the terminal or just projects from the far side of the terminal and in the position most likely to permit a strand (or strands) to escape. The clamping screw or nut is then tightened with a torque equal to two-thirds of that shown in the appropriate column of Table 12.

After the test, no strand of the conductor shall have escaped outside the retaining device.

9.6 Verification of protection against electric shock

This requirement is applicable to those parts of AFDDs which are exposed to the operator when mounted as for normal use.

The test is made with the standard test finger shown in Figure 3, on the AFDD mounted as for normal use (see note of 8.3) and fitted with conductors of the smallest and largest cross-sections which may be connected to the AFDD.

The standard test finger shall be so designed that each of the jointed sections can be turned through an angle of 90° with respect to the axis of the finger, in the same direction only.

The standard test finger is applied in every possible bending position of a real finger, an electrical contact indicator being used to show contact with live parts.

It is recommended that a lamp be used for the indication of contact and that the voltage be not less than 40 V. The standard test finger shall not touch live parts.

AFDDs with enclosures or covers of thermoplastic material are subjected to the following additional test, which is carried out at an ambient temperature of 35 °C ± 2 °C, the AFDD being at this temperature.

AFDDs are subjected for 1 min to a force of 75 N, applied through the tip of a straight unjointed test finger of the same dimensions as the standard test finger. This finger is applied to all places where yielding of insulating material could impair the safety of the AFDD, but is not applied to knock-outs.

During this test, enclosures or covers shall not deform to such an extent that live parts can be touched with the unjointed test finger.

Unenclosed AFDDs having parts not intended to be covered by an enclosure are submitted to the test with a metal front panel, and mounted as for normal use.

9.7 Test of dielectric properties

9.7.1 General

AFDDs shall be tested according to the following subclauses.

9.7.2 Resistance to humidity

9.7.2.1 Preparation of the AFDD for test

Parts of the AFDD which can be removed without the aid of a tool are removed and subjected to the humidity treatment with the main part; spring lids are kept open during this treatment.

Inlet openings, if any, are left open; if knock-outs are provided, one of them is opened.

9.7.2.2 Test conditions

The humidity treatment is carried out in a humidity cabinet containing air with a relative humidity equal to 93 % ± 5 %.

The temperature of the air in which the sample is placed is maintained within ± 2 °C of any convenient value *T* between 20 °C and 30 °C.

Before being placed in the humidity cabinet, the sample is brought to a temperature between *T* °C and *T* °C + 4 °C.

9.7.2.3 Test procedure

The sample is kept in the cabinet for 48 h.

NOTE An example for obtaining a relative humidity between 91 % and 95 % consists of placing in the humidity cabinet a saturated solution of sodium sulphate (Na_2SO_4) or potassium nitrate (KNO_3) in water having a sufficiently large surface in contact with the air.

In order to achieve the specified conditions within the cabinet, it is recommended to ensure constant circulation of the air within and to use a cabinet which is thermally insulated.

9.7.2.4 Condition of the AFDD after the test

After this treatment, the sample shall show no damage within the meaning of this standard and shall withstand the tests of 9.7.3, 9.7.4, 9.7.5, 9.7.7 and 9.7.7.2 (if applicable).

9.7.3 Insulation resistance of the main circuit

The AFDD having been treated as specified in 9.7.2 is then removed from the cabinet.

After an interval between 30 min and 60 min following this treatment, the insulation resistance is measured 5 s after application of a d.c. voltage of approximately 500 V, successively as follows:

a) with the AFDD in the open position, between each pair of terminals which are electrically connected together when the AFDD is in the closed position, in turn on each pole;
b) with the AFDD in the closed position, in turn between each pole and the others connected together, electronic components connected between current paths being disconnected for the test;

c) with the AFDD in the closed position, between all poles connected together and the frame, including a metal foil in contact with the outer surface of the internal enclosure of insulating material, if any;
d) between metal parts of the mechanism and the frame;

NOTE Access to the metal part of the mechanism may be specifically provided for this measurement.

e) for AFDDs with a metal enclosure having an internal lining of insulating material, between the frame and a metal foil in contact with the inner surface of the lining of insulating material, including bushings and similar devices.

Measurements a), b) and c) are carried out after having connected all auxiliary circuits to the frame.

The term "frame" includes:

– all accessible metal parts and a metal foil in contact with the surfaces of insulating material which are accessible after installation as for normal use;
– the surface on which the base of the AFDD is mounted, covered, if necessary, with metal foil;
– screws and other devices for fixing the base to its support;
– screws for fixing covers which have to be removed when mounting the AFDD;
– metal parts of operating means referred to in 8.3.

If the AFDD is provided with a terminal intended for the connection of protective conductors, this is connected to the frame.

For the measurements according to b), c), d) and e), the metal foil is applied in such a way that the sealing compound, if any, is effectively tested.

The insulation resistance shall not be less than:

– 2 MΩ for the measurements according to a) and b);
– 5 MΩ for the other measurements.

9.7.4 Dielectric strength of the main circuit

After the AFDD has passed the tests of 9.7.3, the test voltage specified is applied for 1 min between the parts indicated in 9.7.3, electronic components, if any, being disconnected for the test.

The test voltage shall have a practically sinusoidal waveform, and a frequency between 45 Hz and 65 Hz.

The source of the test voltage shall be capable of supplying a short-circuit current of at least 0,2 A.

No overcurrent tripping device of the transformer shall operate when the current in the output circuit is lower than 100 mA.

The values of the test voltage shall be as follows:

– 2 000 V for a) to d) of 9.7.3;
– 2 500 V for e) of 9.7.3.

Initially, no more than half the prescribed voltage is applied, then it is raised to the full value within 5 s.

No flashover or breakdown shall occur during the test.

Glow discharges without drop in voltage are neglected.

9.7.5 Insulation resistance and dielectric strength of auxiliary circuits

a) The measurement of the insulation resistance and the dielectric strength tests for the auxiliary circuits are carried out immediately after the measurement of the insulation resistance and the dielectric strength tests for the main circuit, under the conditions given in b) and c) below.

   Where electronic components connected to the main circuit in normal service are used, the temporary connections for test shall be made so that, during the tests, there is no voltage between the incoming and outgoing sides of the components.

b) The measurements of the insulation resistance are carried out:
   – between the auxiliary circuits connected to each other and to the frame;
   – between each of the parts of the auxiliary circuits which might be isolated from the other parts in normal service and the whole of the other parts connected together, at a voltage of approximately 500 V d.c. after this voltage has been applied for 1 min.

   The insulation resistance shall be not less than 2 MΩ.

c) A substantially sinusoidal voltage at rated frequency is applied for 1 min between the parts listed under b).

The voltage values to be applied are specified in Table 14.

Table 14 – Test voltage of auxiliary circuits

Rated voltage of auxiliary circuits (a.c. or d.c.) V		**Test voltage** V
Greater than	**Up to and including**	
0	30	600
30	50	1 000
50	110	1 500
110	250	2 000
250	500	2 500

At the beginning of the test the voltage shall not exceed half the value specified. It is then increased steadily to the full value in not less than 5 s, but not more than 20 s.

During the test, there shall be no flashover or perforation.

NOTE 1 Discharges which do not correspond to a voltage drop are disregarded.

NOTE 2 In the case of AFDDs in which the auxiliary circuit is not accessible for verification of the requirements given in b), the tests are made on samples specially prepared by the manufacturer or according to the manufacturer’s instructions.

NOTE 3 Auxiliary circuits do not include the control circuit of AFDDs functionally dependent on line voltage.

NOTE 4 Control circuits other than those of secondary circuit of detection transformers and control circuits connected to the main circuit are submitted to the same tests as the auxiliary circuits.

9.7.6 Capability of control circuits connected to the main circuit in respect of withstanding high d.c. voltages due to insulation measurements

The test is carried out on the AFDD fixed on a metal support, in the closed position, with all control circuits connected as in service.

A d.c. voltage source is used with the following characteristics:

– open voltage: 600 V $^{+25}_{0}$ V;

NOTE This value is provisional.

– maximum ripple: 5 %;

where: ripple = 100 × [(maxvalue – meanvalue) / meanvalue]

– short-circuit current: 12 mA $^{+2}_{0}$ mA.

This test voltage is applied for 1 min, in turn between each pole and the other poles connected together to the frame.

After this treatment, the functionality of the AFDD is verified by repeating the test of 9.9.2.4 at the lowest current of Table 1 or 2, as applicable.

9.7.7 Verification of impulse withstand voltages (across clearances and across solid insulation) and of leakage current across open contacts

9.7.7.1 General testing procedure for the impulse withstand voltage tests

The impulses are given by a generator producing positive and negative impulses having a front time of 1,2 μs, and a time to half-value of 50 μs, the tolerances being as follows:

± 5 % for the peak value;

± 30 % for the front time;

± 20 % for the time to half-value.

For each test, five positive impulses and five negative impulses are applied. The interval between consecutive impulses shall be at least 1 s for impulses of the same polarity and shall be at least 10 s for impulses of the opposite polarity.

When performing the impulse voltage test on a complete AFDD, the attenuation or amplification of the test voltage shall be taken into account. It needs to be assured that the required value of the test voltage is applied across the terminals of the equipment under test.

The surge impedance of the test apparatus shall have a nominal value not higher than 500 Ω.

NOTE 1 In 9.7.6.2, for the verification of clearances within the basic insulation, on a complete AFDD, IEC 60664-1 and IEC/TR 60664-2-1 recommend a very low impedance of the generator for the test. For this purpose, a hybrid generator with a virtual impedance of 2 Ω is appropriate if internal components are not disconnected before testing. IEC 60664-1 and IEC/TR 60664-2-1 recommend measuring the correct test voltage directly at the clearance. The shape of the impulses is adjusted with the AFDD under test connected to the impulse generator. For this purpose, appropriate voltage dividers and voltage sensors can be used. It is recommended to disconnect surge protective components before testing.

For AFDDs with incorporated surge arresters that cannot be disconnected, it is recommended to adjust the shape of the impulses without connection of the AFDD to the impulse generator.

Small oscillations in the impulses are allowed, provided that their amplitude near the peak of the impulse is less than 5 % of the peak value.

For oscillations on the first half of the front, amplitudes up to 10 % of the peak value are allowed.

There shall be no disruptive discharge (sparkover, flashover or puncture) during the tests.

NOTE 2 An oscilloscope can be used to observe the impulse voltage in order to detect disruptive discharge.

9.7.7.2 Verification of clearances with the impulse withstand voltage

If the measurement of clearances of items 2 and 4 Table 7 and arrangements given in 9.7.3 b), c) d) and e) show a reduction of the required length, this test applies. This test is carried out immediately after the measurement of the insulation resistance in 9.7.5.

NOTE The measurement of the clearances can be replaced by this test.

The test is carried out on an AFDD fixed on a metal support and being in the closed position.

The test impulse voltage values shall be chosen in Table 15 in accordance with the rated impulse voltage of the AFDD as given in Table 4. These values are corrected for barometric pressure and/or altitude at which the tests are carried out, according to Table 15.

A first series of tests is made applying the impulse voltage between:

– the phase pole(s) and the neutral pole (or path) connected together;
– and the metal support connected to the terminal(s) intended for the protective conductor(s), if any.

A second series of tests is made applying the impulse voltage between:

– the phase pole(s), connected together;
– and the neutral pole (or path) of the AFDD, as applicable.

A third series of tests is made applying the impulse voltage between arrangements given in 9.7.3 b), c), d) and e) and not tested during the two first sequences described here above.

There shall be no disruptive discharge. If, however, only one such disruptive discharge occurs, ten additional impulses having the same polarity as that which caused the disruptive discharge are applied, the connections being the same as those with which the failure occurred.

No further disruptive discharge shall occur.

Table 15 – Test voltage for verification of impulse withstand voltage

Rated impulse withstand voltage U_{imp} kV	**Test voltages at corresponding altitude** $U_{1,2/50}$ **a.c. peak** kV				
	Sea level	**200 m**	**500 m**	**1 000 m**	**2 000 m**
[C) *text deleted* (C]					
4	4,9	4,8	4,7	4,4	4,0

9.7.7.3 Verification of leakage currents across open contacts (suitability for isolation)

NOTE This verification does not apply to AFDDs classified according to 4.1.2 (because it would be redundant) and 4.1.3 (see Annex D).

Each pole of the AFDD being in the open position is supplied at a voltage 1,1 times its rated operational voltage.

The leakage current flowing across the open contacts is measured after the tests of 9.10 and 9.11 and shall not exceed 2 mA.

9.7.7.4 Verification of resistance of the insulation of open contacts and basic insulation against an impulse voltage in normal conditions

9.7.7.4.1 General

These tests are not preceded by the humidity treatment described in 9.7.2.

The tests of 9.7.7.4, as stated in requirements 8.2.3, shall be carried out before 9.7.2 on 3 samples of test sequence B of Annex A.

The test impulse voltage values shall be chosen from Table 16, in accordance with the rated voltage of the installation for which the AFDD is intended to be used as given in Table 4. These values are corrected for barometric pressure and/or altitude at which the tests are carried out, according to Table 16.

Table 16 – Test voltage for verifying the suitability for isolation, referred to the rated impulse withstand voltage of the AFDD and the altitude where the test is carried out

Nominal voltage of the installation V	Test voltages at corresponding altitude $U_{1,2/50}$ a.c. peak kV				
Single-phase system	Sea level	200 m	500 m	1 000 m	2 000 m
with mid-point earthed [C) *text deleted* (C] [a]	3,5	3,5	3,4	3,2	3.0
Single phase system [C) *text deleted* (C] 240 [b]	6,2	6,0	5,8	5,6	5,0
Three-phase systems 230/400	6,2	6,0	5,8	5,6	5,0

[a] For installation practice in Japan.

[b] For installation practice in North American countries.

9.7.7.4.2 AFDDs in opened position

The test is carried out on an AFDD fixed on a metal support as in normal use.

The impulses are applied between:

– the line terminals connected together; and
– the load terminals connected together with the contacts in the open position.

There shall be no disruptive discharges during the test.

9.7.7.4.3 AFDDs in closed position,

9.7.7.4.3.1 Impulse voltage withstand test

The series of tests is carried out on an AFDD fixed on a metal support, wired as in normal use and being in the closed position.

All components bridging the basic insulation have to be disconnected.

A first series of tests is made, the impulses being applied between:

– the phase pole(s) and the neutral pole (or path) connected together; and
– the metal support connected to the terminal(s) intended for the protective conductor(s), if any.

A second series of tests is made, the impulses being applied between:

– the phase pole(s), connected together;
– and the neutral pole (or path) of the AFDD.

There shall be no disruptive discharge. If, however, only one such disruptive discharge occurs, ten additional impulses having the same polarity as that which caused the disruptive discharge are applied, the connections being the same as those with which the failure occurred.

No further disruptive discharge shall occur.

9.7.7.5 Verification of the behaviour of components bridging the basic insulation

Afterward, it is necessary to ensure that components, bridging the basic insulation and having been disconnected during the impulse voltage test for testing the basic insulation, would not impair the behaviour or the safety of the basic insulation of the AFDD during normal use.

A new AFDD sample is tested in order to check that components bridging the basic insulation would not reduce safety with respect to short term temporary overvoltages.

The test voltage has a frequency of 50/60 Hz. In accordance with IEC 60364-4-44:2007, Table 44.A2 and with IEC 60664-1:2007, the r.m.s. value of the test voltage for the basic insulation is 1 200 V + U_n where U_n is the nominal voltage value between line and neutral.

NOTE 1 As an example, for an AFDD having a rated voltage of U_n = 250 V, the value of the a.c. test voltage for basic insulation is 1 200 V + 250 V, thus the r.m.s. test voltage is 1 450 V.

The voltage is applied during 5 s between:

– the phase pole(s) and the neutral pole (or path) connected together; and
– the metal support connected to the terminal(s) intended for the protective conductor(s), if any.

The AFDD is then visually inspected; no component bridging the basic insulation should show a visible alteration.

NOTE 2 It is accepted to replace a fuse before connecting the AFDD to the mains. If a fuse protecting a surge arrester has blown, it is accepted to replace the surge arrester too.

Then, the AFDD is connected to the mains in accordance with the manufacturer's instructions. The functionality of the AFDD is verified by the test of 9.9.2.4 at the lowest current of Table 1 or 2, as applicable.

This test is not applied to devices with solid neutral.

9.8 Test of temperature-rise

9.8.1 Ambient air temperature

The ambient air temperature shall be measured during the last quarter of the test period by means of at least two thermometers or thermocouples symmetrically distributed around the AFDD at about half its height and at a distance of about 1 m from the AFDD.

The thermometers or thermocouples shall be protected against draughts and radiant heat.

Care should be taken to avoid errors due to sudden temperature changes.

9.8.2 Test procedure

A current equal to I_n, at rated voltage, is passed simultaneously through all the poles of the AFDD for a period of time sufficient for the temperature-rise to reach the steady state value. In practice, this condition is reached when the variation of the temperature-rise does not exceed 1 K/h.

The test is first made by passing the specified current through the two poles.

During these tests the temperature-rise shall not exceed the values shown in Table 9.

9.8.3 Measurement of the temperature of parts

The temperature of the different parts referred to in Table 9 shall be measured by means of fine wire thermocouples or by equivalent means at the nearest accessible position to the hottest spot.

Good heat conductivity between the thermocouple and the surface of the part under test shall be ensured.

9.8.4 Temperature-rise of a part

The temperature-rise of a part is the difference between the temperature of this part measured in accordance with 9.8.3 and the ambient air temperature measured in accordance with 9.8.1.

9.9 Verification of the operating characteristics

9.9.1 General

The AFDD is installed as for normal use.

The test circuit shall be of negligible inductance.

For an AFDD having more than one rated voltage (e.g. [C) *text deleted* (C] 240 V), the tests shall be carried out at the lowest and highest voltage.

For an AFDD having more than one rated frequency, the tests shall be carried out at the lowest and highest frequency.

For the tests of 9.9.2.2 to 9.9.2.5, the cable specimen shall be replaced after each measurement.

9.9.2 Series arc fault tests

9.9.2.1 General

A representative AFDD shall clear the arcing fault in the time specified in Table 1 or 2 for the arc current level being tested. AFDDs shall be tested up to their rated current.

The tests of 9.9.2.2 to 9.9.2.5 shall be conducted by connecting a cable specimen (prepared in accordance with 9.9.2.6) in series with the AFDD according to Figure 4.

The adjustment of the test currents in the cable specimen without arcing is achieved by application of the rated voltage reduced by 50 V to take into account the value of the arc voltage during the test.

The tests shall be conducted at the rated voltage of the AFDD.

The break time is measured at each arc current level and the measured value shall not exceed the times specified in Table 1 or 2.

9.9.2.2 Verification of correct operation in case of sudden appearance of series arc in the circuit

The test switches S1, S3, S4 and the AFDD being in closed position and test current being stabilized, the test arc current is adjusted from lowest arc current value up to the rated current of the AFDD by the resistive load. The test switch S2 is then opened.

Test switch S4 is then suddenly opened to insert the prepared cable specimen in series with the load. The break time is measured three times. No measurement shall exceed the limit value in Table 1 or 2 as applicable.

9.9.2.3 Verification of correct operation in case of inserting load a with a series arc fault

Test switches S3 and S4 being in the open position and test switches S1, and the AFDD being in closed position, test arc current is adjusted by the resistive load to the lowest arc current value in Table 1 or 2 as applicable. The test switch S2 is then opened.

The test switch S1 and the AFDD being in closed position, the test switch S4 and S3 being in the open position, the test switch S3 is suddenly closed to supply the load with a series arc fault.

The break time is measured three times. No measurement shall exceed the limiting value in Table 1 or 2 as applicable.

The test is then repeated for the rated current value of the AFDD.

9.9.2.4 Verification of the correct operation in case of closing on series arc fault

Test switches S1, S3 and the AFDD being in closed position, test arc current is adjusted by the resistive load to the lowest arc current value in Table 1 or 2 as applicable. After test switch S1 is opened, the test switch S2 is opened.

Test switches S1 and S4 being in the open position, the test switch S1 is suddenly closed to supply the AFDD and the load with a series arc fault.

The break time is measured three times. No measurement shall exceed the limiting value in Table 1 or 2 as applicable.

The test is then repeated for the rated current value of the AFDD.

9.9.2.5 Test at the temperature limits

The AFDD shall perform the tests specified in 9.9.2.2 under the following conditions successively:

– ambient temperature: –5 °C, only for the lowest value of Table 1 or 2, as applicable and with a voltage equal to 0,85 times the rated voltage;
– ambient temperature: 40 °C, the AFDD having been previously loaded with the rated current, until it attains thermal steady-state conditions, only for the rated current value of the AFDD and with a voltage equal to 1,1 times the rated voltage. After the steady state has been attained, the tripping tests shall be performed.

9.9.2.6 Preparation of the cable specimens

Two conductors with a cross section area of 1,5 mm^2 (or AWG 16) and closely tied together (e.g. with adhesive tape or equivalent) are to be prepared as follows (see Figure 36).

A cable with parallel conductors shall be used for this test. One of the following cables should be used for testing the AFDD since they provide similar results.

NOTE In case these cables cannot be sourced in a country, an assessment of the results obtained with the cables used in this country has to be done.

- The flexible PVC cable classified IEC 60227 IEC41, according to IEC 60227-1 Annex A, with two conductors are appropriate for this test.
- Specimen cable may also be prepared with two single PVC flexible conductors classified IEC 60227 IEC02 which are kept together with PVC insulation tape.
- The cables SPT2 and H05VV-F with two conductors are particularly appropriate for this test. A self-made cable with single flexible conductors H05V which are kept together with PVC insulation tape can be also used for the test.

a) The material and geometry of the specimen shall be appropriate to perform a sufficient carbonization between the conductors and initiate arcing by applying the rated voltage.

b) The cable specimens are to be cut to a minimum length of 200 mm (or 8 inches) and the individual wires separated at each end of the cable specimen for 25 mm (or 1 inch).

c) The insulation across both wires is to be slit 50 mm (or 2 inches) from one end to a depth to expose the conductors without severing any strands.

d) The slit in the insulation is to be wrapped with a double layer of electrical grade black PVC tape and overwrapped with a double layer of fiberglass tape.

e) The conductors are to be stripped at the end farthest from the slit approximately 12 mm (or 0,5 in) for connection to the test circuits.

The cable specimen shall be then conditioned to create a carbonized conductive path across insulation between the two cable conductors:

f) The cable specimen is to be connected to a circuit providing 30 mA short circuit current and an open circuit voltage of at least 7 kV. The circuit is to be energized for approximately 10 s or until the smoking stops.

g) The cable specimen is to be connected to a circuit providing 300 mA short circuit at a voltage of at least 2 kV or sufficient to cause the current to flow. The circuit is to be energized for approximately one minute or until the smoking stops.

The carbonized path shall be considered complete if a 100 W/120 V incandescent lamp starts to glow at 120 V or a resistance having an equivalent resistance value (with 100 W/120 V incandescent lamp) in series with the path draws 0,3 A at 120 V or a 100 W/230 V incandescent lamp starts to glow at 230 V or a resistance having an equivalent resistance value (with 100 W/230 V incandescent lamp).

It shall be permissible to modify the test circuit such that current does not flow through the device under test during the high voltage conditioning cycle.

9.9.2.7 Arc generator

An arc generator test is an apparatus consisting of a stationary electrode and a moving electrode as shown in Figure 5.

NOTE The value *a* in Figure 5 is not very important it can be around 17 mm ± 7,5 mm (0,7 in ± 0,3 in) .

One electrode shall consist of a 6 mm ± 0,5 mm diameter carbon-graphite rod and the other electrode shall be a copper rod. The arcing end of one or both electrodes may be pointed as shown in Figure 5.

It may be necessary to clean and sharpen the rods in order to have repeatable arc conditions.

When inserted in a circuit, the separation of two electrodes at a convenient distance shall generate a consistent arc between two electrodes.

When using the arc generator, the AFDD shall clear the arcing fault in less than 2,5 times the break time in Table 1 or 2.

NOTE The arc energy during arcing with the carbonized path is in the range of 2,5 times the arc energy provided by the arc generator.

9.9.3 Parallel arc fault tests

9.9.3.1 Verification of correct operation in case of parallel arc with limited current

An AFDD shall clear the arcing fault if the number of half-cycles of arcing mentioned in Table 3 occurs within a period of 0,5 s. For the purposes of these requirements, an arcing half-cycle is considered to be all of the current traces occurring within a period of 10 ms for a device rated 50 Hz and 8,3 ms for a device rated 60 Hz. Within that time period there may be current flow for some but not all of the time.

Prior to and following each period of current flow, there may be a period with no current or very reduced current. Very reduced current is considered to be current with amplitude less than 5 % of the available current or current that continues for not more than 5 % of the duration of half-cycle. This may last for either a portion of a half cycle or for several half cycles. A complete sinusoidal half cycle of current flow is not considered to be an arcing half cycle.

The tests shall be performed at fault current levels of 75 A and 100 A.

The test is performed according to Figure 6.

The cable specimen is prepared in the same way as in 9.9.2.6.

The test current is adjusted to 75 A with line impedance Z in the circuit, the test switches S1, S2, S3 and S4 being in closed position. The switches S2, S3 and S4 are then opened, the AFDD and the test switch S1 are closed. The test switch S3 is suddenly closed.

The AFDD shall open according to Table 3.

The test is then repeated with a current adjusted to 100 A with the impedance Z. The AFDD shall open according to Table 3.

The AFDD shall clear the arcing fault if the number of half-cycles of arcing mentioned in Table 3 occur within a period of 0,5 s. The 0,5 s period is considered to begin with the first arcing half cycle.

The test is to be repeated with a new cable specimen if the arcing is of a shorter duration than the number of half-cycles mentioned in Table 3 and the AFDD does not trip.

9.9.3.2 Verification of correct operation in case of parallel arc cable cutting test

An AFDD shall clear the arcing fault if the number of half-cycles of arcing mentioned in Table 3 occurs within a period of 0,5 s. For the purposes of these requirements, an arcing half-cycle is considered to be all of the current traces occurring within a period of 10 ms for a device rated 50 Hz and 8,3 ms for a device rated 60 Hz. Within that time period there may be current flow for some but not all of the time.

Prior to and following each period of current flow, there may be a period with no current or very reduced current. Very reduced current is considered to be current with amplitude less than 5 % of the available current or current that continues for not more than 5 % of the duration of half-cycle. This may last for either a portion of a half cycle or for several half cycles. A complete sinusoidal half cycle of current flow is not considered to be an arcing half cycle.

The test is performed according to Figure 7.

The test apparatus T for the cable cutting test shall be as shown in Figure 8 or equivalent.

The steel blade shall be [C) *text deleted* (C] 3 mm thick (nominal) for a 230 V AFDD, with approximate dimensions of 32 mm by 140 mm. The blade may be replaced as necessary. The blade may be sharpened if agreeable to all concerned. This shall be attached to a lever arm to maintain a cutting angle to produce the effect. Using the test apparatus shown in Figure 8, or equivalent, the blade is to be positioned so that solid contact is made with one conductor and arcing contact is made with the second conductor.

The conductor samples to be tested shall be two conductors used in the country and closely tied together (e.g. with adhesive tape) and with cross sectional area according to Table 11. The samples shall be a maximum of 1,2 m long and shall be positioned below the blade as shown in Figure 8.

NOTE The cables SPT2 and H05VV-F are particularly appropriate for this test.

The tests shall be conducted at rated voltage of the AFDD and at test arc current of Table 3. The test arc current shall be adjusted with the impedance Z and test switches S1, S2, S3 and S4 being in the closed position. The AFDD shall be tested with three wire samples at each current level. Each wire sample shall only be used for one test.

The cutting edge of the lever arm (the length of the blade edge to be in contact with the representative conductors) is to be anywhere along the length of the cutting edge of the blade. With test switches S1 and S3 being in the closed position, a slow steady vertically direct force shall be applied to the lever arm so as to allow the blade to cut through the insulation of the conductor specimen under test. The blade is to make solid contact with one conductor and then point contact with the other conductor.

The AFDD shall clear the arcing fault if the number of half-cycles of arcing mentioned in Table 3 occur within a period of 0,5 s.

The test is to be repeated with a new cable specimen if the arcing is of a shorter duration than the number of half-cycles mentioned in Table 3 and the AFDD does not trip.

9.9.3.3 Verification of correct operation in case of earth arc fault

The test of 9.9.3.1 is repeated at 5 A and 75 A, but in a way to produce an arc to ground.

The testing arrangement is described in Figure 9.

The AFDD shall open according to Table 1 or 2 for 5 A and according to Table 3 for 75 A.

The AFDD shall clear the arcing fault if the number of half-cycles of arcing mentioned in Table 3 occur within a period of 0,5 s. The 0,5 s period is considered to begin with the first arcing half cycle.

The test is to be repeated with a new cable specimen if the arcing is of a shorter duration than the number of half-cycles mentioned in Table 3 and the AFDD does not trip.

9.9.4 Masking test, verification of correct operation

9.9.4.1 General

The correct operation of the AFDD shall be checked in different inhibition configurations. These inhibition tests are made based on test method 9.9.2.2. Either an arc generator or carbonized cable specimen can be used to generate arc fault, as declared by the manufacturer.

9.9.4.2 Masking test with inhibition loads

A first series of tests with no inhibition load is performed. The AFDD and arc generator or cable specimen are connected in the circuit according to Figure 10 with current limited and adjusted by a resistive load. S1 is opened.

Test voltage shall be the rated voltage of the AFDD. Each AFDD shall be tested three times at 2,5 A for 230 V rated voltage AFDD [C) *text deleted* (C].

A second series of tests are then applied with inhibition loads, using the same resistive load. The AFDD, the resistive load, if any, and arc fault tester are connected in each of configuration shown in Figure 11.

The AFDD shall be tested with each of the following masking loads:

a) A vacuum cleaner, rated at 5 A to 7 A for a 230 V rated voltage AFDD [C) *text deleted* (C], full load having a universal motor shall be started and run;
b) An electronic switching mode power supply (or power supplies), having a total load current of at least 2,5 A for a 230 V rated voltage AFDD [C) *text deleted* (C], with a minimum total harmonic distortion (THD) of 100 %, and individual minimum current harmonics of 75 % at the 3rd , 50 % at the 5th, and 25 % at the 7th. The power supply (or power supplies) shall be turned on;
c) A capacitor start (air compressor type) motor, with a peak inrush current of 65 A ± 10 % for a 230 V rated voltage AFDD [C) *text deleted* (C], is to be started under load (compressor operating without any air pressure in the air tank) and operated. For 230 V rated voltage AFDD, a 2,2 kW capacitor start (air compressor type) motor is to be used;
d) [C) *text deleted* (C]

   For AFDD with rated voltage of 230 V an electronic lamp dimmer (thyristor type) 600 W with a filtering coil controlling a 600 W tungsten load.

   NOTE In case incandescent tungsten bulbs cannot be found, they can be replaced by a resistive load with the same power.

   The dimmer is to be turned on with the dimmer preset at full on, conduction angles of 60°, 90°, 120°, and at the minimum setting that causes the lamps to ignite;
e) Two 40 W fluorescent lamps plus an additional 5 A resistive load;
f) 12 V halogen lamps powered with electronic transformer with a total power of at least 300 W plus an additional 5 A resistive load;
g) Electric hand tool such as a drill with at least 600 W power.

The arc fault tester in Figure 11 shall be either arc generator defined in 9.9.2.7 or the carbonized cable specimen as described in 9.9.2.6.

The AFDD shall clear the arcing fault as specified in Table 1 or 2 when using carbonised cable specimen and 2,5 times the break time in Table 1 or 2 when using the arc generator.

When applying configuration A or C of Figure 11 this test is not required for conditions in which the masking load current, when measured before the arc is placed in the circuit, is lower than ⓒ *text deleted* ⓒ 2,5 A r.m.s. for a 230 V rated voltage AFDD.

Test voltage shall be the rated voltage of the AFDD. Each AFDD shall be tested three times for each load configuration.

For the first and second series of tests with arc generator, the electrodes shall first touch each other, the circuit shall be closed. The electrodes then shall be separated slowly using the lateral adjustment until arcing occurs.

9.9.4.3 Masking test with EMI filter

The AFDD shall be installed in the circuit shown in Figure 11 configuration B. An arc test shall be introduced with a 2,5 A load for a 230 V rated voltage AFDD ⓒ *text deleted* ⓒ.

The AFDD shall clear the arcing fault as specified in Table 1 or 2 when using carbonised cable specimens and 2,5 times the break time in Table 1 or 2 when using the arc generator.

NOTE The type of cables mentioned in 9.9.2.6 can be used for this masking test

a) Two EMI filters of 0,22 μF shall be installed. One filter shall be installed at one end of two resistive loads of 15 m (or 50 feet) in length and 2,5 mm^2 (or 12 AWG) in diameter. Each filter shall be on the end of approximately 2,0 m (or 6 feet) in length and of 1,5 mm^2 (or 16 AWG) in diameter. The arcing shall be initiated as shown in Figure 12.
b) An EMI filter as described in Figure 14 shall be installed at the end of 15 m (or 50 feet), in length and 2,5 mm^2 (or 12 AWG) in diameter. The filter shall be on the end of 2,0 m (or 6 feet) in length and 1,5 mm^2 (or 16 AWG) in diameter flexible cable. The AFDD and the arcing shall be located as shown in Figure 13.

9.9.4.4 Masking test with line impedance

The AFDD shall be installed as intended on a branch circuit, and under the following conditions of line impedance, the AFDD shall operate in accordance with the break time specified in Table 1 or 2 when using carbonised cable specimen and 2,5 times the break time in Table 1 or 2 when using arc generator.

A branch circuit consisting of 30 m (or 100 feet) of 2,5 mm^2 (or 12 AWG) armoured cable, 2-conductor with steel armour. The arcing fault shall occur in series with a ⓒ *text deleted* ⓒ 2,5 A load for a 230 V rated voltage AFDD (see Figure 15).

9.9.5 Unwanted tripping test

9.9.5.1 General

The AFDD shall perform the tests in 9.9.5.2, 9.9.5.3, and 9.9.5.4 in order to ensure that the device will not trip in situations where it should not trip.

9.9.5.2 Cross talk test

Two branch circuits installed as close as possible in the same panel are supplied with the same phase and neutral as described in Figure 16, one with AFDD protection and one without AFDD protection (but with conventional overcurrent protection). Both circuits are connected to a resistive load drawing a current equal to 5 A.

An arc is initiated with an arc generator in the circuit without the AFDD, according to the test conditions of 9.9.2.4. The arc shall have a duration equal to 0,5 s for 230 V circuit or a duration equal to 1 s for 120 V circuit, the AFDD shall not trip.

9.9.5.3 Burst test

This test is already covered in 9.21.

9.9.5.4 Test with various disturbing loads

The AFDD is tested as in 9.9.4.1 but without arc generator or cable specimen shown in Figure 10 (S1 being closed).

The AFDD shall be tested with each of the following loads:

a) A vacuum cleaner, rated at 5 A to 7 A for a 230 V rated voltage AFDD [C〉 *text deleted* 〈C], full load having a universal motor shall be started and run;

b) An electronic switching mode power supply (or power supplies), having a total load current of at least 2,5 A for a 230 V rated voltage AFDD [C〉 *text deleted* 〈C], with a minimum total harmonic distortion (THD) of 100 %, and individual minimum current harmonics of 75 % at the 3rd, 50 % at the 5th, and 25 % at the 7th. The power supply (or power supplies) shall be turned on;

c) A capacitor start (air compressor type) motor, with a peak inrush current [C〉 *text deleted* 〈C], is to be started under load (compressor operating without any air pressure in the air tank) and operated. For 230 V rated voltage AFDD, a 2,2 kW capacitor start (air compressor type) motor is to be used;

d) [C〉 *text deleted* 〈C]

   For AFDD with rated voltage of 230 V an electronic lamp dimmer (thyristor type) 600 W with a filtering coil controlling a 600 W tungsten load.

   NOTE In case incandescent tungsten bulbs cannot be found, they can be replaced by a resistive load with the same power.

   The dimmer is to be turned on with the dimmer preset at full on, conduction angles of 60°, 90°, 120°, and at the minimum setting that causes the lamps to ignite;

e) Two 40 W fluorescent lamps plus an additional 5 A resistive load;

f) 12 V halogen lamps powered with electronic transformer with a total power of at least 300 W plus an additional 5 A resistive load;

g) Electric hand tool such as a drill with at least 600 W power.

The electric hand tool g) shall be previously conditioned by 24 h operation.

The loads are energized during at least 5 s. Five Start/Stop operations shall be performed.

The AFDD shall not trip.

9.10 Verification of mechanical and electrical endurance

9.10.1 General test conditions

The AFDD is fixed to a metal support.

AFDDs classified according to 4.1.3 shall be assembled with the declared protective device.

The test is made at rated voltage, at a current adjusted to the rated current by means of resistors and reactors in series, connected to the load terminals.

If air-core reactors are used, a resistor taking approximately 0,6 % of the current through the reactors is connected in parallel with each reactor.

If iron-core reactors are used, the iron power losses of these reactors shall not appreciably influence the recovery voltage.

The current shall have substantially sine-wave form and the power factor shall be between 0,85 and 0,9.

The AFDD is connected to the circuit with conductors of the sizes indicated in Table 11.

9.10.2 Test procedure

AFDDs are subjected to 2 000 operating cycles, each operating cycle consisting of a closing operation followed by an opening operation.

The AFDD shall be operated as for normal use.

The opening operations shall be effected as follows:

- for the first 1 000 operations using manual operating means;
- 500 operations using test device, if any;
- 500, or in the case of no test device 1000, operating cycles by providing arcs. The tripping means and conditions will be decided between the manufacturer and the laboratory.

In addition, the AFDD is further subjected without load, using the manual operating means, to

- 2 000 operating cycles for AFDDs having $I_n \leq 25$ A;
- 1 000 operating cycles for AFDDs having $I_n > 25$ A.

The operating frequency shall be

- four operating cycles per minute for AFDDs of $I_n \leq 25$ A, the ON period having a duration of 1,5 s to 2 s;
- two operating cycles per minute for AFDDs of $I_n > 25$ A, the ON period having a duration of 1,5 s to 2 s.

9.10.3 Condition of the AFDD after test

Following the test of 9.10.2, the AFDD shall not show:

- undue wear;
- damage of the enclosure permitting access to live parts by the standard test finger;
- loosening of electrical or mechanical connections;
- seepage of the sealing compound, if any.

Afterward the functionality of the AFDD is verified by repeating the test of 9.9.2.4 at the lowest current of Table 1 or 2 and at the AFDD rated current, as applicable, without measurement of the break time.

The AFDD shall then perform satisfactorily the dielectric strength test in 9.7.4 for 1 min but at a voltage of 900 V without previous humidity treatment.

9.11 Verification of the behaviour of the AFDD under short-circuit conditions

9.11.1 General

AFDDs classified according to 4.1.1 shall be tested according to 9.11.2.

AFDDs classified according to 4.1.2 and 4.1.3 (according to Annex D depending on the assembled protection device) are tested according to IEC 60898, IEC 61008-1, IEC 61009-1, or IEC 62423, as applicable.

Afterward, the functionality of the AFDD is verified by repeating the test of 9.9.2.4 at 1,25 times the lowest current of Table 1 or 2, as applicable, without measurement of the break time.

9.11.2 Short-circuit tests for AFDDs according to 4.1.1

9.11.2.1 General

The various tests to verify the behaviour of the AFDD according to 4.1.1 under short-circuit conditions are shown in Table 17.

Table 17 – Tests to be made to verify the behaviour of AFDDs under short-circuit conditions

Verification of	Subclause
Rated making and breaking capacity I_m	9.11.2.3
One pole making and breaking capacity I_{m1} and suitability for IT systems	9.11.2.4
Coordination at rated conditional short-circuit current I_{nc}	9.11.2.5 a)
Coordination at rated making and breaking capacity I_m	9.11.2.5 b)
Coordination at rated conditional short-circuit current for one pole I_{nc1}	9.11.2.5 c)

9.11.2.2 General conditions for test

The conditions of 9.11.2 are applicable to any test intended to verify the behaviour of AFDDs under short-circuit conditions.

a) Test circuit

Figure 19, Figure 20 and Figure 21 give diagrams of the circuits to be used for the tests concerning:

– a single-pole AFDD with two current paths;

– a two-pole AFDD.

The supply S feeds a circuit including impedance Z, the declared protective device, as applicable, the AFDD under test (D), and the additional impedance Z_1 and/or Z_2, as applicable.

The values of the resistors and reactors of the test circuit shall be adjusted to satisfy the specified test conditions.

The reactors L shall be preferably air-cored. They shall always be connected in series with the resistors R and their value shall be obtained by series coupling of individual reactors; parallel connecting of reactors is possible when these reactors have practically the same time-constant.

Since the transient recovery voltage characteristics of test circuits including large air-cored reactors are not representative of normal service conditions, the air-cored reactor in any phase shall be shunted by a resistor r taking approximately 0,6 % of the current through the reactor, (see Figure 21). This resistor may be omitted if agreed by manufacturer

In each test circuit the impedance Z is inserted between the supply source S and the AFDD.

The declared protective device, or the equivalent impedance (see 9.11.2.3 a) and 9.11.2.4 a)), is inserted between the impedance Z and the AFDD.

The additional impedance Z_1, if used, shall be inserted on the load side of the AFDD.

For the tests in 9.11.2.5 a) and c), the AFDD shall be connected with cables having a length of 0,75 m per pole and the maximum cross-section corresponding to the rated current according to Table 8 of this standard.

It is recommended that 0,5 m be connected on the supply side and 0,25 m on the load side of the AFDD.

The diagram of the test circuit shall be given in the test report. It shall be in accordance with the relevant figure.

There shall be one and only one point of the test circuit which is directly earthed; this may be the short-circuit link of the test circuit or the neutral point of the supply or any other convenient point. The method of earthing shall be stated in the test report.

Z_2, suitably calibrated, is an impedance used to obtain one of the following currents:

– the rated residual making and breaking current I_{m1};

– the rated conditional residual short-circuit current I_{nc1}.

S_1 is an auxiliary switch.

For the purpose of verifying the minimum I^2t and I_p values to be withstood by the AFDD as given in Table 18, tests have to be performed. The declared overcurrent protective device shall be used in the tests.

For the purpose of this test, verification of the declared overcurrent protective device (I^2t and I_p) is made prior to testing, the AFDD being replaced by a temporary connection having a negligible impedance.

The minimum values of let-through energy I^2t and peak current I_p, based on an electrical angle of 45°, are given in Table 18.

Without an agreement of the manufacturer, these values shall not be higher than 1,1 times the values given in Table 18.

Table 18 – Minimum values of I^2t and I_p

		I_n A					
I_{nc} and I_{nc1} A		**≤ 16**	**≤ 20**	**≤ 25**	**≤ 32**	**≤ 40**	**≤ 63**
500	I_p (kA)	0,45	0,47	0,5	0,57		
	I^2t (kA²s)	0,4	0,45	0,53	0,68		
1 000	I_p (kA)	0,65	0,75	0,9	1,18		
	I^2t (kA²s)	0,50	0,9	1,5	2,7		
1 500	I_p (kA)	1,02	1,1	1,25	1,5	1,9	2,1
	I^2t (kA²s)	1	1,5	2,4	4,1	9,75	22
3 000	I_p (kA)	1,1	1,2	1,4	1,85	2,35	3,3
	I^2t (kA²s)	1,2	1,8	2,7	4,5	8,7	22,5
4 500	I_p (kA)	1,15	1,3	1,5	2,05	2,7	3,9
	I^2t (kA²s)	1,45	2,1	3,1	5,0	9,7	28
6 000	I_p (kA)	1,3	1,4	1,7	2,3	3	4,05
	I^2t (kA²s)	1,6	2,4	3,7	6,0	11,5	25
10 000	I_p (kA)	1,45	1,8	2,2	2,6	3,4	4,3
	I^2t (kA²s)	1,9	2,7	4	6,5	12	24

NOTE 1 At the request of the manufacturer, higher values of I^2t and I_p can be used.

For intermediate values of short-circuit test currents, the next higher short-circuit current shall apply.

The verification of the minimum I^2t and I_p values is not needed if the manufacturer has stated for AFDDs values higher than the minimum ones in which case the stated values shall be verified.

For coordination with circuit-breakers, tests with this combination are necessary.

All the conductive parts of the AFDD normally earthed in service, including the metal support on which the AFDD is mounted or any metal enclosure (see 9.11.2.2 f)), shall be connected to the neutral point of the supply or to a substantially non-inductive artificial neutral permitting a prospective fault current of at least 100 A.

This connection shall include a copper wire F of 0,1 mm diameter and not less than 50 mm in length for the detection of the fault current and, if necessary, a resistor R_2 limiting the value of the prospective fault current to about 100 A.

The voltage sensors are connected:

– across the terminals of the pole, for single-pole AFDDs;
– across the supply terminals, for multipole AFDDs.

Unless otherwise stated in the test report, the resistance of the measuring circuits shall be at least 100 Ω per volt of the power frequency recovery voltage.

AFDDs are supplied on the line side with the rated voltage (or, if relevant, with a voltage having the lower value of its range of rated voltages).

b) Tolerances on test quantities

All the tests concerning the verification of rated making and breaking capacity and of the correct coordination between AFDDs and declared protective devices shall be performed at values of influencing quantities and factors as stated by the manufacturer in accordance with Table 6 of this standard, unless otherwise specified.

The tests are considered as valid if the quantities as recorded in the test report are within the following tolerances for the specified values:

– Current: $^{+5}_{0}$ %;
– Frequency: see 9.2 of this standard;
– Power factor: $^{0}_{-0,05}$;
– Voltage: (including recovery voltage): ± 5 %.

c) Power factor of the test circuit

The power factor of each phase of the test circuit shall be determined according to a recognized method which shall be stated in the test report.

Two examples are given in Annex IA.

The power factor of a polyphase circuit is considered as the mean value of the power factor of each phase.

The power factor shall be in accordance with Table 19.

Table 19 – Power factors for short-circuit tests

Short-circuit current (I_c) A	Power factor
$I_c \leq$ 500	0,95 to 1,00
500 < $I_c \leq$ 1 500	0,93 to 0,98
1 500 < $I_c \leq$ 3 000	0,85 to 0,90
3 000 < $I_c \leq$ 4 500	0,75 to 0,80
4 500 < $I_c \leq$ 6 000	0,65 to 0,70
6 000 < $I_c \leq$ 10 000	0,45 to 0,50
10 000 < $I_c \leq$ 25 000	0,20 to 0,25

d) Power frequency recovery voltage

The value of the power frequency recovery voltage shall be equal to a value corresponding to 105 % of the rated voltage of the AFDD under test.

NOTE 2 The value of 105 % of the rated voltage is deemed to cover the effects of the variations of the system voltage under normal service conditions. The upper limit value may be increased with the approval of the manufacturer.

After each arc extinction, the power frequency recovery voltage shall be maintained for not less than 0,1 s.

e) Calibration of the test circuit

The AFDD and the declared protective device, if any, are replaced by temporary connections G_1 having a negligible impedance compared with that of the test circuit.

For the test in 9.11.2.5 a) the load terminals of the AFDD being short-circuited by means of the connections G_2 of negligible impedance, the impedance Z is adjusted so as to obtain, at the test voltage, a current equal to the rated conditional short-circuit current at the prescribed power-factor; the test circuit is energized simultaneously in all poles and the current curve is recorded with the current sensor O_1.

Moreover, for the tests in 9.11.2.3, 9.11.2.4, 9.11.2.5 b) and c) the additional impedances Z_1 and/or Z_2 are used, as necessary, so as to obtain the required test current values (I_m, I_{m1} and I_{c1} respectively).

f) Condition of the AFDD for test

AFDDs shall be tested in free air according to f1) of this subclause, unless they are designed for use only in enclosures specified by the manufacturer or are intended for use in individual enclosures only, in which cases they shall be tested according to f2) of this subclause or, with the agreement of the manufacturer, according to f1) of this subclause.

NOTE 3 An individual enclosure is an enclosure designed to accept one device only.

The AFDD shall be operated simulating as closely as possible the normal operation.

1) Test in free air

The AFDD under test is mounted as shown in Figure C.1 of Annex C.

The polyethylene sheet and the barrier of insulating material specified in Annex C are placed as shown in Figure C.1 for opening (O) operations only.

The grid(s) specified in Annex C shall be so positioned that the bulk of the emitted ionized gases passes through the grid(s). The grid(s) shall be placed in the most unfavourable position(s).

NOTE 4 If the position of the vents is not obvious, or if there are no vents, the appropriate information is provided by the manufacturer.

The grid circuit(s) (see Figure C.3 of Annex C) shall be connected to the points B and C according to the test circuit diagrams of Figure 19 and Figure 20.

The resistor R' shall have a resistance of 1,5 Ω. The copper wire F' (see Figure C.3 of Annex C) shall have a length of 50 mm and a diameter of 0,12 mm for AFDDs having a rated voltage of 230 V.

NOTE 5 The data for other voltages are under consideration.

For test currents up to and including 1 500 A, the distance "a" shall be 35 mm.

For higher short-circuit currents up to I_{nc}, the distance "a" may be increased and/or additional barriers or insulating means may be fitted, as stated by the manufacturer; "a", if increased, shall be chosen from the series 40 mm – 45 mm – 50 mm – 55 mm, etc. and stated by the manufacturer.

2) Test in enclosures

The grid and the barrier of insulating material shown in Figure C.1 of Annex C are omitted.

The test shall be performed with the AFDD placed in an enclosure having the most unfavourable configuration, under the most unfavourable conditions.

This means that if other AFDDs (or other devices) are normally fitted in the direction(s) in which the grid(s) would be placed, they should be installed there. These AFDDs (or other devices) are supplied as in normal use but via F' and R' as defined in f1) of this subclause and connected as shown in the appropriate Figures 19 and 20.

In accordance with the manufacturer's instructions, barriers or other means, or adequate clearances may be necessary to prevent ionized gases from affecting the installation.

The polyethylene sheet as described in Annex C is placed as shown in Figure C.1 at a distance of 10 mm from the operating means, for O operations only.

g) Sequence of operations

The test procedure consists of a sequence of operations.

The following symbols are used for defining the sequence of operations:

O represents an opening operation, the short-circuit being established by the switch T, with the AFDD and the declared protective device, if any, in the closed position;

CO represents a closing operation of the AFDD, both the switch T and the SCPD, if any, being in the closed position, followed by an automatic opening (in the case of a SCPD see 9.11.2.5) or by manual opening;

t represents the time interval between two successive short-circuit operations which shall be 3 min or such longer time as may be required for resetting or renewing the SCPD, if any.

h) Behaviour of the AFDD during tests

During tests, the AFDD shall not endanger the operator.

Furthermore, there shall be no permanent arcing, no flashover between poles or between poles and exposed conductive parts, no melting of the fuse F.

i) Condition of the AFDD after tests

After each of the tests applicable carried out in accordance with 9.11.2.3, 9.11.2.4, 9.11.2.5 a), 9.11.2.5 b) and 9.11.2.5 c), AFDDs shall show no damage impairing their further use and shall be capable, without maintenance, of withstanding the following tests:

– leakage current across open contacts, according to 9.7.6.3;
– dielectric strength tests according to 9.7.3 carried out between 2 h and 24 h after the short-circuit test at a voltage of twice its rated voltage, for 1 min, without previous humidity treatment;
– making and breaking its rated current at its rated voltage.

During these tests, after the test carried out under the conditions specified in item a) of 9.7.2. it shall be verified that the indicating means show the open position and during the test carried out under the condition specified in item b) of 9.7.2 the indicating means shall show the closed position.

Under the test conditions of 9.9.2.4, the AFDD shall trip with a test current equal to 1,25 times the lowest current of Table 1 or 2, as applicable, without measurement of breaktime. The polyethylene sheet shall show no holes visible with normal or corrected vision without additional magnification.

j) Interpretation of records

1) determination of the applied and power-frequency recovery voltages

The applied and power frequency recovery voltages are determined from the record corresponding to the break test made with the AFDD under test. The applied voltage is evaluated as indicated in Figure 22.

The voltage on the supply side shall be measured during the first cycle after arc extinction in all poles and after high frequency phenomena have subsided.

2) determination of the prospective short-circuit current

The a.c. component of the prospective current is taken as being equal to the r.m.s. value of the a.c. component of the calibration current (value corresponding to A_2 of Figure 22).

Where applicable, the prospective short-circuit current shall be the average of the prospective currents in all the phases.

9.11.2.3 Verification of the rated making and breaking capacity (I_m)

This test is intended to verify the ability of the AFDD to make, to carry for a specified time and to break short-circuit currents.

a) Test conditions

The AFDD is tested in a circuit according to the general test conditions prescribed in 9.11.2.2 without any protective device being inserted in the circuit.

The connections G_1 of negligible impedance are replaced by the AFDD and by connections having approximately the impedance of the declared protective device.

The auxiliary switch S_1 remains opened.

b) Test procedure

The following sequence of operations is performed, the CO operation is performed by an actuator closing the mechanism and opening at least 0,05 s later to ensure that current flows in the AFDD:

CO – t – CO – t – CO.

9.11.2.4 Verification of the rated making and breaking capacity on one pole (I_{m1}) of AFDDs and their suitability for use in IT systems

This test is intended to verify the ability of the AFDD to make, to carry for a specified time and to break short-circuit currents on one pole and to verify suitability for IT systems.

a) Test conditions

The AFDD shall be tested according to the general test conditions prescribed in 9.11.2.2, without any protective device being inserted in the circuit, but connected in such a manner that the short-circuit current flows in one pole.

For this test the impedance Z1 is not used, the circuit being left open.

The current paths which do not carry the short-circuit current are connected to the supply voltage at their line terminals.

The connections G_1 of negligible impedance are replaced by the AFDD and by connections having approximately the impedance of the declared protective device.

The auxiliary switch S1 remains closed.

The test is performed on each pole in turn excluding the switched neutral pole, if any.

b) Test procedure

The following sequence of operations is performed. The opening is performed by an actuator operating the mechanism and opening at least 0,05 s later to ensure that current flows in the AFDD.

As an alternative to performing the opening operations with an actuator the manufacturer may provide specially prepared samples which can be opened by external electrical means which simulate automatic opening under arc fault conditions.

CO – t – CO – t – CO.

c) For the verification of the suitability in the IT system, this test is repeated on new samples:

– at a voltage of 105 % of the rated phase to phase voltage value for the phase poles and at a voltage of 105 % of U_0 for the pole marked N if any; and

– according to 5.3.5, with a current of 500 A or 10 I_n, whichever is the greater.

Each pole is subjected individually to a test in a circuit the connections of which are shown in Figure 20.

The test sequence being CO – t – CO.

AFDDs with uninterrupted neutral are not subjected to this test.

9.11.2.5 Verification of the coordination between the AFDD and the declared protective device

These tests are performed according to Figure 19.

These tests are intended to verify that the AFDD, protected by the declared protective device, is able to withstand, without damage, short-circuit currents up to its rated conditional short-circuit current (see 5.3.6).

The short-circuit current is interrupted by the association of the AFDD and the declared protective device.

During the test either both the AFDD and the protective device or the protective device only may operate. However, if only the AFDD opens, the test is also considered as satisfactory.

The protective device is renewed or reset as applicable after each operation.

The following tests (see also Table 17) are made under the general conditions of 9.11.2.2:

– a test (see 9.11.2.5 a)) to check that at the rated conditional short-circuit current I_{nc} the declared protective device protects the AFDD.
– a test (see 9.11.2.5 b)) to check that at short-circuit currents of a value corresponding to the rated making and breaking capacity I_m, the declared protective device operates and protects the AFDD.
– a test (see 9.11.2.5 c)) to check that in the case of phase to earth short-circuits with currents up to the value of the rated conditional short-circuit current for one phase I_{nc1}, the AFDD is able to withstand the corresponding stresses.

a) Verification of the coordination at the rated conditional short-circuit current (I_{nc})

 3) Test conditions

 The connections G_1 of negligible impedance are replaced by the AFDD and by the declared protective device.

 The auxiliary switch S1 remains open

 4) Test procedure

 The following sequence of operations is performed:

 CO – t – CO.

b) Verification of the coordination at the rated making and breaking capacity (I_m)

 1) Test conditions

 The connections G_1 of negligible impedance are replaced by the AFDD and by the declared protective device.

 The auxiliary switch S1 remains open.

 2) Test procedure

 The following sequence of operations is performed:

 CO – t – CO – t – CO.

c) Verification of the coordination at rated conditional short-circuit current for one pole (I_{nc1})

 1) Test conditions

 The AFDD shall be tested according to the general test conditions prescribed in 9.11.2.2, but connected in such a manner that the short-circuit current flows only in one pole.

 The test is performed on one pole only which shall not be the switched neutral of the AFDD, in case of multipole devices, the test is repeated on each pole.

The current paths which have not to carry the residual short-circuit current are connected to the supply voltage at their supply terminals.

The connections G_1 of negligible impedance are replaced by the AFDD and by the SCPD.

The auxiliary switch S1 remains closed.

2) Test procedure

The following sequence of operations is performed:

CO – t – CO – t – CO.

9.12 Verification of resistance to mechanical shock and impact

9.12.1 Mechanical shock

9.12.1.1 Test device

The AFDD is subjected to mechanical shocks using apparatus as shown on Figure 23. A wooden base A is fixed to a concrete block and a wooden platform B is hinged to A. This platform carries a wooden board C, which can be fixed at various distances from the hinge and in two vertical positions. The end of B bears a metal stop-plate D which rests on a coiled spring having a flexion constant of 25 N/mm.

The AFDD is secured to C in such a way that the distance of the horizontal axis of the sample is 180 mm from B, C being in turn so fixed that the distance of the mounting surface is 200 mm from the hinge, as shown in Figure 23.

On C, opposite to the mounting surface of the AFDD, an additional mass is fixed so that the static force on D is 25 N, in order to ensure that the moment of inertia of the complete system is substantially constant.

9.12.1.2 Test procedure

With the AFDD in the closed position, but not connected to any electrical source, the platform is lifted at its free end and then allowed to fall 50 times from a height of 40 mm, the interval between consecutive falls being such that the sample is allowed to come to rest.

The AFDD is then secured to the opposite side of C and B is again allowed to fall 50 times as before. After this test, C is turned through 90° about its vertical axis and, if necessary, repositioned so that the vertical axis of symmetry of the AFDD is 200 mm from the hinge.

The platform is then allowed to fall 50 times, as before, with the AFDD on one side of C, and 50 times with the AFDD on the opposite side.

Before each change of position the AFDD is manually opened and closed.

During the tests, the AFDD shall not open.

9.12.2 Mechanical impact

9.12.2.1 General

Compliance is checked on those exposed parts of the AFDD mounted as for normal conditions of use (see note in 8.3), which may be subjected to mechanical impact in normal use, by the test of 9.12.2.2, for all types of AFDDs and, in addition, by the tests of 9.12.2.3 for AFDDs intended to be mounted on a rail.

NOTE AFDDs only intended to be totally enclosed are not submitted to this test.

9.12.2.2 The samples are subjected to blows by means of an impact-test apparatus as shown on Figures 24 to 26.

The head of the striking element has a hemispherical face of 10 mm in radius and is polyamide having a Rockwell hardness of HR 100. The striking element has a mass of 150 g ± 1 g and is rigidly fixed to the lower end of a steel tube with an external diameter of 9 mm and a wall thickness of 0,5 mm, which is pivoted at its upper end in such a way that it swings only in a vertical plane.

The axis of the pivot is 1 000 mm ± 1 mm above the axis of the striking element.

For determining the Rockwell hardness of the polyamide of the head of the striking element, the following conditions apply:

– diameter of the ball: 12,7 mm ± 0,0025 mm;
– initial load: 100 N ± 2 N;
– overload: 500 N ± 2,5 N.

NOTE 1 Additional information concerning the determination of the Rockwell hardness of plastics is given in ASTM D 785-08.

The design of the test apparatus is such that a force of between 1,9 N and 2,0 N has to be applied to the face of the striking element to maintain the tube in the horizontal position.

Surface-type AFDDs are mounted on a sheet of plywood, 175 mm × 175 mm, 8 mm thick, secured at its top and bottom edges to a rigid bracket, which is part of the mounting support, as shown in Figure 26.

The mounting support shall have a mass of 10 kg ± 1 kg and shall be mounted on a rigid frame by means of pivots. The frame is fixed to a solid wall.

Flush-type AFDDs are mounted in a device, as shown on Figure 27, which is fixed to the mounting support.

Panel-mounting type AFDDs are mounted in a device, as shown in Figure 28, which is fixed to the mounting support.

Plug-in type AFDDs are mounted in their appropriate sockets, which are fixed on the sheet of plywood or in the devices according to Figure 27 or 28, as applicable.

AFDDs for rail mounting are mounted on their appropriate rail which is rigidly fixed to the mounting support.

The design of the test apparatus is such that:

– the sample can be moved horizontally and turned about an axis perpendicular to the surface of the plywood;
– the plywood can be turned about a vertical axis.

The AFDD, with its covers if any, is mounted as in normal use on the plywood or in the appropriate device, as applicable, so that the point of impact lies in the vertical plate through the axis of the pivot of the pendulum.

Cable entries which are not provided with knock-outs are left open. If they are provided with knock-outs, two of them are opened.

Before applying the blows, fixing screws of bases, covers and the like are tightened with a torque equal to two-thirds of that specified in Table 12.

The striking element is allowed to fall from a height of 10 cm on the surfaces which are exposed when the AFDD is mounted as for normal use.

The height of fall is the vertical distance between the position of a checking point when the pendulum is released and the position of that point at the moment of impact. The checking point is marked on the surface of the striking element where the line through the point of intersection of the axis of the steel tube of the pendulum and that of the striking element, and perpendicular to the plane through both axes, meets the surface.

NOTE 2 Theoretically, the centre of gravity of the striking element is the checking point. As the centre of gravity is difficult to determine, the checking point is chosen as specified above.

Each AFDD is subjected to ten blows, two of them being applied to the operating means and the remainder being evenly distributed over the parts of the sample likely to be subjected to impact.

The blows are not applied to knock-out areas or to any openings covered by a transparent material.

In general, one blow is applied on each lateral side of the sample after it has been turned as far as possible, but not through more than 60°, about a vertical axis, and two blows each approximately midway between the side blow on a lateral side and the blows on the operating means.

The remaining blows are then applied in the same way, after the sample has been turned through 90° about its axis perpendicular to the plywood.

If cable entries or knock-outs are provided, the sample is so mounted that the two lines of blows are as nearly as possible equidistant from these entries.

The two blows on the operating means shall be applied: one when the operating means is in the ON position and the other when the operating means is in the OFF position.

After the test, the samples shall show no damage within the meaning of this standard. In particular, covers which, when broken, make live parts accessible or impair the further use of the AFDD, operating means, linings or barriers of insulating material and the like, shall not show such damage.

In case of doubt, it is verified that removal and replacement of external parts, such as enclosures and covers, is possible without these parts or their lining being damaged.

NOTE 3 Damage to the appearance, small dents which do not reduce the creepage distances or clearances below the values specified in 8.2.3 and small chips which do not adversely affect the protection against electric shock are neglected.

When testing AFDDs designed for screw fixing as well as for rail mounting, the test is made on two sets of AFDDs, one of them being fixed by means of screws and the other being mounted on a rail.

9.12.2.3 AFDDs designed to be mounted on a rail are mounted as for normal use on a rail rigidly fixed on a vertical rigid wall, but without cables being connected and without any cover or cover-plate.

A downward vertical force of 50 N is applied in one smooth and continuous motion for 1 min on the forward surface of the AFDD, immediately followed by an upward vertical force of 50 N for 1 min (Figure 29).

During this test, the AFDD shall not become loose and after the test the AFDD shall show no damage impairing its further use.

Afterward, the functionality of the AFDD is verified by repeating the test 9.9.2.4 at the lowest current of Table 1 or 2, as applicable.

9.13 Test of resistance to heat

9.13.1 The samples, without removable covers, if any, are kept for 1 h in a heating cabinet at a temperature of 100 °C ± 2 °C; removable covers, if any, are kept for 1 h in the heating cabinet at a temperature of 70 °C ± 2 °C.

During the test, the samples shall not undergo any change impairing their further use, and sealing compound, if any, shall not flow to such an extent that live parts are exposed.

After the test, and after the samples have been allowed to cool down to approximately room temperature, there shall be no access to live parts which are normally not accessible when the samples are mounted as for normal use, even if the standard test finger is applied with a force not exceeding 5 N.

Afterward, the functionality of the AFDD is verified by repeating the test of 9.9.2.4 at the lowest current of Table 1 or 2, as applicable.

After the test, markings shall still be legible.

Discoloration, blisters or a slight displacement of the sealing compound are disregarded, provided that safety is not impaired within the meaning of this standard.

9.13.2 External parts of AFDDs made of insulating material necessary to retain in position current-carrying parts or parts of the protective circuit are subjected to a ball pressure test by means of the apparatus shown in Figure 30, except that, where applicable, the insulating parts necessary to retain in position terminals for protective conductors in a box, shall be tested as specified in 9.13.3.

The part to be tested is placed on a steel support with the appropriate surface in the horizontal position, and a steel ball of 5 mm diameter is pressed against this surface with a force of 20 N.

The test is made in a heating cabinet at a temperature of 125 °C ± 2 °C.

After 1 h, the ball is removed from the sample which is then cooled down within 10 s to approximately room temperature by immersion in cold water.

The diameter of the impression caused by the ball is measured and shall not exceed 2 mm.

9.13.3 External parts of AFDDs made of insulating material not necessary to retain in position current-carrying parts and parts of the protective circuit, even though they are in contact with them, are subjected to a ball pressure test in accordance with 9.13.2, but the test is made at a temperature of 70 °C ± 2 °C or at a temperature of 40 °C ± 2 °C plus the highest temperature rise determined for the relevant part during the test of 9.8, whichever is higher.

NOTE For the purpose of the tests of 9.13.2 and 9.13.3, bases of surface-type AFDDs are considered as external parts.

The tests of 9.13.2 and 9.13.3 are not made on parts of ceramic material.

If two or more of the insulating parts referred to in 9.13.2 and 9.13.3 are made of the same material, the test is carried out only on one of these parts, according to 9.13.2 or 9.13.3 respectively.

9.14 Test of resistance to abnormal heat and to fire

The glow-wire test is performed on a complete AFDD in accordance with IEC 60695-2-10:2000 under the following conditions:

– for external parts of AFDDs made of insulating material necessary to retain in position current-carrying parts and parts of the protective circuit, by the test made at a temperature of 960 °C ± 15 °C;

– for all other external parts made of insulating material, by the test made at a temperature of 650 °C ± 10 °C.

NOTE For the purpose of this test, bases of surface-type AFDDs are considered as external parts.

If insulating parts within the above groups are made of the same material, the test is carried out only on one of these parts, according to the appropriate glow-wire test temperature.

The test is not made on parts of ceramic material.

The glow-wire test is applied to ensure that an electrically heated test wire under defined test conditions does not cause ignition of insulating parts or to ensure that a part of insulating material, which might be ignited by the heated test wire under defined conditions, has a limited time to burn without spreading fire by flame or burning parts or droplets falling from the tested part.

The test is carried out on three samples.

Each test is made on a separate sample with a different situated point of application of the glow wire.

The glow wire cannot be applied directly to terminals area or arc chamber or magnetic tripping device area, where the glow-wire cannot protrude far through the outer surface before touching either relatively big metal parts or even ceramics, which will cool down the glow-wire quickly and in addition limit the amount of insulating material ever getting in touch with the glow-wire. In this situation the parts ensure minimum severity of the test by cooling down the glow-wire and limiting access to the insulating material under test.

The sample shall be positioned during the test in the most unfavourable position of its intended use (with the surface tested in a vertical position).

If an internal part of insulation material influences the test with a negative result, it is allowed to remove the relevant identified internal part(s) of insulation material from a new sample. Then, the glow wire test shall be repeated in the same place on this new sample.

In accordance with the manufacturer, it is acceptable as an alternative method to remove the part under examination in its entirety and test it separately (see IEC 60695-2-11:2000, Clause 4).

The sample is regarded as having passed the glow-wire test if:

– there is no visible flame and no sustained glowing; or

– flames and glowing on the sample extinguish themselves within 30 s after the removal of the glow-wire.

There shall be no ignition of the tissue paper or scorching of the pine-wood board.

9.15 Verification of the trip-free mechanism

9.15.1 General test conditions

The AFDD is mounted and wired as in normal use in accordance with 9.1.1.

It is tested in a substantially non-inductive circuit, the diagram of which is shown in Figure 4.

9.15.2 Test procedure

The AFDD having been closed and the operating means being held in the closed position, the test in 9.9.2.4 is repeated at the lowest current of Table 1 or 2, as applicable.

The AFDD shall trip.

This test is then repeated by moving the operating means of the AFDD slowly over a period of approximately 1 s to a position where the current starts to flow. Tripping shall occur without further movement of the operating means.

Both tests are carried out three times, at least once on each pole intended to be connected to a phase.

NOTE If the AFDD is fitted with more than one operating means, the trip-free operation is verified for all operating means.

9.16 Test of resistance to rusting

All grease is removed from the parts to be tested by immersion in a cold chemical degreaser such as methyl-chloroform or refined petrol, for 10 min. The parts are then immersed for 10 min in a 10 % solution of ammonium chloride in water at a temperature of (20 ± 5) °C.

Without drying, but after shaking off any drops, the parts are placed for 10 min in a box containing air saturated with moisture at a temperature of (20 ± 5) °C.

After the parts have been dried for 10 min in a heating cabinet at a temperature of (100 ± 5) °C, their surfaces shall show no signs of rust.

NOTE 1 Traces of rust on sharp edges and any yellowish film removable by rubbing are ignored.

For small springs and the like and for inaccessible parts exposed to abrasion, a layer of grease may provide sufficient protection against rusting. Such parts are only subjected to the test if there is a doubt as to the effectiveness of the grease film, and in such a case the test is made without previous removal of the grease.

NOTE 2 When using the liquid specified for the test, adequate precautions are taken to prevent inhalation of the vapour.

9.17 Verification of limiting values of the non-operating current under overcurrent conditions

AFDDs classified according to 4.1.2 and 4.1.3 (according to Annex D depending on the assembled protection device) are tested according to IEC 60898, IEC 61008-1, IEC 61009-1, or IEC 62423, as applicable. There is no need for additional testing.

AFDDs classified according to 4.1.1 shall be tested according to the following procedure:

– The AFDD is connected as for normal use with a substantially non-inductive load equal to 6 I_n;
– The load is switched on using a two-pole test switch and then switched off after 1 s;

– The test is repeated three times, the interval between two successive closing operations being at least 1 min;
– The AFDD shall not open.

9.18 Verification of behaviour of AFDDs in case of current surges caused by impulse voltages

9.18.1 General

AFDDs classified according to 4.1.1 shall be tested according to 9.18.2.

AFDDs classified according to 4.1.2 and 4.1.3 (according to Annex D depending on the assembled protection device) are tested according to IEC 60898, IEC 61008-1, IEC 61009-1, or IEC 62423, as applicable. There is no need for additional testing.

9.18.2 Verification of behaviour at surge currents up to 3 000 A (8/20 μs surge current test)

9.18.2.1 Test conditions

The AFDD is tested using a current generator capable of delivering a damped surge current 8/20 μs (IEC 60060-2) as shown in Figure 31. An example of circuit diagram connection of the AFDD is shown in Figure 32.

One pole of the AFDD chosen at random shall be submitted to 10 applications of the surge current. The polarity of the surge current wave shall be inverted after every two applications. The interval between two consecutive applications shall be about 30 s.

The current impulse shall be measured by appropriate means and adjusted using an additional AFDD of the same type with the same I_n, to meet the following requirements:

– peak value 3 000 A $^{+10}_{0}$ %;
– virtual front time: 8 μs ± 20 %;
– virtual time to half value: 20 μs ± 20 %;
– peak of reverse current: less than 30 % of peak value.

The current should be adjusted to the asymptotic current shape. For the tests on other samples of the same type with the same I_n, the reverse current, if any, should not exceed 30 % of the peak value.

9.18.2.2 Test results

During the test, the AFDD may trip. After any tripping, the AFDD shall be re-closed.

After the surge current tests, the correct operation of the AFDD is verified by repeating the test 9.9.2.4 at the lowest current of Table 1 or 2, as applicable.

9.19 Verification of reliability

9.19.1 General

Compliance is checked by the tests of 9.19.2 and 9.19.3.

For AFDDs having multiple settings, the tests shall be made at the lowest setting.

9.19.2 Climatic test

9.19.2.1 General

The test is based on IEC 60068-2-30, taking into account IEC 60068-3-4.

9.19.2.2 Test chamber

The chamber shall be constructed as stated in Clause 4 of IEC 60068-2-30:2005. Condensed water shall be continuously drained from the chamber and not used again until it has been re-purified. Only distilled water shall be used for the maintenance of chamber humidity.

Before entering the chamber, the distilled water shall have a resistivity of not less than 500 Ωm and a pH value of 7,0 ± 0,2. During and after the test the resistivity should be not less than 100 Ωm and the pH value should remain within 7,0 ± 1,0.

9.19.2.3 Severity

The cycles are effected under the following conditions:

– upper temperature: 55 °C ± 2 °C;
– number of cycles: 28.

9.19.2.4 Testing procedure

The test procedure shall be in accordance with Clause 4 of IEC 60068-2-30:2005 and IEC 60068-3-4.

a) Initial verification

   An initial verification is made by submitting the AFDD to the test 9.9.2.4 at the lowest current of Table 1 or 2, as applicable.

b) Conditioning

   1) The AFDD mounted and wired as for normal use is introduced into the chamber.

      It shall be in the closed position.

   2) Stabilizing period (see Figure 33)

      The temperature of the AFDD shall be stabilized at 25 °C ± 3 °C:

      – either by placing the AFDD in a separate chamber before introducing it into the test chamber; or

      – by adjusting the temperature of the test chamber to 25 °C ± 3 °C after the introduction of the AFDD and maintaining it at this level until temperature stability is attained.

      During the stabilization of temperature by either method, the relative humidity shall be within the limits prescribed for standard atmospheric conditions for testing (see Table 6).

      During the final hour, with the AFDD in the test chamber, the relative humidity shall be increased to not less than 95 % at an ambient temperature of 25 °C ± 3 °C.

   3) Description of the 24-hour cycle (see Figure 34)

      – The temperature of the chamber shall be progressively raised to the appropriate upper temperature prescribed in 9.19.2.3.

        The upper temperature shall be achieved in a period of 3 h ± 30 min and at a rate within the limits defined by the shaded area in Figure 34.

        During this period, the relative humidity shall not be less than 95 %. Condensation shall occur on the AFDD during this period.

The condition that condensation shall occur implies that the surface temperature of the AFDD is below the dew point of the atmosphere. This means that the relative humidity has to be higher than 95 % if the thermal time-constant is low. Care should be taken so that no drops of condensed water can fall on the sample.

– The temperature shall then be maintained for 12 h ± 30 min from the beginning of the cycle at a substantially constant value within the prescribed limits of ± 2 °C, for the upper temperature.

  During this period, the relative humidity shall be 93 % ± 3 % except for the first and the last 15 min when it shall be between 90 % and 100 %.

  Condensation shall not occur on the AFDD during the last 15 min.

– The temperature shall then fall to 25 °C ± 3 °C within 3 h to 6 h. The rate of fall for the first 1 h 30 min shall be such that, if maintained as indicated in Figure 34, it would result in a temperature of 25 °C ± 3 °C being attained in 3 h ± 15 min.

  During the temperature fall period, the relative humidity shall be not less than 95 %, except for the first 15 min when it shall be not less than 90 %.

– The temperature shall then be maintained at 25 °C ± 3 °C with a relative humidity not less than 95 % until the 24 h cycle is completed.

9.19.2.5 Recovery

At the end of the cycles, the AFDD shall not be removed from the test chamber.

The door of the test chamber shall be opened and the temperature and humidity regulation is stopped.

A period of 4 h to 6 h shall then elapse to permit the ambient conditions (temperature and humidity) to be re-established before making the final measurement.

During the 28 cycles, the AFDD shall not trip.

9.19.2.6 Final verification

The functionality of the AFDD is verified by repeating the test 9.9.2.4 at 1,25 times the lowest current of Table 1 or 2, as applicable.

9.19.3 Test with temperature of 40 °C

The AFDD is mounted as for normal use on a dull black painted plywood wall, about 20 mm thick.

For each pole, a single-core cable, 1 m long and having a nominal cross-sectional area as specified in Table 11, is connected on each side of the AFDD, the terminal screws or nuts being tightened with a torque equal to two-thirds of that specified in Table 12. The assembly is placed in a heating cabinet.

The AFDD is loaded with a current equal to rated current at any convenient voltage and is subjected, at a temperature of 40 °C ± 2 °C, to 28 cycles, each cycle comprising 21 h with current passing and 3 h without current. The current is interrupted by an auxiliary switch, the AFDD being not operated.

NOTE For four-pole AFDDs, this is under consideration.

At the end of the last period of 21 h with current passing, the temperature rise of the terminals is determined by means of fine wire thermocouples; this temperature rise shall not exceed 65 K.

After this test, the AFDD, in the cabinet, is allowed to cool down to approximately room temperature without current passing.

The functionality of the AFDD is verified by repeating the test 9.9.2.4 at the lowest current of Table 1 or Table 2, as applicable.

9.20 Verification of ageing of electronic components

The AFDD is placed for a period of 168 h in an ambient temperature of 40 °C ± 2 °C and loaded with the rated current. The voltage on the electronic parts shall be 1,1 times the rated voltage.

After this test, the AFDD in the cabinet is allowed to cool down to approximately room temperature without current passing. The electronic parts shall show no damage.

The functionality of the AFDD is verified by repeating the test 9.9.2.4 at 1,25 times the lowest current of Table 1 or 2, as applicable.

NOTE An example for the test circuit of this verification is given in Figure 35.

9.21 Electromagnetic compatibility (EMC)

9.21.1 General

AFDDs shall be submitted to the EMC tests according to IEC 61543:1995, Amendment 1:2004 and according to the additional information given in 9.21.1, 9.21.2, and 9.21.3.

9.21.2 EMC tests covered by other clauses of the present standard

The tests listed in the following Table 20 are already covered by another test clause of this standard and need not to be repeated.

Table 20 – Tests already covered in this standard

Reference to Tables 4 and 5 of IEC 61543:1995, Amendment 1:2004	Electromagnetic phenomena	Tests of present standard
T 1.3	Voltage amplitude variations	9.9.2.4
T 1.4	Voltage unbalance	9.9.2.4
T 1.5	Power frequency variations	9.2
T 1.8	Magnetic fields	9.11 and 9.17
T 2.4	Current oscillatory transients	9.18

9.21.3 EMC tests to be performed

The remaining tests in Tables 4, 5 and 6 of IEC 61543:1995, Amendment 1:2004 shall be carried out according to the test listed in Annex A of this standard. The test levels and performance criteria are performed according to Table 21.

Table 21 – Tests to be applied for EMC

Reference to Tables 5 and 6 of IEC 61543:1995, Amendment 1:2004 Amendment 2:2005	Electromagnetic phenomena	Reference of basic standard for test description	Test Level and test specification	Performance criteria
T 2.1	Conducted sine-wave form voltages or currents	IEC 61000-4-6 [e, i]	Level 2 0,15 MHz to 80 MHz Z = 150 Ω – 3 V	A
T 2.2	Fast transcients (burst) common mode	IEC 61000-4-4 [b]	Level 4 4 kV (peak) Tr/Th 5/50 ns Repetition frequency 2,5 kHz	B[c]
T 2.3a	Surges	IEC 61000-4-5	Tr/Th 1,2/50 μs 5 kV / 12 Ω (peak)[a] common mode 4 kV / 2 Ω (peak)[a] differential mode	B,C [g, h]
T 2.3b			Tr/Th 1,2/50 μs 4 kV / 12 Ω (peak)[a] common mode 2 kV/2 Ω (peak) [a] differential mode	B [h]
T 2.5	Radiated electromagnetic field	IEC 61000-4-3 [e, f]	Level 2 3 V/m	A
T 2.6 [l]	Conducted common mode disturbances in the frequency range lower than 150 k Hz	IEC 61000-4-16	Level 3 [j] 1 kHz to 1,5 kHz: 1 V 1,5 kHz to 15 kHz: 1 V to 10 V 15 kHz to 150 kHz: 10 V	A
T 3.1	Electrostatic discharges	IEC 61000-4-2	Level 3 8 kV air 6 kV contact	C [k]

[a] Tests with lower voltages than those given in Table 21 are not required (reason: IEC 61000-4-5, 8.2 requires to carry out the tests at each voltage up to the chosen level). This test shall be carried out on the device in the closed position. Pulses shall be applied successively:

- between the metal support and parts intended to be earthed (PE conductor, earthing terminal), if any, connected together and each live conductor in turn at an impulse voltage of 5 kV, with an impedance of 12 Ω;
- between each phase and neutral, in turn, and between each couple of poles, in turn, at an impulse voltage of 4 kV, with an impedance of 2 Ω.

[b] In addition, the sample shall be mounted as in normal use on a flat insulating support at a distance of 10 cm from the earth plane.

[c] The test is carried out in single phase on one pole of each sample taken at random. Three new samples are submitted to the test. If one sample does not comply with the criterion by tripping during the test, three further samples are tested, which shall fully comply with the criterion of B.

[d] void

[e] With the agreement of the manufacturer, the conducted test T2.1 can be extended from 80 MHz to 230 MHz. In this case, the test T2.5 is to start from 230 MHz instead of 80 MHz.

[f] Verification of non-tripping (performance criteria A) shall be done by sweeping the specified frequency range. For the verifications of tripping (performance criteria A), only five tests are carried out on each sample at different frequencies selected at random over the frequency range and different from one sample to another, but one of them being 450 MHz and another 900 MHz.

[g] The tests of T2.3b shall be applied only to AFDDs not meeting the pass criteria of B during the tests of T2.3a, in which case the test is repeated at the surge voltage levels specified in T2.3b only for the configuration(s) in which tripping occurred during the tests of T2.3a

[h] The test shall be carried out on the device in the closed position. Each sample is tested:

1) first, in differential mode test: between each load current path in turn and each other load current path;
2) secondly, in common mode test: between each load current path in turn and the metal support and parts intended to be earthed (PE conductor, earthing terminal) if any, all connected together.

   In each case, the sample is submitted to five positive pulses on the positive half cycles followed by five negative pulses on the negative half cycles.

   All pulses shall be applied successively at random point on wave with a repetition rate of 1 impulse/min.

   For the test T2.3a, according to the above procedure, the total of impulses is: Differential mode test: 10 impulses; Common mode test: 20 impulses.

   The AFDD is permitted to trip during the tests of T2.3 a) (pass criteria C). If the device trips during this test it shall be reclosed before the application of a subsequent impulse.

   For the test T2.3b, the total of impulses is the same as for T2.3 a) if applicable.

[i] Verification of non-tripping (performance criteria A) shall be done by sweeping the specified frequency range.

For the verifications of tripping (performance criteria A), only five tests are carried out on each sample at different frequencies selected at random over the frequency range and different from one sample to another.

[j] The test is made once at 1,1 U_n of the AFDD by sweeping the frequency from 1 kHz to 150 kHz at the rate according to IEC 61000-4-16:1998, Amendment 2:2009, 6.1.3. The device shall not trip;

Tripping tests are carried out on each sample at 5 different frequency values selected at random over the frequency range and different from one sample to another. The device shall trip.

[k] Three new samples are submitted to the test. All three samples shall pass the test.

The point to which discharges shall be applied is selected by an exploration of the accessible surfaces of the AFDD, when installed as for normal use. During exploration, the selection is made with twenty discharges per second.

The selected point is tested with ten positive and ten negative polarity discharges with a time interval of minimum 1 s between subsequent discharges.

[l] In the USA, this test is not applicable.

For devices containing a continuously operating oscillator, the test of CISPR 14-1 shall be carried out on the samples prior to the tests of Table 21.

9.21.4 AFDDs Performance criteria

9.21.4.1 General

When submitting AFDDs to EMC, tests of 9.21.3, performance criteria referred in Table 21 shall be applied.

9.21.4.2 Criteria A

During the test making reference to this performance criteria, the AFDD shall remain closed when powered at 1,1 U_n with sinusoidal current equal to the rated current of the AFDD and shall trip under conditions of 9.9.2.2 at the rated current of the AFDD.

NOTE For EMC testing it is allowed to use the arc generator as an alternative to the carbonized cable specimen if agreed by the manufacturer.

9.21.4.3 Criteria B

During the test making reference to this performance criteria, the AFDD shall remain closed when powered at 1,1 U_n with sinusoidal current equal to the rated current of the AFDD. After the test, compliance with 9.9.2.2, only at the rated current of the AFDD shall be checked.

NOTE For EMC testing it is allowed to use the arc generator as an alternative to the carbonized cable specimen if agreed by the manufacturer

9.21.4.4 Criteria C

During the test making reference to this performance criteria, the AFDD is supplied at 1,1 U_n with sinusoidal current equal to the lowest value of Table 1 or 2, as applicable and the device may trip. After the test, compliance with 9.9.2.2, only at the lowest value of Table 1 or 2 as applicable shall be checked.

NOTE For EMC testing it is allowed to use the arc generator as an alternative to the carbonized cable specimen if agreed by the manufacturer.

9.22 Verification of protection due to overvoltage due to a broken neutral in a three phase system

In case of a broken neutral within a three phase installation an overvoltage phase to neutral may occur. The maximum value of this overvoltage could reach the phase to phase value. The abnormal increase of temperature within the overvoltage loads can ignite a fire.

AFDDs can include an optional characteristic providing protection in this case. This additional optional characteristic is under consideration.

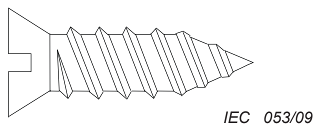


Figure 1 – Thread forming tapping screw

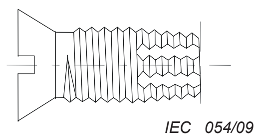
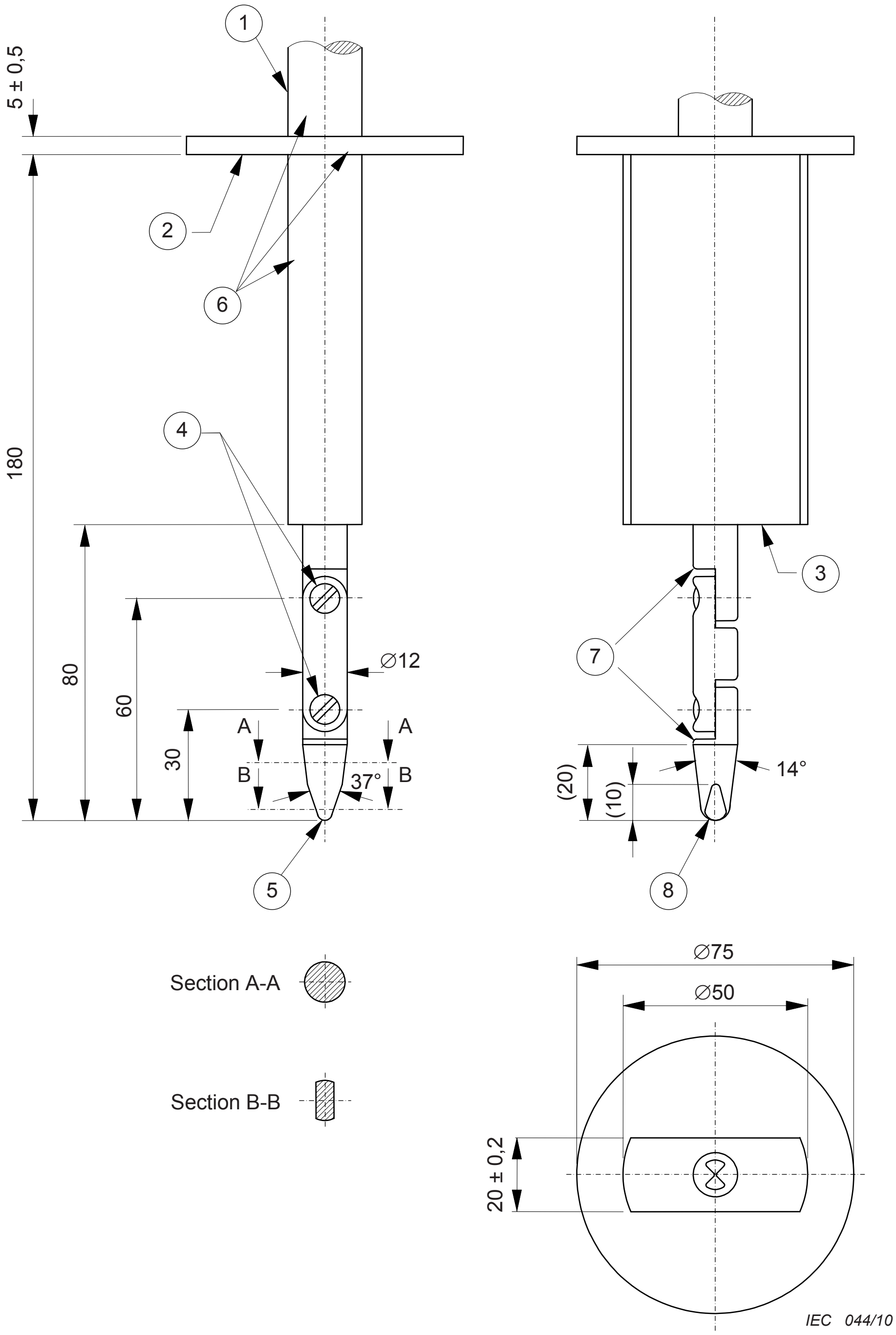


Figure 2 – Thread cutting tapping screw



Key

1	Handle	5	R2 ∅ 0,05 cylindrical
2	Guard	6	Insulating material
3	Stop face	7	Chamfer all edges
4	Joints	8	R4 ∅ 0,05 spherical

Material: metal, except where otherwise specified

Linear dimensions in millimetres

Tolerances on dimensions without specific tolerance:

on angles: 0/–10’

on linear dimensions:

up to 25 mm: 0/-0,05

over 25 mm: ± 0,2

Both joints shall permit movement in the same plane and the same direction through an angle of 90 ° with a 0 ° to +10 ° tolerance.

Figure 3 – Standard test finger (9.6)

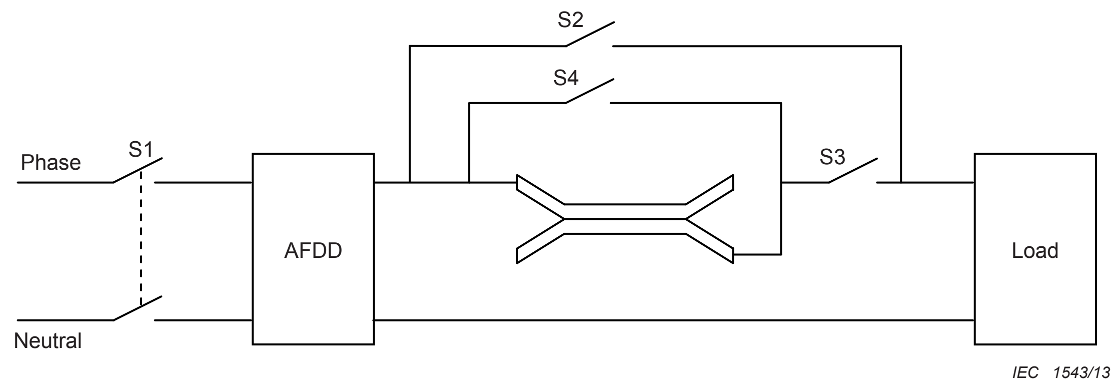


Figure 4 – Test circuit for series arc fault tests

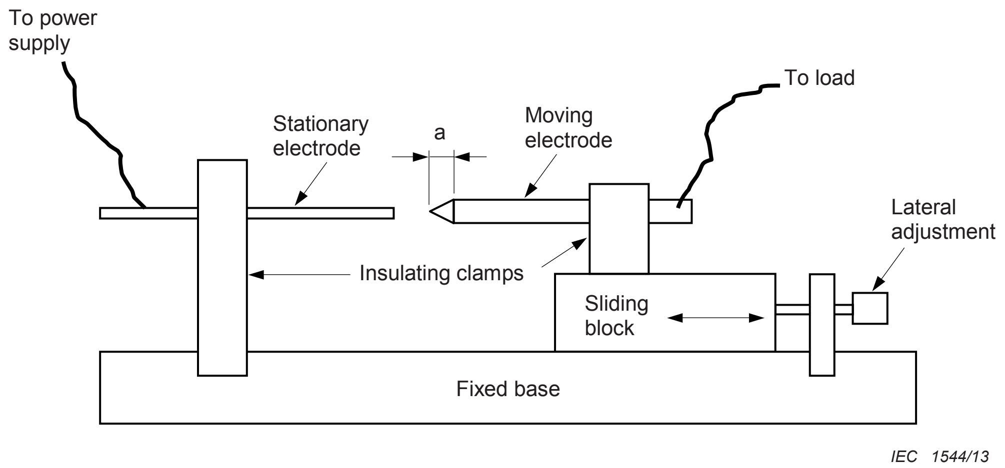


Figure 5 – Arc generator

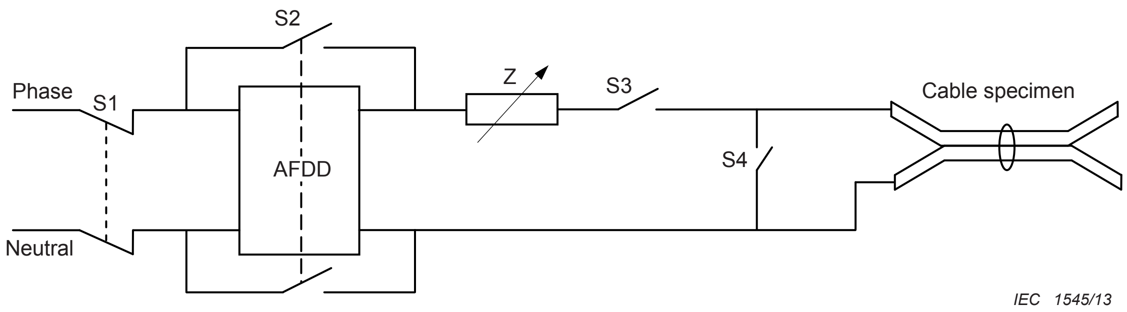


Figure 6 – Test circuit for parallel arc fault tests

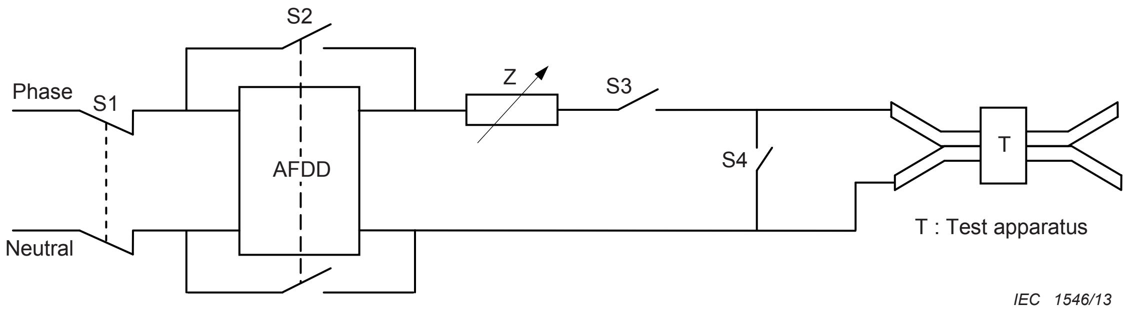


Figure 7 – Test circuit for parallel arc cable cutting test

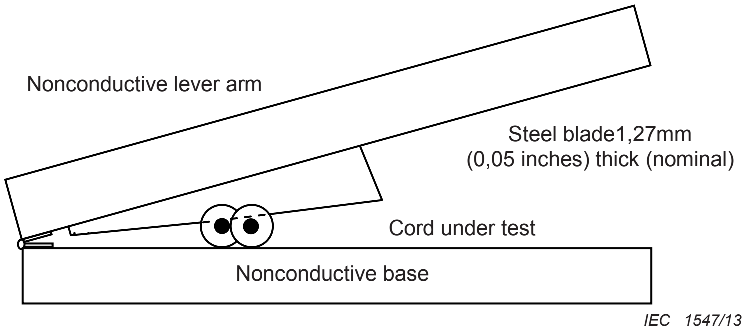


Figure 8 – Test apparatus

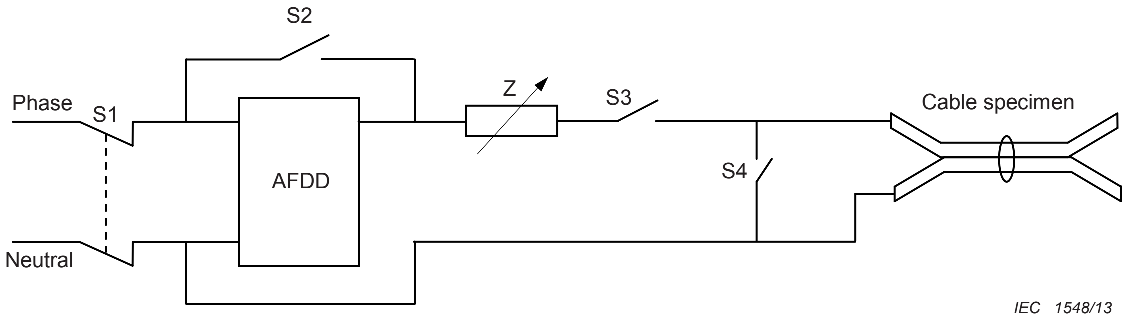


Figure 9 – Test for verification of correct operation in case of parallel arc to ground

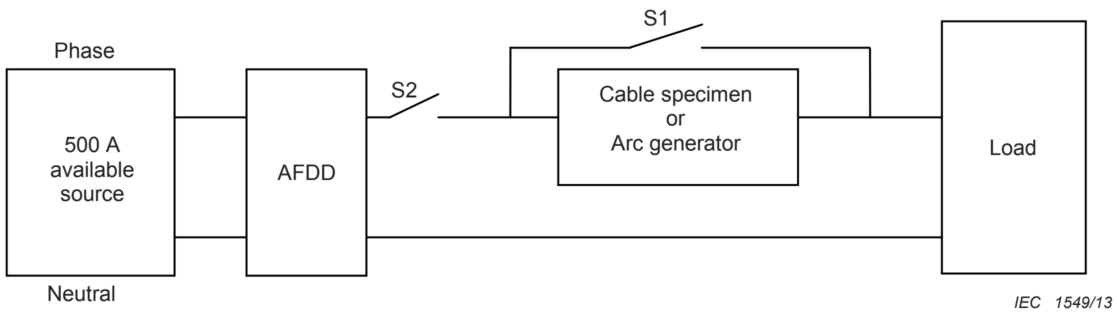
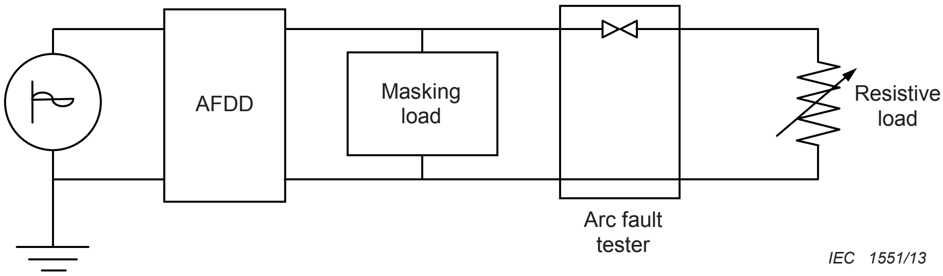


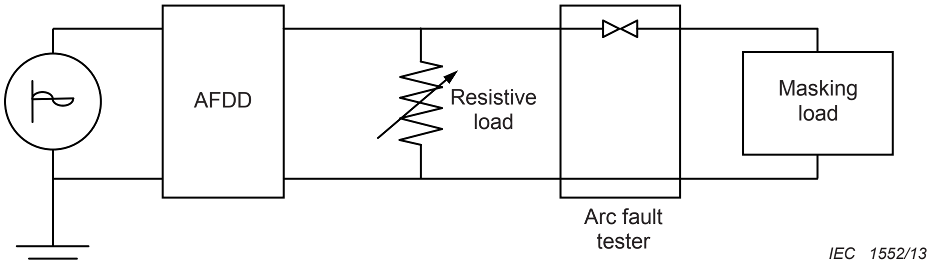
Figure 10 – Test circuit for masking tests (inhibition and disturbing loads)

Configuration A

Configuration B



Configuration C



Configuration D

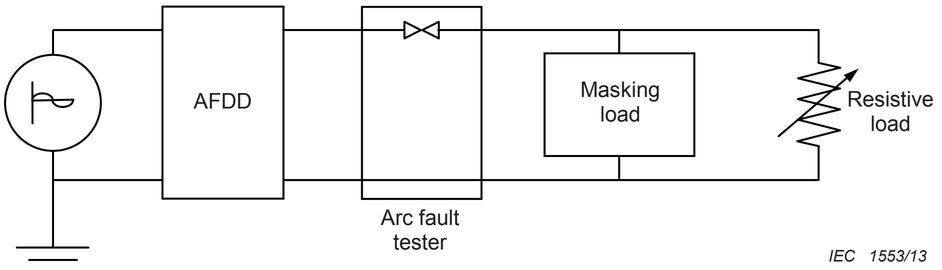


Figure 11 – Test configuration for masking tests

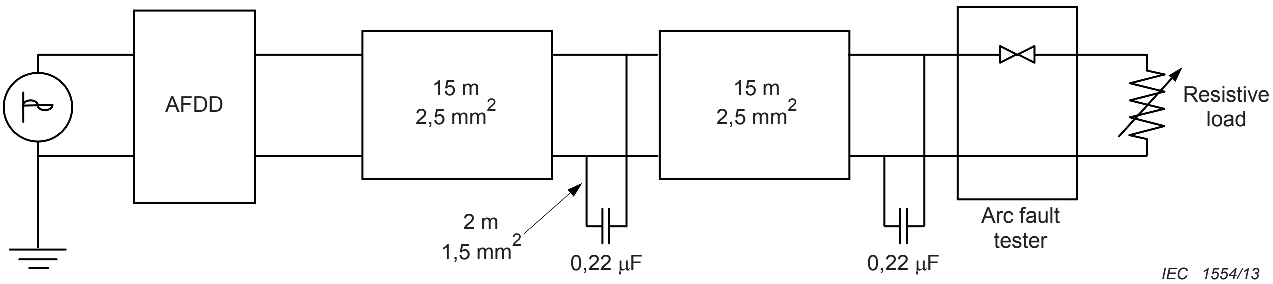


Figure 12 – EMI filter 1 for masking tests

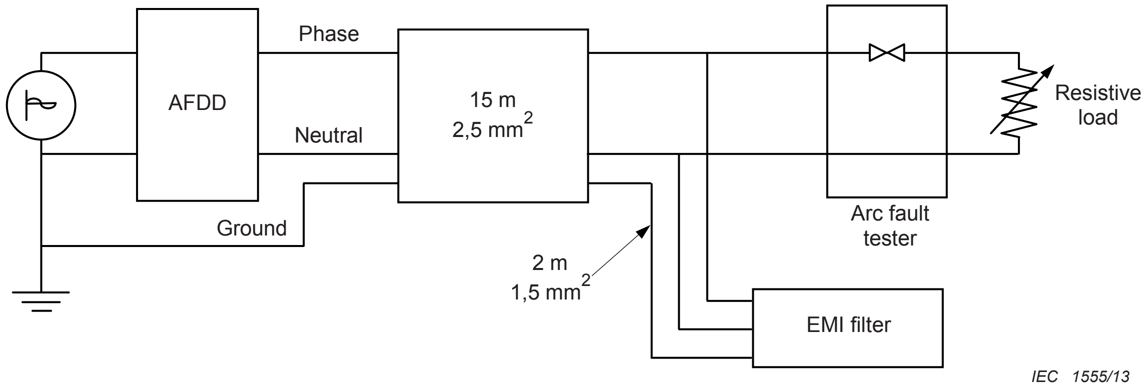
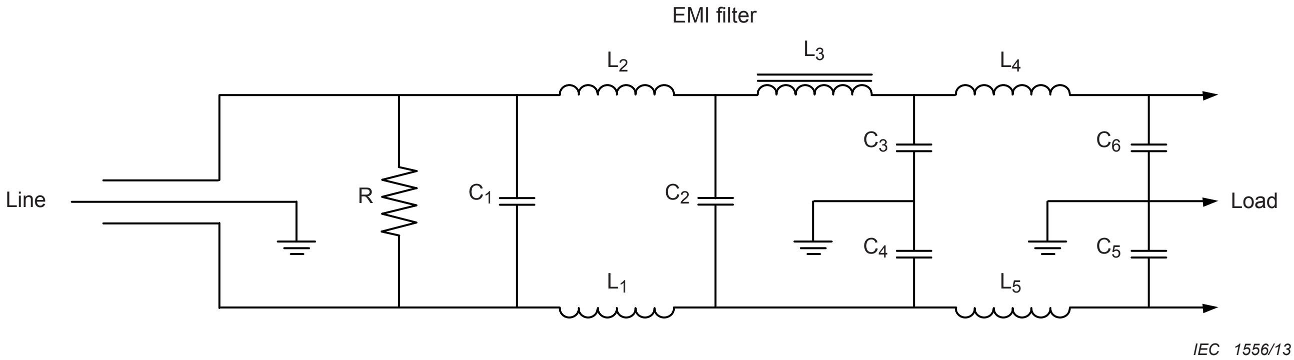


Figure 13 – EMI filter 2 for masking tests



$L_1 = L_2 = 6$ mH ±-10 %

$L_3 = 0{,}037$ mH ±10 %

$L_4 = L_5 = 1{,}5$ mH ±10 %

$C_1 = 100$ nF ±10 % for 240 V [C] *text deleted* [C]

$C_2 = 0{,}33$ µF ±10 %

$C_3 = C_4 = C_5 = C_6 = 0{,}002\ 2$ µF ±10 %

R = 330 kΩ ±10 %

Figure 14 – EMI filter description installed in Figure 13

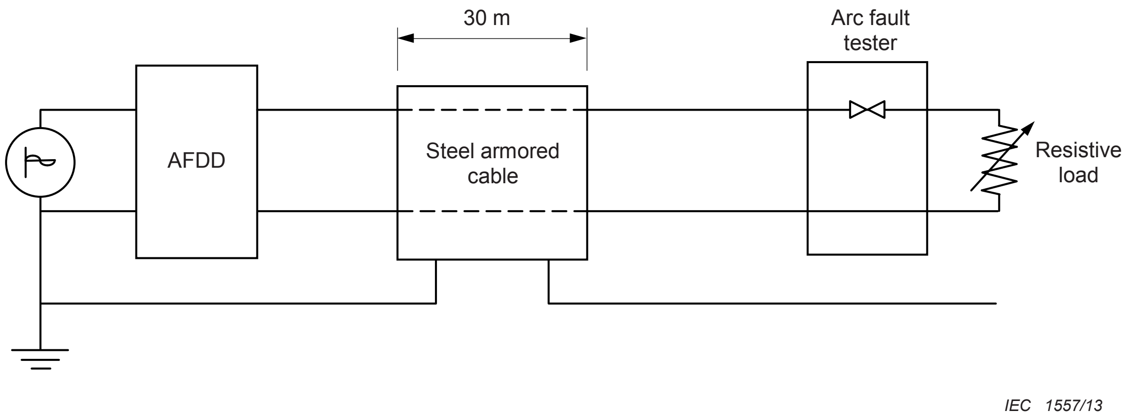


Figure 15 – Test circuit for masking tests with line impedance

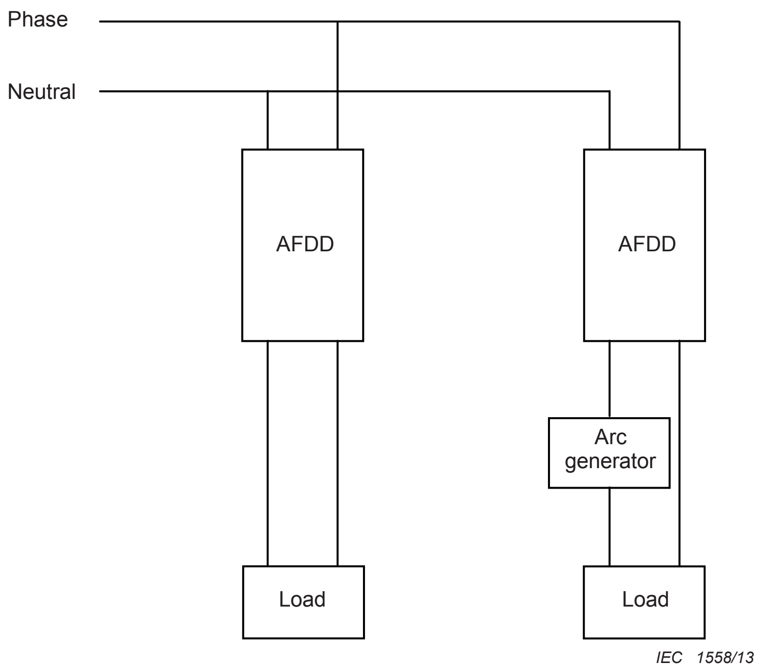


Figure 16 – Cross talk test

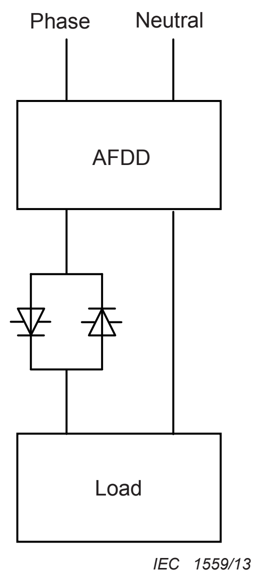
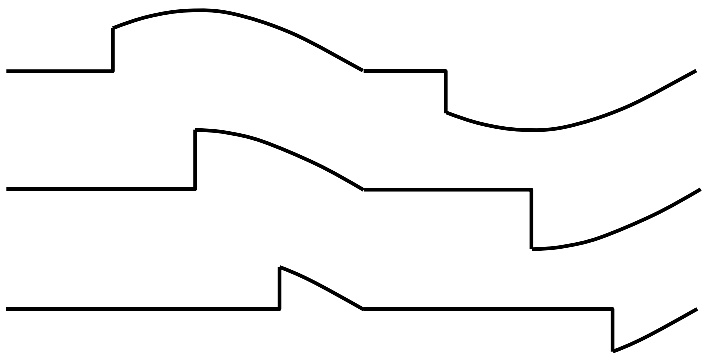


Figure 17 – Controlled current test circuit



IEC 1560/13

Figure 18 – Controlled current with delay angle 45 °, 90 ° and 135 °

Explanation of letter symbols used in Figures 19, 20 and 21

N = Neutral conductor

S = Supply

R = Adjustable resistor(s)

Z = Impedance in each phase for the calibration of the rated conditional short-circuit current. The reactors shall preferably be air-cored and connected in series with resistors in order to obtain the required power factor.

Z_1 = Adjustable impedance to obtain current below the rated conditional short-circuit current

Z_2 = Adjustable impedance for the calibration of I_Δ

P = Short-circuit protective device

D = Device under test

Frame = All conductive parts normally earthed in service, including FE, if any

G_1 = Temporary connection(s) for calibration

G_2 = Connection(s) for the test with rated conditional short-circuit current

T = Making switch for the short circuit

I_1, I_2, I_3 = Current sensor(s)May be situated on the supply or on the load side of device under test, but always on the secondary side of the transformer

I_4 = Additional residual current sensor, if needed

Ur_1 = Voltage sensor(s)

F = Device for the detection of a fault current

R_1 = Resistance drawing a current of approximately 10 A

R_2 = Resistor limiting the current in the device F

r = Resistor(s) taking approximately 0,6 % of the current (see 9.11.2.2)

S_1 = Auxiliary switch

B and C = Points for the connections of the grid(s) shown in Annex C

L = Adjustable air cored inductance(s)

The closing device T may alternatively be situated between the load side terminals of the device under test and current sensors I_1, I_2 and I_3 as applicable.

The adjustable load Z may be located at the high-voltage side of the supply circuit

Resistances R1 may be omitted with the agreement of the manufacturer.

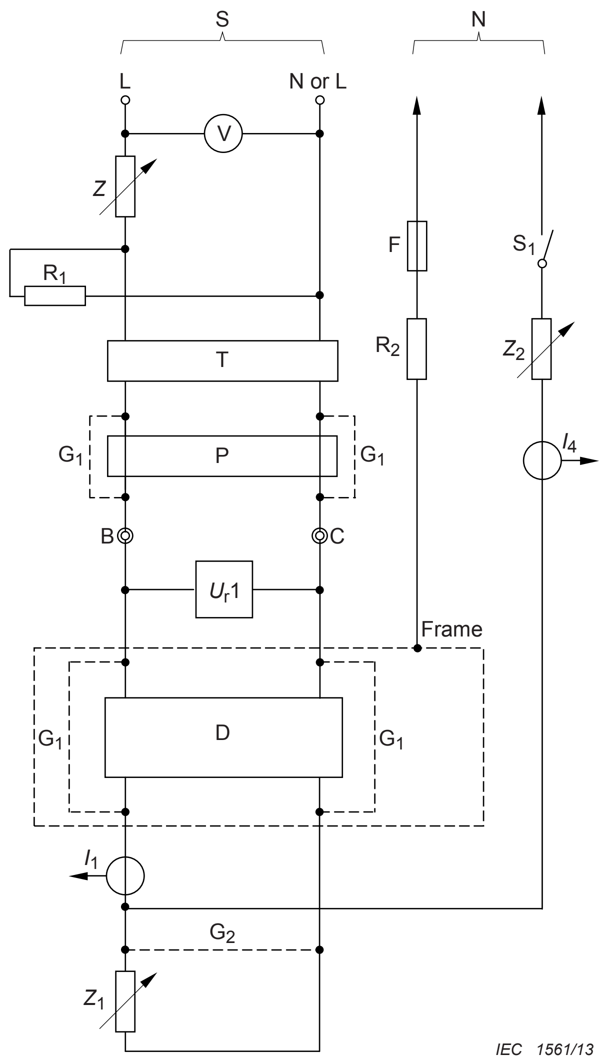


Figure 19 – Short circuit test

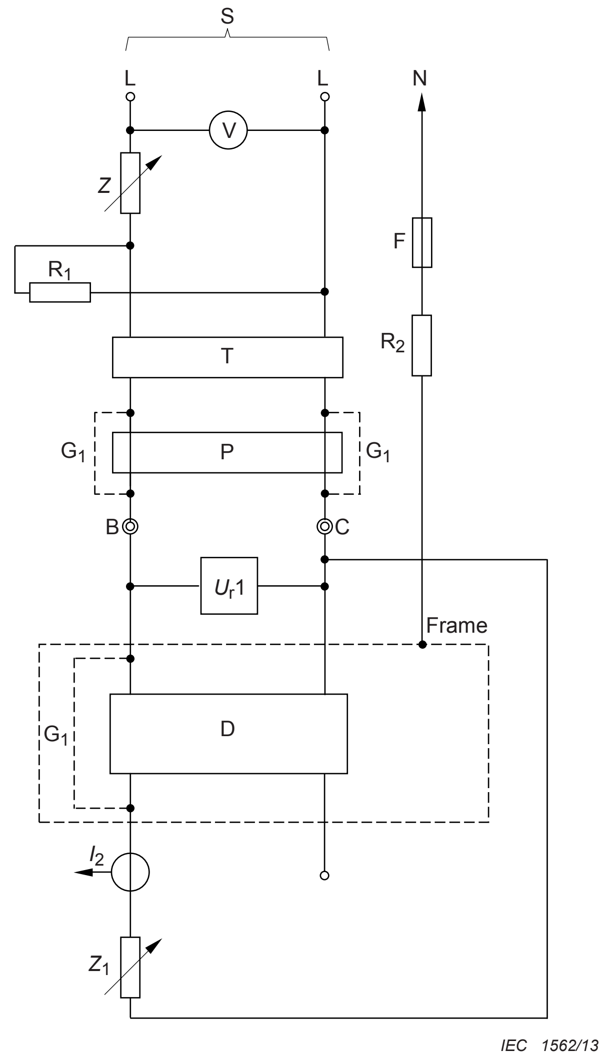


Figure 20 – Typical diagram for short circuit tests ((9.11.2.4c)

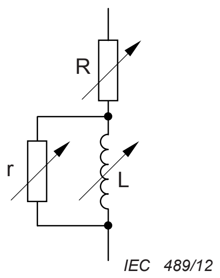
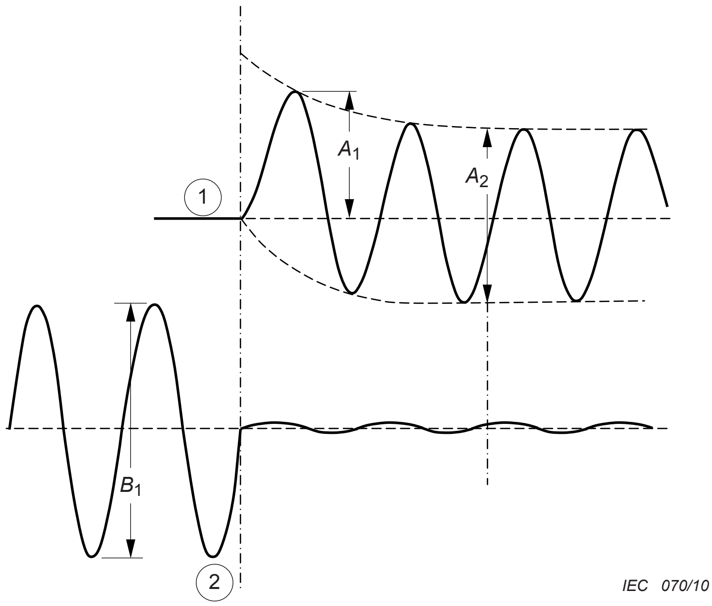


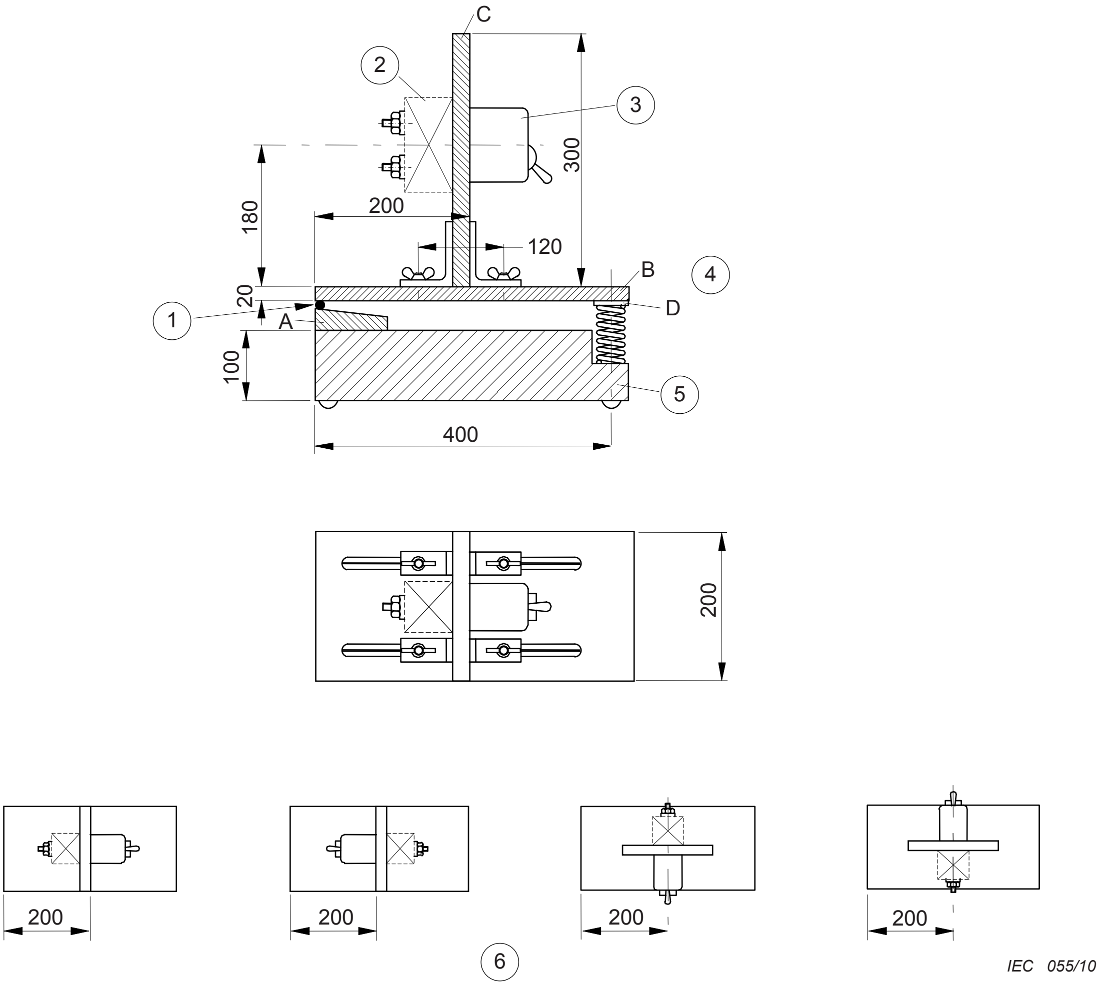
Figure 21 – Detail of impedance Z, Z_1 and Z_2



Key

1 Current
2 Voltage

Figure 22 – Example of calibration record for short-circuit test (9.11.2.2 j)

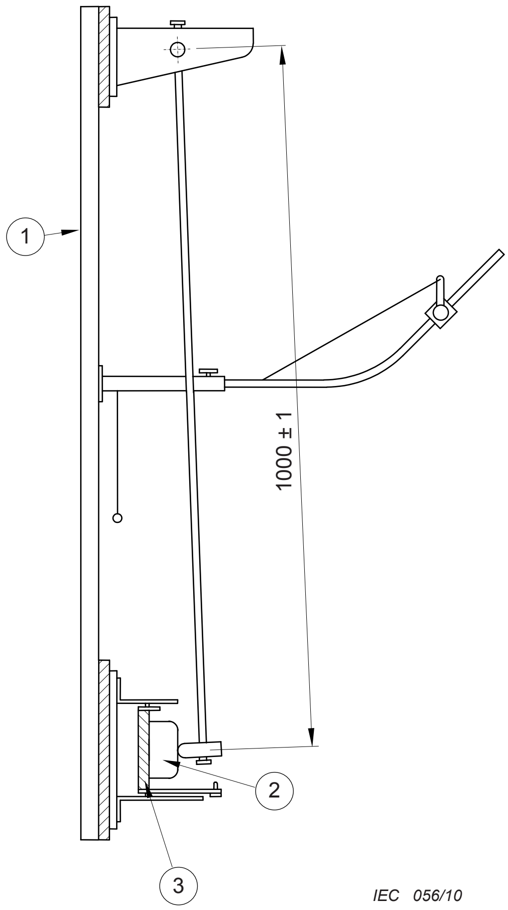


Dimensions in millimetres

Key

1 Hinge
2 Additional mass
3 Sample
4 Metal stop plate
5 Concrete block
6 Consecutive test positions

Figure 23 – Mechanical shock test apparatus (9.12.1)

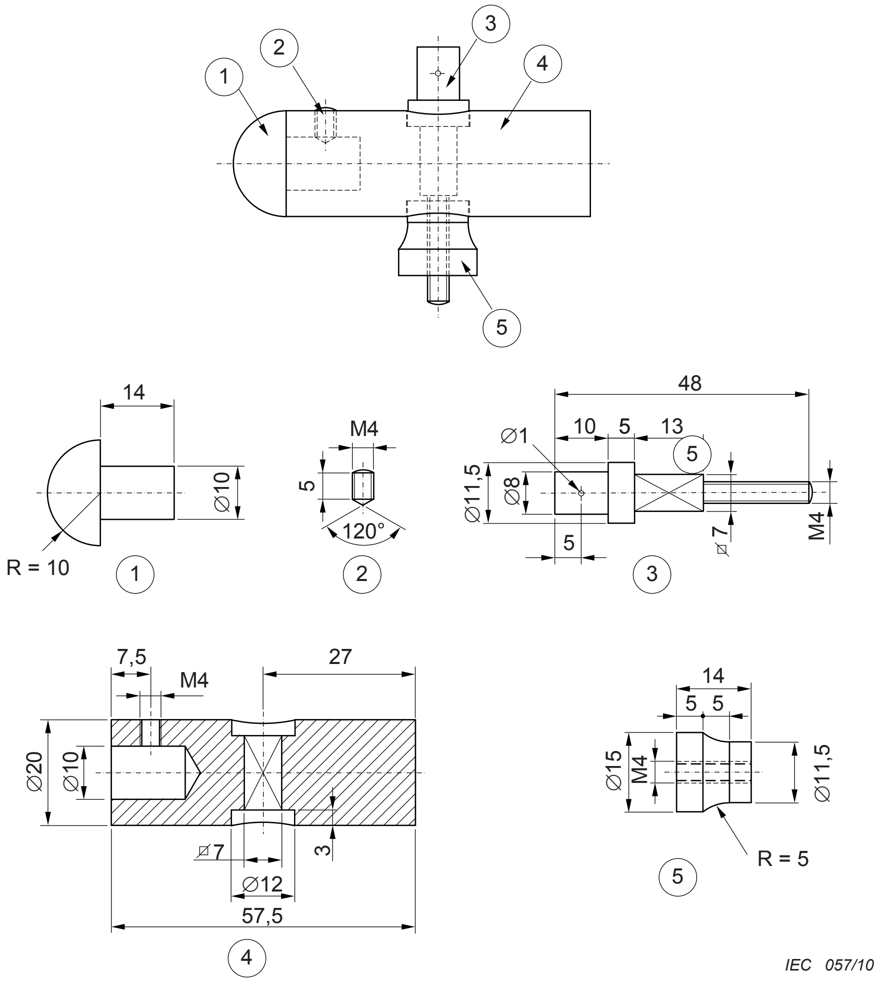


Dimensions in millimetres

Key

1	Frame
2	Sample
3	Mounting support

Figure 24 – Mechanical impact test apparatus (9.12.2.2)



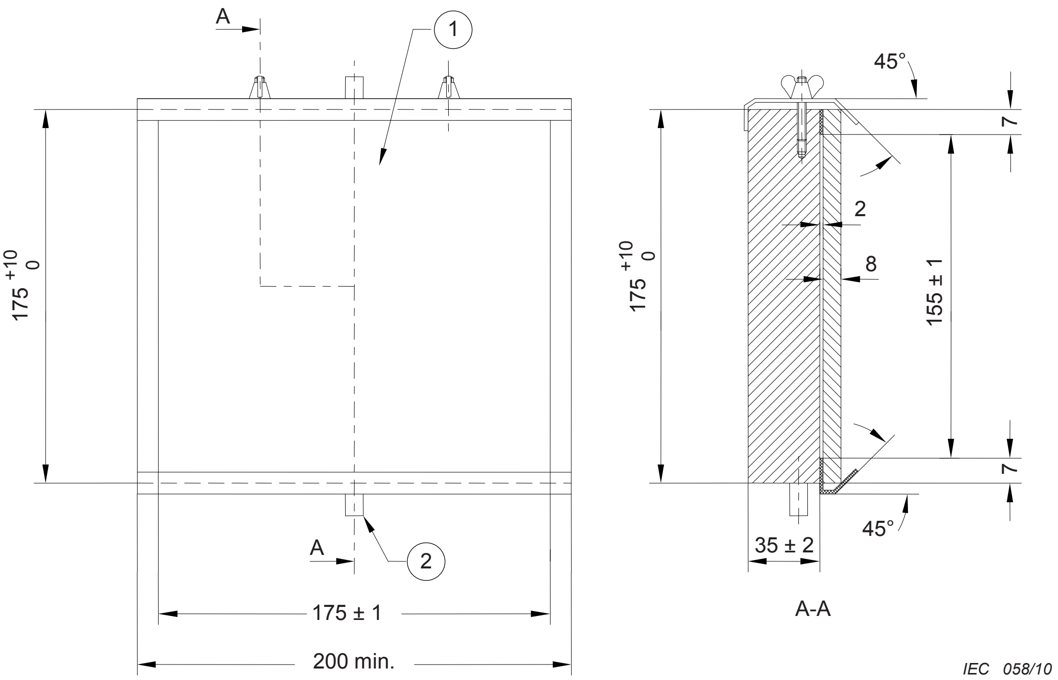
Dimensions in millimetres

Key

1 Polyamide

2, 3, 4, 5 Steel Fe 360

Figure 25 – Striking element for pendulum impact test apparatus (9.12.2.2)



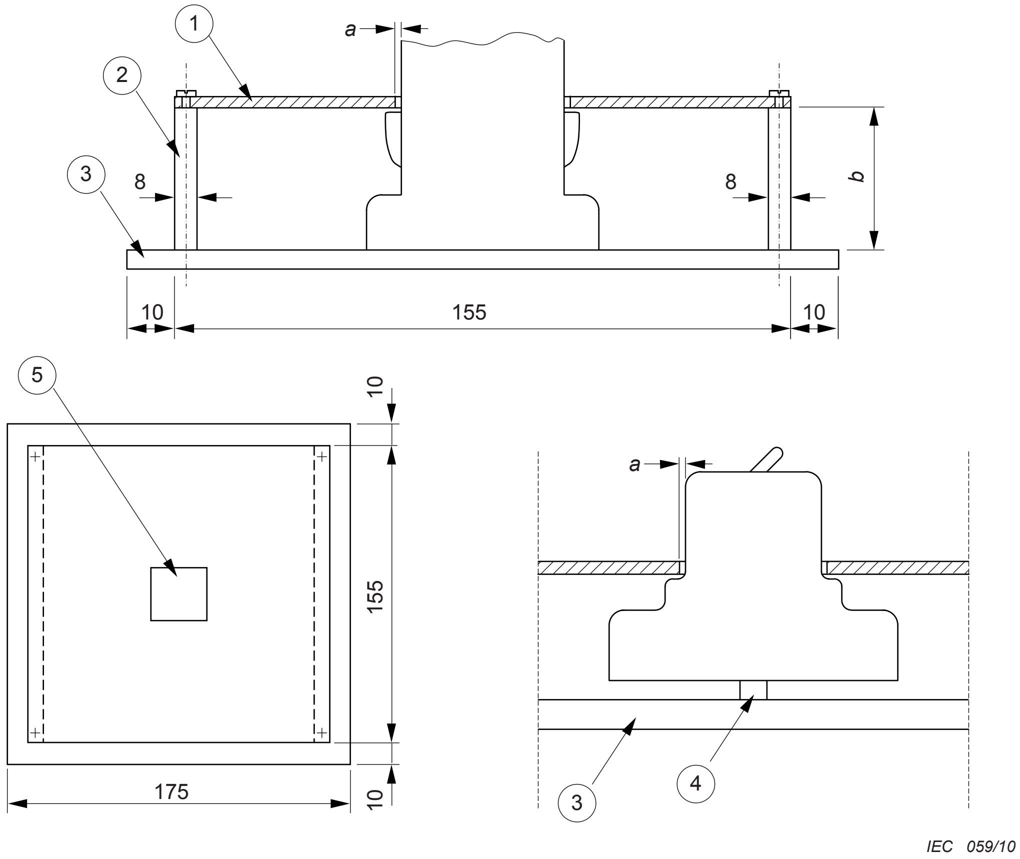
Dimensions in millimetres

Key

1 Sheet of plywood

2 Pivot

Figure 26 – Mounting support for sample for mechanical impact test (9.12.2.2)

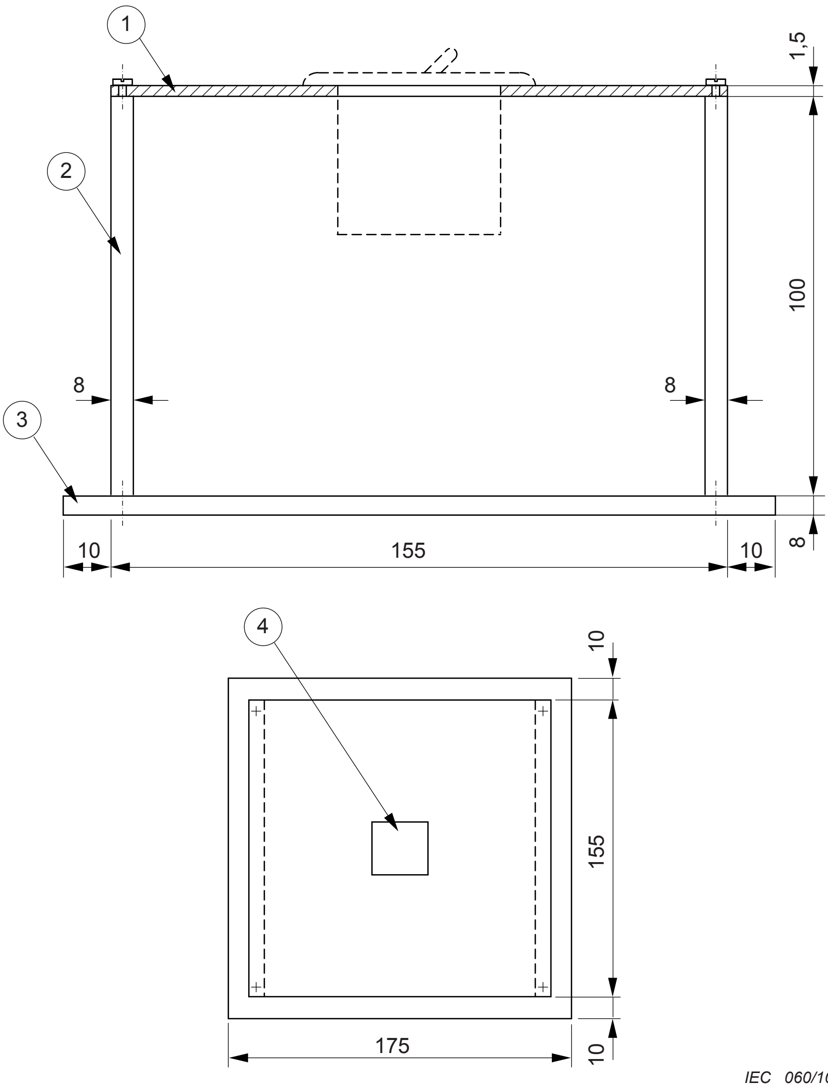


Dimensions in millimetres

Key

1 Interchangeable steel plate with a thickness of 1 mm
2 Aluminium plates with a thickness of 8 mm
3 Mounting plate
4 Rail for the AFDD designed to be mounted on a rail
5 Cut-out for the AFDD in the steel plate
a the distance between the edges of the cut-out and the faces of the AFDD shall be between 1 mm and 2 mm
b the height of the aluminium plates shall be such that the steel plate rests on the supports of the AFDD if the AFDD has no such supports, the distance from live parts, which are to be protected by an additional cover plate, to the underside of the steel, is 8 mm.

Figure 27 – Example of mounting of unenclosed AFDD for mechanical impact test (9.12.2.2)



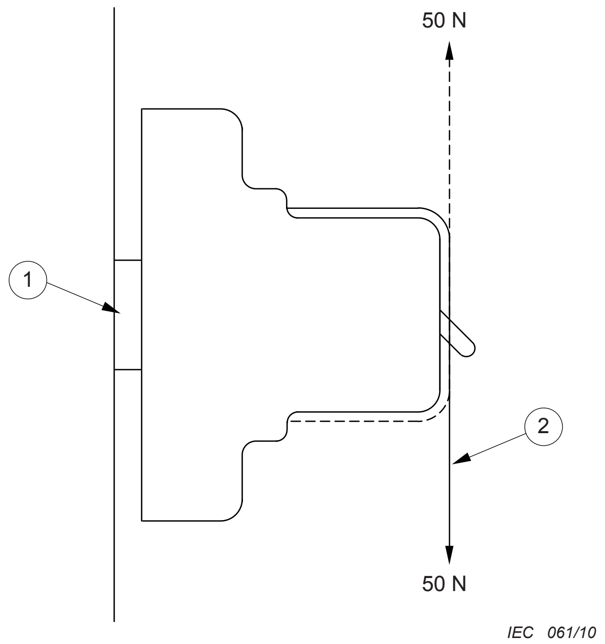
Dimensions in millimetres

Key

1 Interchangeable steel plate with a thickness of 1,5 mm
2 Aluminium plates with a thickness of 8 mm
3 Mounting plate
4 Cut-out for the AFDD in the steel plate

In particular cases the dimensions may be increased.

Figure 28 – Example of mounting of panel mounting type AFDD for the mechanical impact test (9.12.2.2)

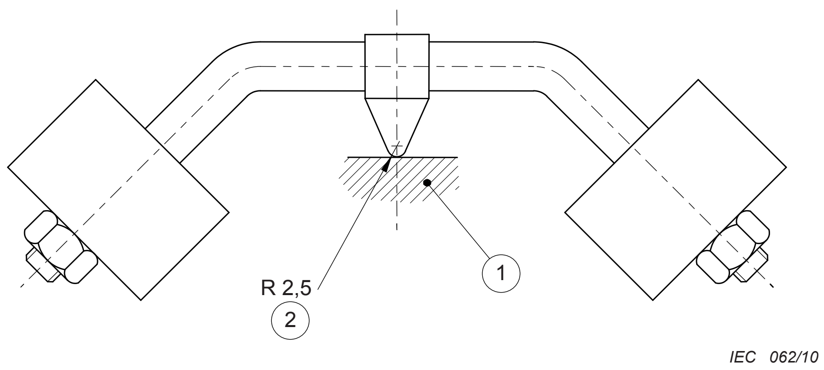


Key

1 Rail

2 Cord

Figure 29 – Application of force for mechanical test of rail mounted AFDD (9.12.2.3)



Key

1 Sample

2 Spherical

Figure 30 – Ball-pressure test apparatus (9.13.2)

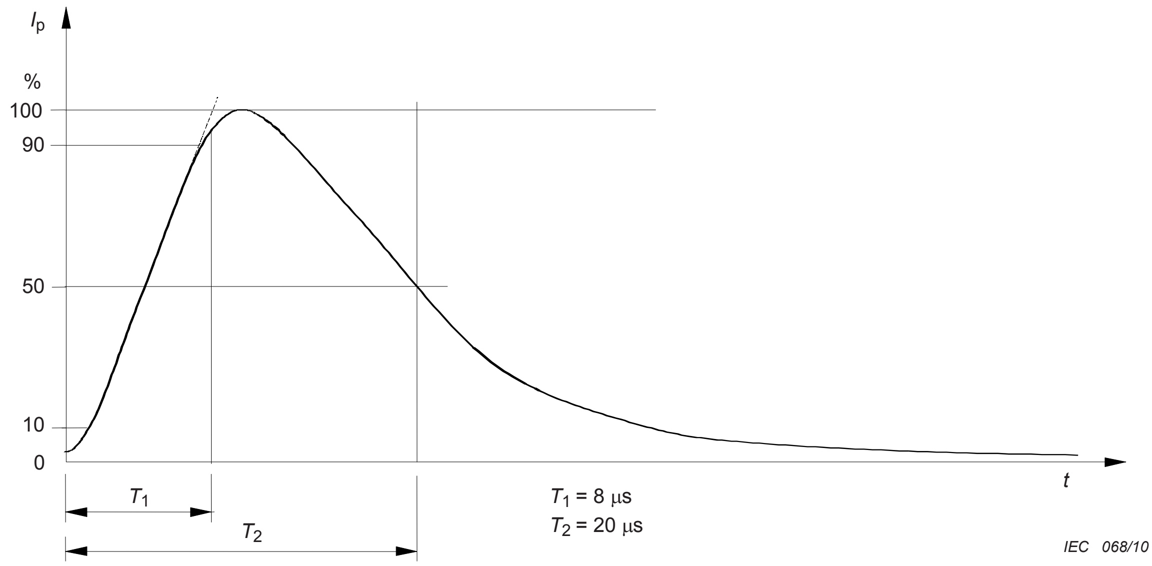
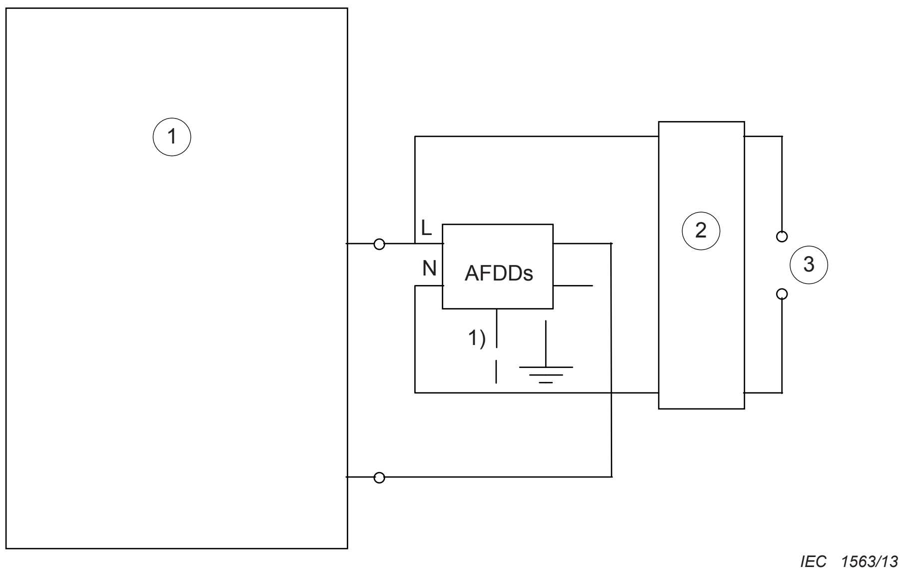


Figure 31 – Surge current impulse 8/20 µs



Key

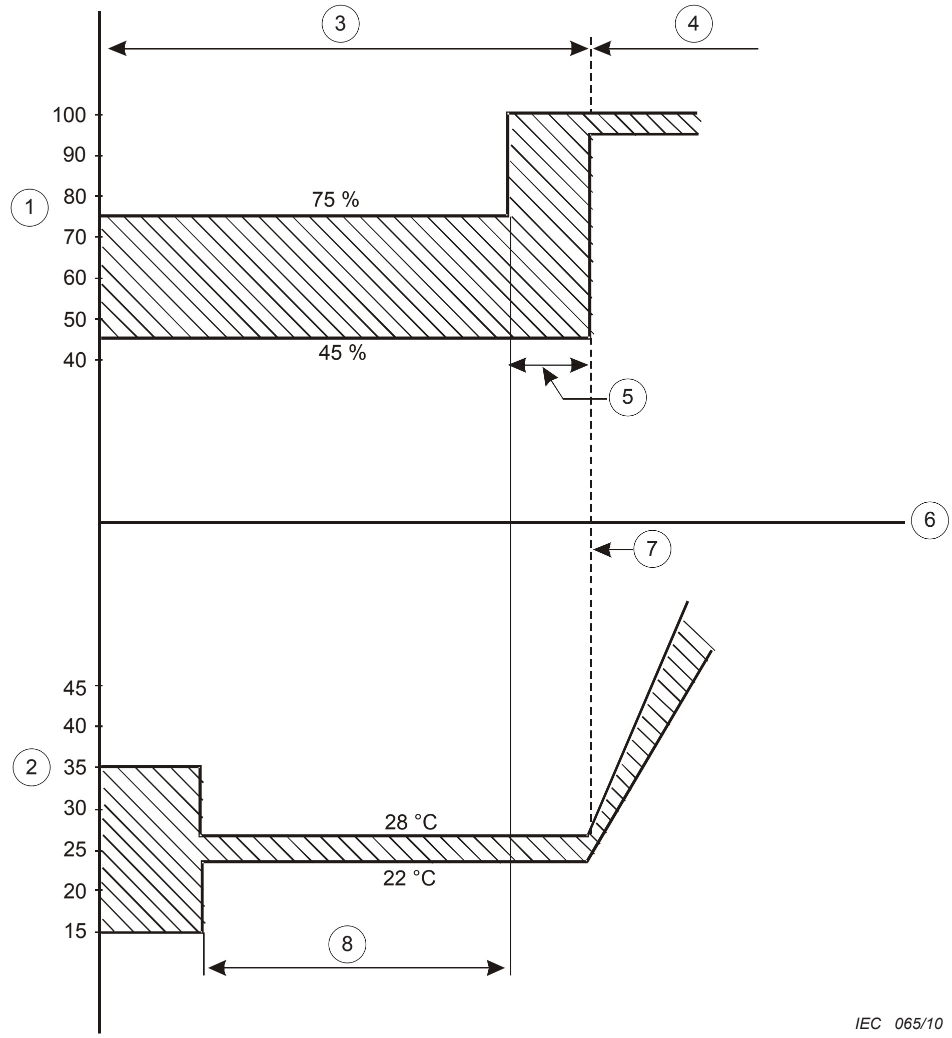
1 Surge current generator 8/20 µs

2 Filter

3 Supply

1) If the AFDD has an earthing terminal, it should be connected to the neutral terminal, if any, and if so marked on the AFDD or, failing that, to any phase terminal.

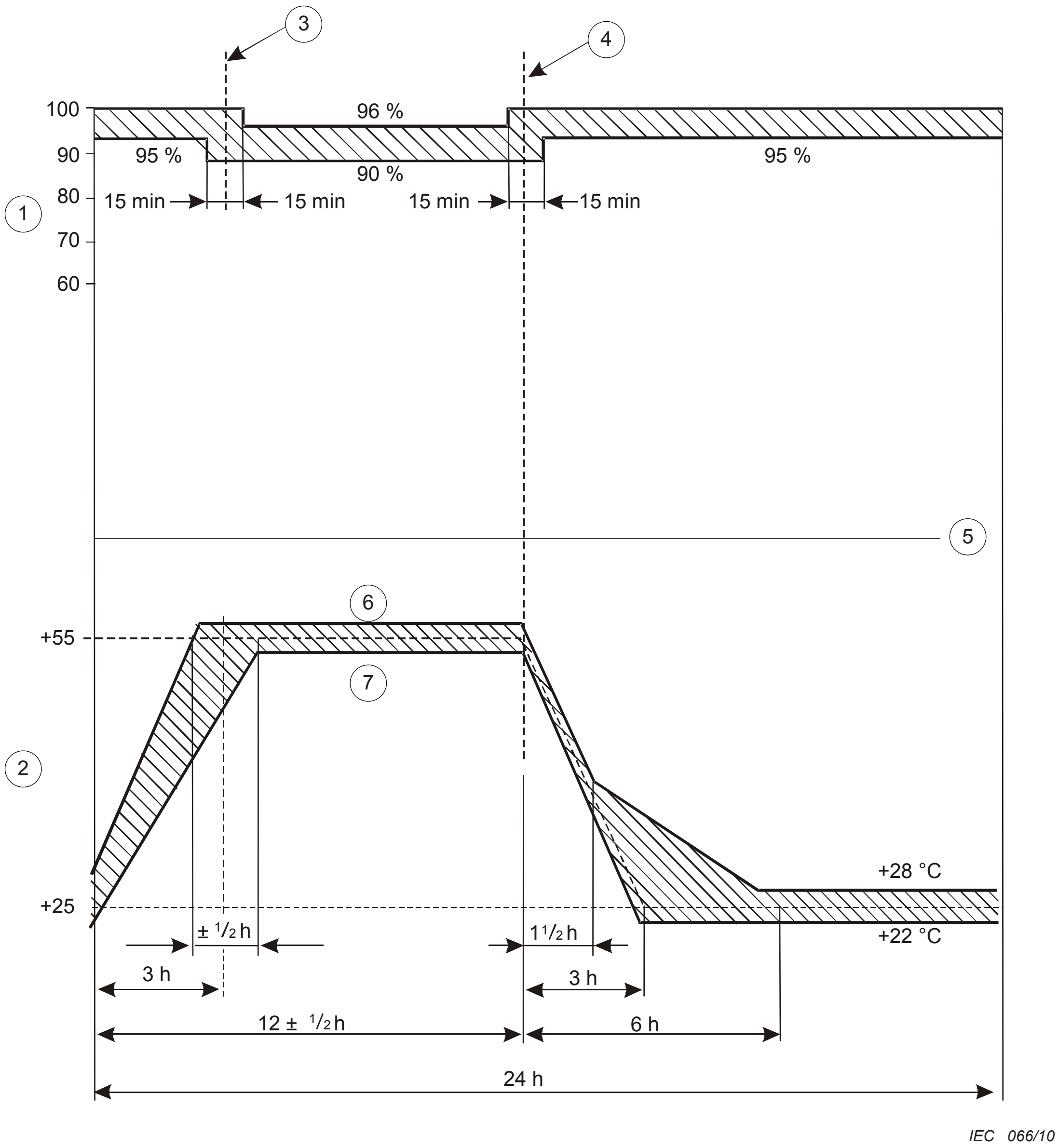
Figure 32 – Test circuit for the surge current test at AFDDs



Key

1 Relative humidity (%)
2 Ambient temperature (°C)
3 Stabilizing period
4 First cycle
5 Time required to reach 95 %-100 % relative humidity (not exceeding 1 h)
6 Time
7 Start of the first cycle
8 Time required for test specimen toreach temperature stability

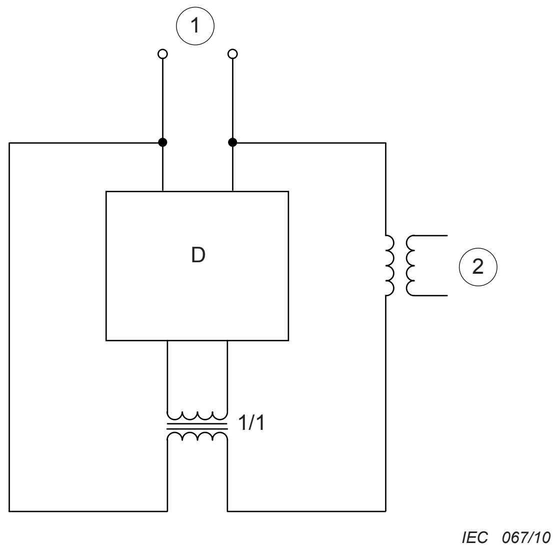
Figure 33 – Stabilizing period for reliability test (9.19.2.3)



Key

1 Relative humidity (%)
2 Ambient temperature (°C)
3 End of the temperature rise
4 Start of the temperature fall
5 Time
6 Upper temperature +57 °C
7 Lower temperature +53 °C

Figure 34 – Reliability test cycle (9.19.2.3)



Key

1 Supply at 1,1 U_n

2 Current supply

Figure 35 – Example for test circuit for verification of ageing of electronic components (9.20)

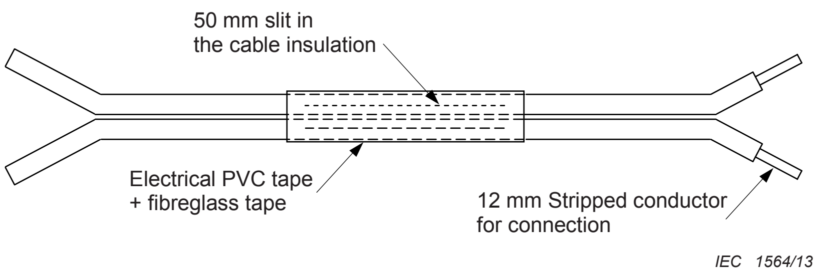


Figure 36 – Preparation of the cable specimens (9.9.2.6)

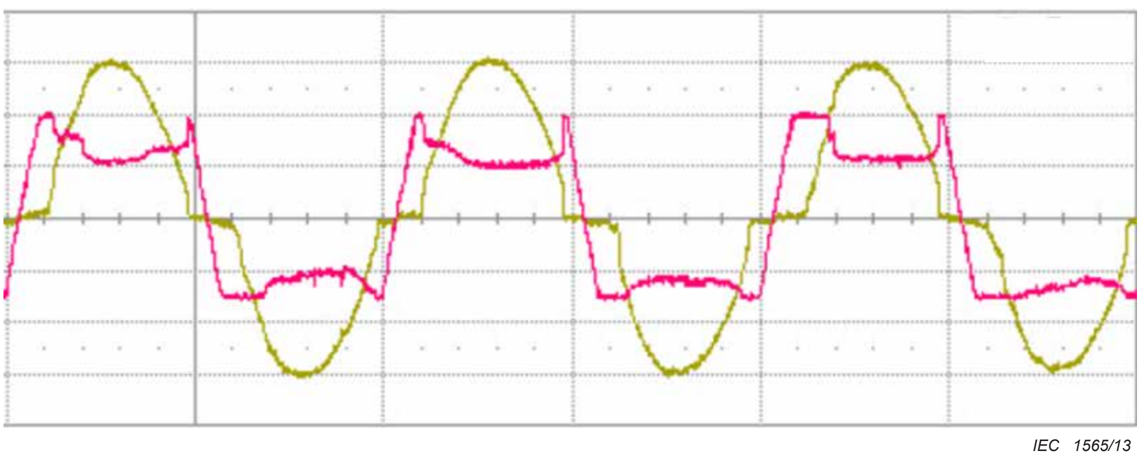


Figure 37 – Example of arc voltage and current waveform obtained with cable specimen

Annex A
(normative)

Test sequence and number of samples to be submitted for certification[1] purposes

A.1 Test sequences

The tests are made according to Table A.1 of this annex where the tests in each sequence are carried out in the order indicated.

For devices classified according to 4.1.1, tests sequences are given in Table A.1.

For devices classified according to 4.1.2, AFDDs shall first be tested according to IEC 60898-1, IEC 61008-1, IEC 61009-1, IEC 62423 or IEC 60269, as applicable. The additional tests sequences are given in Table A.2.

In case tests sequences included in this standard were also included in IEC 60898-1, IEC 61008-1, IEC 61009-1, or IEC 62423, the most stringent tests among all applicable standards shall be applied only once but the acceptance criteria combines the acceptance criteria of all applicable standard.

For devices classified according to 4.1.3, AFDDs shall first be assembled as declared by the manufacturer with the declared protective device(s).

Afterward, the testing procedure given in this standard together with the additional requirements and test given in Annex D shall be applied. The additional tests sequences are given in Table A.3.

In case the AFDDs are intended to be assembled with several protective devices, the testing procedure has to be either repeated with each protective device declared by the manufacturer or the most stringent tests among all applicable standards shall be applied only once but the acceptance criteria combines any acceptance criteria of any applicable standard

1 The term “certification” denotes either a Declaration of Conformity by the manufacturer, or a Third Party Certification, e.g. by an independent testing station.

Table A.1 – Test sequences for AFDDs classified according to 4.1.1

Test sequence	Clause or subclause	Test (or Inspection)
A	6	Marking
	8.2.1	General
	8.2.2	Mechanism
	9.3	Indelibility of marking
	8.2.3	Clearance and creepage distances (external parts only)
	9.15	Trip-free mechanism
	9.4	Reliability of screws, current-carrying parts and connections
	9.5	Reliability of terminals for external conductors
	9.6	Protection against electric shock
	9.13	Resistance to heat
	8.2.3	Clearances and creepage distances (internal parts)
	9.16	Resistance to rusting
A_2	9.14	Resistance to abnormal heat and to fire
B	9.7	Test of dielectric properties
	9.8	Temperature rise
	9.19.3	Reliability at 40 °C
	9.20	Ageing of electronic components
C	9.10	Mechanical and electrical endurance
D D_0	9.9.2	Operating characteristics (series arc fault)
	9.9.3	Operating characteristics (parallel arc fault)
D_1	9.9.4	Masking test
	9.9.5	Unwanted tripping
	9.18	Behaviour in the case of surge currents
	9.11.2.4 a) b)	Performance at I_{m1}
	9.12	Resistance to mechanical shock and impact
	9.17	Non-operating current under overcurrent conditions
D_2	9.11.2.4 c)	Verification of the suitability in IT-systems
E	9.11.2.5 a)	Coordination at I_{nc}
	9.11.2.3	Performance at I_m
F	9.11.2.5 b)	Coordination at I_m
	9.11.2.5 c)	Coordination at I_{nc1}
G	9.19.2	Reliability (climatic tests)
H [a]	IEC 61543:1995, Amendment 1:2005 Table 6 – T1.1	Harmonics, interharmonics
	IEC 61543:1995, Amendment 1:2005 Table 6 – T1.2	Signalling voltage
	9.21 Table 21 – T2.3	Surges
I	9.21 Table 21 – T2.1	Conducted sine-wave form voltages or currents
	9.21 Table 21 – T2.5	Radiated electromagnetic field
	9.21 Table 21 – T2.2	Fast transients (burst)

Test sequence	Clause or subclause	Test (or Inspection)
J	9.21 Table 21 – T2.6 9.21 Table 21 – T3.1	Conducted common mode disturbances in the frequency range lower than 150 kHz Electrostatic discharges
[a] For devices containing a continuously operating oscillator, the test of CISPR 14-1 shall be carried out on the samples prior to the tests of this sequence.		

Table A.2 – Test sequences for AFDDs classified according to 4.1.2

Test sequence	Clause or subclause	Test (or Inspection)
A	6	Marking
	8.2.1	General
	8.2.2	Mechanism
	9.3	Indelibility of marking
	8.2.3	Clearance and creepage distances (external parts only)
	9.15	Trip-free mechanism
	9.4	Reliability of screws, current-carrying parts and connections
	9.5	Reliability of terminals for external conductors
	9.6	Protection against electric shock
	9.13	Resistance to heat
	8.2.3	Clearances and creepage distances (internal parts)
	9.16	Resistance to rusting
A_2	9.14	Resistance to abnormal heat and to fire
B	9.7	Test of dielectric properties
	9.8	Temperature rise
	9.19.3	Reliability at 40 °C
	9.20	Ageing of electronic components
C	9.10	Mechanical and electrical endurance
D D_0	9.9.2	Operating characteristics (series arc fault)
	9.9.3	Operating characteristics (parallel arc fault)
D_1	9.9.4	Masking test
	9.9.5	Unwanted tripping
	9.18	Behaviour in the case of surge currents
	9.12	Resistance to mechanical shock and impact
	9.17	Non-operating current under overcurrent conditions
D_2	9.11.1	Verification of AFDDs after sequence C_2 of IEC 60898-1, or sequence D_2 of IEC 61008-1 or sequence C_2 of IEC 61009-1
E	9.11.1	Verification of AFDDs after sequence E_1 of IEC 60898-1, or sequence F of IEC 61008-1 or sequence F_0 of IEC 61009-1
F	9.11.1	Verification of AFDDs after sequence E_2 of IEC 60898-1, or sequence E of IEC 61008-1 or sequence F_1 of IEC 61009-1
G	9.19.2	Reliability (climatic tests)
H [a]	IEC 61543:1995, Amendment 1:2005 Table 6 – T1.1 IEC 61543:1995, Amendment 1:2005 Table 6 – T1.2 9.21 Table 21 – T2.3	Harmonics, interharmonics Signalling voltage Surges

Test sequence	Clause or subclause	Test (or Inspection)
I	9.21 Table 21 – T2.1 9.21 Table 21 – T2.5 9.21 Table 21 – T2.2	Conducted sine-wave form voltages or currents Radiated electromagnetic field Fast transients (burst)
J	9.21 Table 21 – T2.6 9.21 Table 21 – T3.1	Conducted common mode disturbances in the frequency range lower than 150 kHz Electrostatic discharges
[a] For devices containing a continuously operating oscillator, the test of CISPR 14-1 shall be carried out on the samples prior to the tests of this sequence.		

Table A.3 – Test sequences for AFDDs classified according to 4.1.3

Test sequence	Clause or subclause	Test (or Inspection)
A [b]	6, D.4 8.2.1, D.5.1 8.2.2 9.3 8.2.3 9.15 9.4 9.5 9.6 9.13 8.2.3 9.16 D.6.4	Marking General Mechanism Indelibility of marking Clearance and creepage distances (external parts only) Trip-free mechanism Reliability of screws, current-carrying parts and connections Reliability of terminals for external conductors Protection against electric shock Resistance to heat Clearances and creepage distances (internal parts) Resistance to rusting Verification for devices declared to be disassembled
A_2	9.14	Resistance to abnormal heat and to fire
B	9.7 9.8 9.19.3 9.20	Test of dielectric properties Temperature rise Reliability at 40 °C Ageing of electronic components
C	9.10	Mechanical and electrical endurance
D D_0 D_1	9.9.2 9.9.3 9.9.4 9.9.5 9.18 9.12 9.17	Operating characteristics (series arc fault) Operating characteristics (parallel arc fault) Masking test Unwanted tripping Behaviour in the case of surge currents Resistance to mechanical shock and impact Non-operating current under overcurrent conditions
D_2	9.11.1	Verification of AFDDs after sequence C_2 of IEC 60898-1, or sequence D_2 of IEC 61008-1 or sequence C_2 of IEC 61009-1
E	9.11.1	Verification of AFDDs after sequence E_1 of IEC 60898-1, or sequence F of IEC 61008-1 or sequence F_0 of IEC 61009-1
F	9.11.1	Verification of AFDDs after sequence E_2 of IEC 60898-1, or sequence E of IEC 61008-1 or sequence F_1 of IEC 61009-1
G	9.19.2	Reliability (climatic tests)
H [a]	IEC 61543:1995, Amendment 1:2005 Table	Harmonics, interharmonics

Test sequence	Clause or subclause	Test (or Inspection)
	6 – T1.1 IEC 61543:1995, Amendment 1:2005 Table 6 – T1.2 9.21 Table 21 – T2.3	Signalling voltage Surges
I	9.21 Table 21 – T2.1 9.21 Table 21 – T2.5 9.21 Table 21 – T2.2	Conducted sine-wave form voltages or currents Radiated electromagnetic field Fast transients (burst)
J	9.21 Table 21 – T2.6 9.21 Table 21 – T3.1	Conducted common mode disturbances in the frequency range lower than 150 kHz Electrostatic discharges

[a] For devices containing a continuously operating oscillator, the test of CISPR 14-1 shall be carried out on the samples prior to the tests of this sequence.

[b] Tests 9.3, 9.4, 9.5, 9.13, 9.14 and 9.15 are performed additionally on AFD unit according to D.6.2.

A.2 Number of samples to be submitted for full test procedure

If only one type of AFDDs of one current rating is submitted for test, the number of samples to be submitted to the different test series are those indicated in Table A.4 where the minimum performance criteria are also indicated.

If all samples submitted according to the second column of Table A.4 pass the tests, compliance with the standard is met. If the minimum numbers given in the third column only pass the tests, additional samples as shown in the fourth column shall be tested and all shall then satisfactorily complete the test sequence.

Table A.4 – Number of samples for full test procedure

Test sequence [a]	Number of samples	Minimum number of accepted samples [b]	Number of samples for repeated tests [c]
A	1	1	–
A_2	3	2	3
B	3	2	3
C	3	2	3
D_0	3	2 [d]	3
D_1	3	2 [d]	3
D_2	3	3	3
E	3	2 [d]	3
F	3	2 [d]	3
G	3	2	3
H [e]	3	2	3
I [e]	3	2	3
J [e]	3	2	3

[a] In total, a maximum of three test sequences may be repeated.

[b] It is assumed that a sample which has not passed a test has not met the requirements due to workmanship or assembly defects which are not representative of the design.

[c] In the case of repeated tests, all test results must be acceptable.

[d] All samples shall meet the requirements in 9.9.2, 9.9.3, and 9.11.2.4, as appropriate. In addition, permanent arcing or flashover between poles or between poles and frame shall not occur in any sample during tests of 9.11.2.3, 9.11.2.5 a), 9.11.2.5 b) or 9.11.2.5 c).

[e] On request of the manufacturer, the same set of samples may be subjected to more than one of these test sequences.

A.3 Number of samples to be submitted for simplified test procedures in case of submitting simultaneously a range of AFDDs of the same fundamental design

A.3.1 If a range of AFDDs of the same fundamental design, or additions to such a range of AFDDs are submitted for certification, the number of samples to be tested may be reduced according to Table A.5.

NOTE For the purposes of this annex, the same fundamental design comprises a series of rated current (I_n) and/or different number of poles.

AFDDs can be considered to be of the same fundamental design if all of the following conditions are met:

1) they have the same basic design;
2) the operating means have identical tripping mechanism;
3) the materials, finish and dimensions of the internal current carrying parts are identical other than the variations detailed in a) below;
4) the terminals are of similar design (see b) below);
5) the contact size, material, configuration and method of attachment are identical;
6) the manual operating mechanism, materials and physical characteristics are identical;
7) the moulding and insulating materials are identical;
8) the method, materials and construction of the extinction device are identical;
9) the basic design of the current sensing device is identical, for a given type of characteristic other than the variations permitted in c) below;
10) the basic design of the test device, if any, is identical.

The following variations are permitted provided that AFDDs comply in all other respects to the requirements detailed above:

a) cross sectional area of the internal current carrying connections, and lengths of the toroid connections;
b) size of terminals;
c) number of turns and cross sectional area of the windings and the size and material of the core of the current sensor as far as applicable.

A.3.2 For AFDDs having the same classification according to the method of construction (4.1), having different current rating, the number of samples to be tested may be reduced, according to Table A.5.

Table A.5 – Number of samples for simplified test procedure

Test sequence	Number of samples [a] [b]
A	1 max. rating I_n
B	3 max. rating I_n
C D_0 D_1 D_2	3 max. rating I_n 3 max. rating I_n 3 max. rating I_n 3 max. rating I_n
E	3 max. rating I_n
F	3 max. rating I_n 3 min. rating I_n
G	3 max. rating I_n 3 min. rating I_n
H	3 samples of the same rating In chosen at random [c]
I	3 samples of the same rating In chosen at random [c]
J	3 samples of the same rating In chosen at random [c]

[a] If a test is to be repeated according to the minimum performance criteria of Clause A.2, a new set of samples is used for the relevant test. In the repeated test, all test results shall be acceptable.

[b] Also applicable to 1-pole AFDDs with uninterrupted neutral and to 2-pole AFDDs with 1 protected pole.

[c] Only the highest number of current paths.

Annex B
(normative)

Determination of clearances and creepage distances

In determining clearances and creepage distances, it is recommended that the following points should be considered.

B.1 Orientation and location of a creepage distance

If necessary, the manufacturer shall indicate the intended orientation of the equipment or component in order for creepage distances to not be adversely affected by the accumulation of pollution for which they were not designed.

B.2 Creepage distances where more than one material is used

A creepage distance may be split in several portions of different materials and/or have different pollution degrees if one of the creepage distances is dimensioned to withstand the total voltage or if the total distance is dimensioned according to the material having the lowest CTI.

B.3 Creepage distances split by floating conductive part

A creepage distance may be split into several parts, made with insulation material having the same CTI, including or separated by floating conductors as long as the sum of the distances across each individual part is equal or greater than the creepage distance required if the floating part did not exist.

The minimum distance X for each individual part of the creepage distance is given in 6.2 (see also Example 11) of IEC 60664-1:2007.

B.4 Measurement of creepage distances and clearances

In determining creepage distances according to IEC 60664-1:2007, the dimension X, specified in the following examples, has a minimum value of 1,0 mm for pollution degree 2.

If the associated clearance is less than 3 mm, the minimum dimension X may be reduced to one third of this clearance.

The methods of measuring creepage distances and clearances are indicated in the following Examples 1 to 11. These cases do not differentiate between gaps and grooves or between types of insulation.

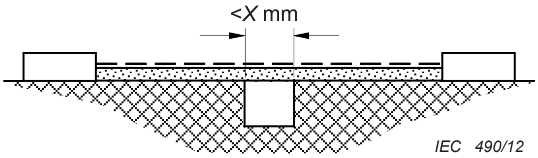
The following assumptions are made:

– any recess is assumed to be bridged with an insulating link having a length equal to the specified width X and being placed in the most unfavourable position (see Example 3);
– where the distance across a groove is equal to or larger than the specified width X, the creepage distance is measured along the contours of the groove (see Example 2);
– creepage distances and clearances measured between parts which can assume different positions in relation to each other, are measured when these parts are in their most unfavourable position.

— — — Clearance

Creepage distance

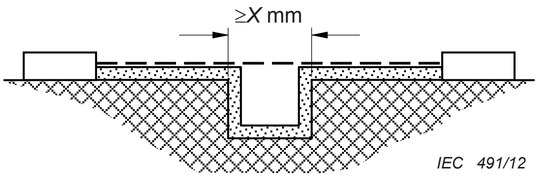
Example 1



Condition: Path under consideration includes a parallel- or converging-sided groove of any depth with a width less than *X* mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

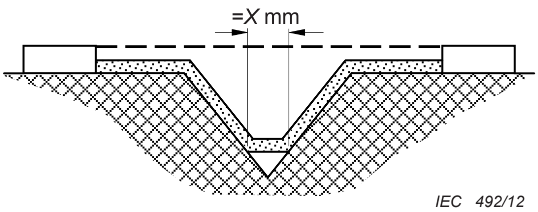
Example 2



Condition: Path under consideration includes a parallel-sided groove of any depth and and with width equal to or more than *X* mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove.

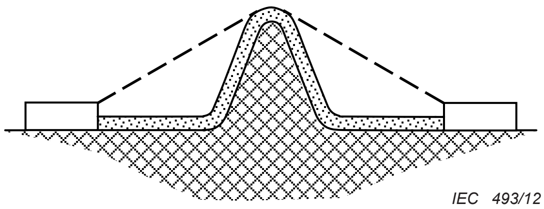
Example 3



Condition: Path under consideration includes a V-shaped groove with a width greater than *X* mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove but "short-circuits" the bottom of the groove by *X* mm link.

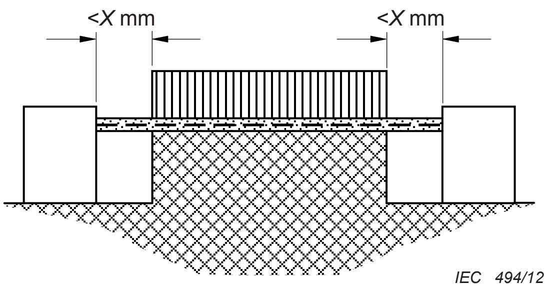
Example 4



Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib.

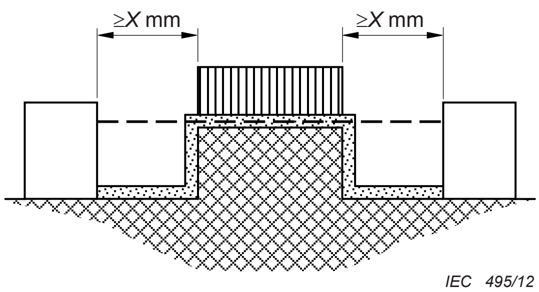
Example 5



Condition: Path under consideration includes an uncemented joint with grooves less than *X* mm wide on each side.

Rule: Creepage and clearance path is the "line of sight" distance shown.

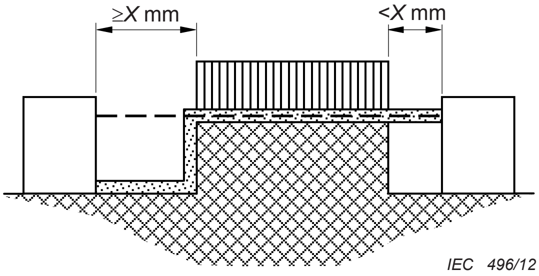
Example 6



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than *X* mm wide on each side.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the grooves.

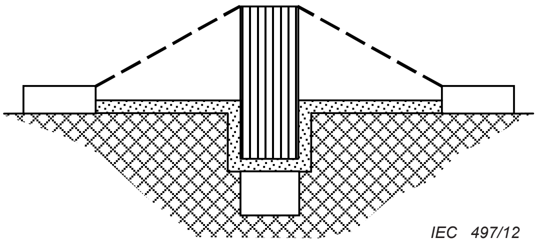
Example 7



Condition: Path under consideration includes an uncemented joint with a groove on one side less than *X* mm wide and the groove on the other side equal to or more than *X* mm wide.

Rule: Clearance and creepage paths area as shown.

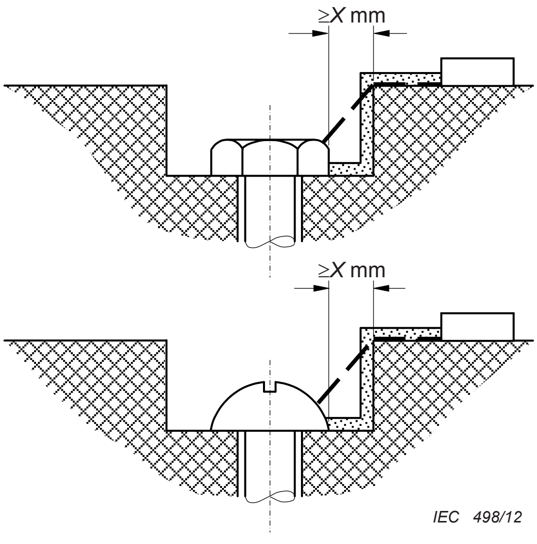
Example 8



Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

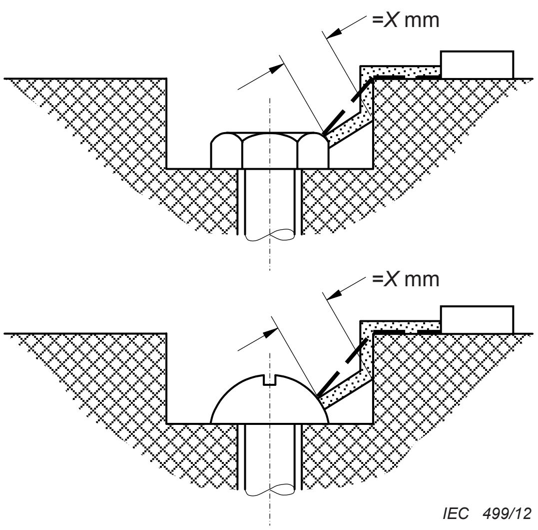
Rule: Clearance is the shortest direct air path over the top of the barrier.

Example 9



Gap between head of screw and wall of recess wide enough to be taken into account.

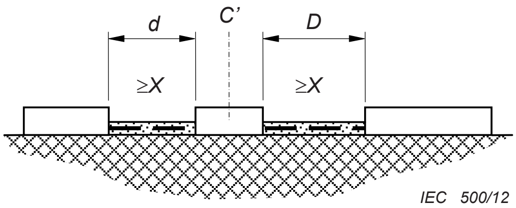
Example 10



Gap between head of screw and wall of recess too narrow to be taken into account.

Measurement of creepage distance is from screw to wall when the distance is equal to *X* mm.

Example 11



C' floating part

Clearance is the distance = $d + D$

Creepage distance is also = $d + D$

Annex C
(normative)

Arrangement for the detection of the emission of ionized gases during short-circuit tests

The device under test is mounted as shown in Figure C.1 which may require adapting to the specific design of the device, and in accordance with the manufacturer's instructions.

When required (i.e. during "O" operations), a clear polyethylene sheet (0,05 ± 0,01) mm, of a size at least 50 mm larger, in each direction, than the overall dimensions of the front face of the device, but not less than 200 mm × 200 mm, is fixed and reasonably stretched in a frame, placed at a distance of 10 mm from

– either the maximum projection of the operating means of a device without recess for the operating means;
– or the rim of a recess for the operating means of a device with recess for the operating means.

The sheet should have the following physical properties:

Density at 23 °C: 0,92 g/cm^3 ± 0,05 g/cm^3;

Melting point: 110 °C to 120 °C.

When required, a barrier of insulating material, at least 2 mm thick, is placed, as shown in figure C.1, between the arc vent and the polyethylene foil to prevent damage of the foil due to hot particles emitted from the arc vent.

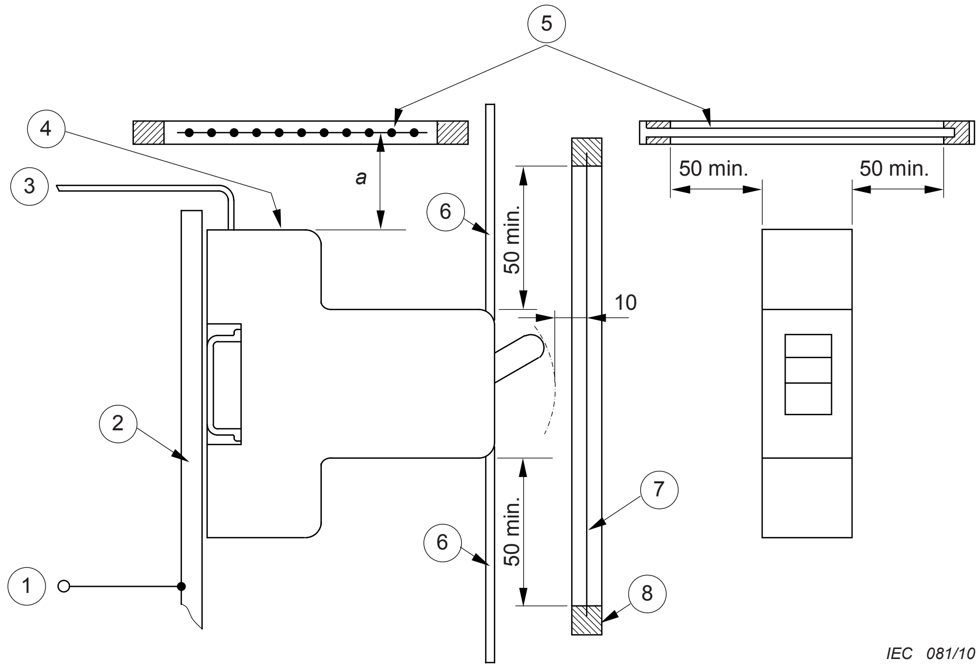
When required, a grid (or grids) according to Figure C.2, is (are) placed at a distance of "a" mm from each arc vent side of the device.

The grid circuit (see Figure C.3) shall be connected to the points B and C.

The parameters for the grid circuit(s) are as follows:

Resistor R′: 1,5 Ω

Copper wire F′: length 50 mm and diameter in accordance with 9.11.2.2 f)1).

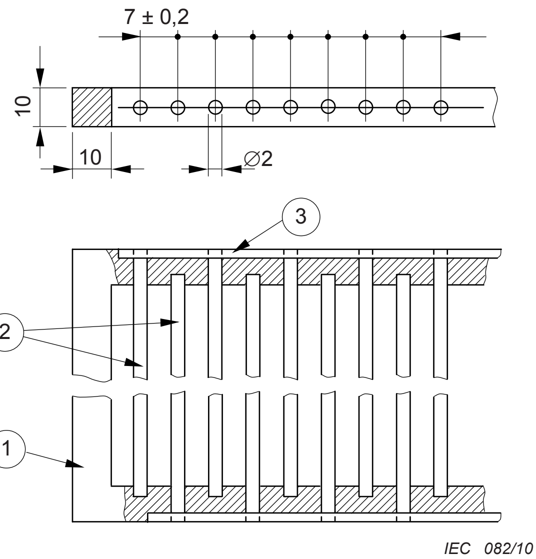


Dimensions in millimetres

Key

1 To the fuse F
2 Metal plate
3 Cable
4 Arc vent
5 Grid
6 Barrier
7 Polyethylene sheet
8 Frame

Figure C.1 – Test arrangement



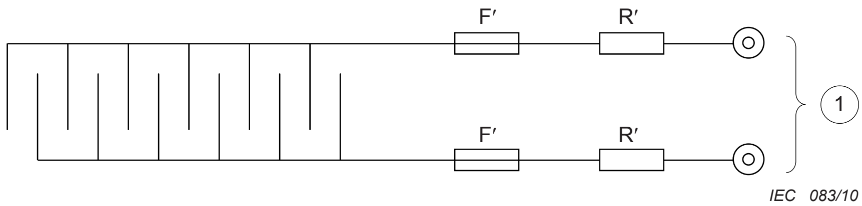
Key

1 Frame of insulating material

2 Copper wires

3 Metal interconnection of copper wires

Figure C.2 – Grid



Key

1 Connected to points B and C

Figure C.3 – Grid circuit

Annex D
(normative)

Additional requirements and tests for AFDDs according to the classification 4.1.3 designed to be assembled on site together with a main protective device (circuit-breaker or RCCB or RCBO)

D.1 General

The main body of this standard applies in all respects to devices covered by this annex, unless otherwise specified.

D.2 Scope

This annex applies to AFDDs consisting of an arc fault detection unit (AFD unit), which may also include residual current protection, designed for being mechanically assembled on site in accordance with the manufacturer's instructions to one or more declared protective device(s) which can be either a circuit breaker in compliance with IEC 60898-1, or a RCD in compliance with IEC 61008-1, IEC 61009-1 or IEC 62423.

The manufacturer shall declare which types of AFD units and protective device(s) are suitable to be assembled all together.

D.3 Terms and definitions

Void

D.4 Marking and other product information

D.4.1 Manufacturer's name or trade mark

With reference to Clause 6 item a) of this standard, the circuit-breaker and / or the RCD and the AFD unit with which it is to be assembled shall bear the same manufacturer's name or trade mark.

D.4.2 Marking

D.4.2.1 Marking of the circuit-breaker or RCD

Marking of the circuit-breaker shall be in accordance with IEC 60898-1.

Marking of the RCD shall be in accordance with IEC 61008-1, IEC61009-1 or IEC 62423, as applicable.

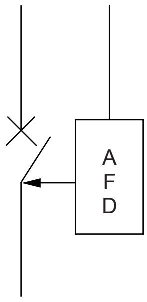
D.4.2.2 Marking of the AFD unit

The AFD unit shall be marked with the following items, with reference to Clause 6, Table 5 of this standard:

a), b), c), d) and g)

In addition, the AFD unit shall be marked with

– the maximum rated current of the circuit-breaker or RCD with which it may be assembled (e.g. 16 A max.)
– the symbol (AFD may also be shown on the left side of the breaker)



For AFD units also including residual current protection, the following items shall be marked with the following:

– rated residual operating current (visible when the device is installed);
– the symbol (S in a square) for type S devices (visible when the device is installed);
– indication that the RCCB is functionally dependent on line voltage, if applicable (under consideration);
– operating means of the test device, by the letter T (visible when the device is installed);
– wiring diagram;
– operating characteristics in presence of residual currents with d.c. components (visible when the device is installed);
– RCCBs of type AC with the symbol  IEC 60417-6148 (2012-01);
– RCCBs of type A with the symbol  IEC 60417-6149 (2012-01);
– RCCBs of type B with the symbol  IEC 60417-6149 (2012-01) and IEC 60417-5031 (2002-10).

It is recommended that the references of the circuit-breakers and/or RCD with which the AFD unit can be assembled be marked.

D.4.2.3 Marking of the assembled circuit-breaker or RCD and AFD unit (AFDD)

The following marking on the AFD unit specified in D.4.2.2 shall not be visible after assembly:

– c);
– maximum rated current of the circuit-breaker with which the AFD unit may be assembled.

Marking h) of the AFD unit, if applicable, shall remain visible after assembly.

D.4.3 Instructions for assembly and operation

The manufacturer shall provide adequate instructions with the AFD unit. These instructions shall cover at least the following:

– reference to the type(s) and catalogue number(s), covering current and voltage ratings, number of poles, etc. of the circuit-breakers or RCDs with which the AFD unit is designed to be assembled;

NOTE The number of paths of the circuit breaker or RCD corresponds to the number of paths of the AFD unit. A neutral terminal or link may take the place of the neutral pole of a circuit-breaker or RCD.

– derating factor if any;

– method of assembly;
– need for checking operation after assembly to verify the mechanical operation.

D.5 Constructional requirements

D.5.1 General

The design shall be such that it shall be possible to assemble the AFDD on site.

Design may be such that the device may be disassembled on site in accordance with the manufacturer's instructions.

For devices declared not suitable for disassembling, the disassembly shall leave permanent visible damage.

Compliance is checked according to D.6.4.

D.5.2 Degree of protection

D.5.2.1 General

The degree of protection of the AFD unit shall be no less than that of the circuit-breaker or RCD with which it is to be assembled.

D.5.2.2 Mechanical requirements

The circuit-breaker or RCD and the AFD unit shall fit together readily in the correct manner, and the design shall be such as to prevent an incorrect assembly.

There shall be no loose parts for coupling the tripping mechanisms.

Fixing means for assembly shall be captive.

Terminal covers, if any, are not covered by this requirement.

D.5.3 Electrical compatibility

It shall not be possible to use a circuit-breaker or RCD of a given rated voltage with an AFD unit of a lower rated voltage.

NOTE An incorrect combination can be excluded by mechanical or electrical design.

It shall not be possible to assemble a circuit-breaker or RCD of a given rated current with a AFD unit of a lower maximum current marking (see D.4.2.2).

The terminals of the AFD unit shall be able to clamp the range of nominal cross-sections of conductors specified in Table 7 of IEC 60898-1:2002 for the rated currents of the circuit-breakers or in Table 8 of IEC 61008-1:2008 with which it is designed to be assembled.

The electrical interconnections between the AFD unit and the circuit-breaker or RCD with which it is to be assembled shall form part of the AFD unit.

It shall not be possible to assemble a circuit-breaker or RCD of a given rated short-circuit capacity with an AFD unit so as to result in a lower short-circuit performance.

Compliance is checked by inspection and manual test.

D.6 Type tests and verifications

D.6.1 Tests on circuit-breakers and RCDs

The circuit-breakers intended to be assembled with the AFD unit shall comply with the type tests of IEC 60898-1.

The RCDs intended to be assembled with the AFD unit shall comply with the type tests of IEC 61008-1, IEC61009-1 or IEC 62423, as applicable.

D.6.2 Tests on AFD units

The AFD units shall comply with the following type tests specified in Table 10 of 9.1.2 of this standard: tests of 9.3, 9.4, 9.5, 9.13, 9.14 and 9.15.

D.6.3 Tests on assembled AFDDs

For AFD units with an integrated residual current protection shall first be tested according to IEC 61008-1, IEC 61009-1 or IEC 62423, as applicable. After completion of these tests, the additional tests specified in Table 10 of 9.1.2 given in this standard shall be applied in order to show conformity to this standard.

In case of AFD units intended to be assembled with several protective devices or AFD units with integrated residual current protection, the testing procedure has to be either repeated with each protective device declared by the manufacturer or the most stringent tests among all applicable standards shall be applied only once but the acceptance criteria combines any acceptance criteria of any applicable standard.

The type tests specified in Table 10 of 9.1.2 of this standard apply to AFDDs covered by this annex except as follows:

– 9.3, 9.5, 9.13 and 9.14 do not apply;
– 9.4: tests shall be made on the interconnections between the circuit-breaker or RCD and the AFD unit.

D.6.4 Verification of marking and constructional requirements of AFDDs

Compliance with the requirements of D.4.1, D.4.2, D.4.3, D.5.1, D.5.2, D.5.3 and D.5.4 shall be checked by inspection and manual test, as applicable.

For devices declared suitable to be disassembled, compliance with the requirements of D.5.1 is checked by the following test to be performed at the beginning of test sequence D_0 in Table A.1.

The number of samples shall be in accordance with test sequence $D_0 + D_1$ in Table A.4.

The AFD unit and compatible circuit-breakers or RCDs, as declared by the manufacturer, have to be assembled and disassembled 5 times. The AFD unit and the compatible circuit breaker or RCDs are then reassembled and used for the test of test sequence D0. After each assembly the correct operation of the combination shall be verified for RCDs by using the test button and for circuit breakers with the upper limit of the instantaneous tripping current. The AFDD shall trip each time.

D.7 Routine tests on the AFD unit

Annex E applies, but the tests shall be made on the AFD units in association with a test circuit breaker or RCD adjusted to the most onerous conditions.

Annex E
(normative)

Routine tests

E.1 General

The tests specified in this standard are intended to reveal, as far as safety is concerned, unacceptable variations in material or manufacture.

In general, more tests have to be made to ensure that every AFDD conforms with the samples that withstood the tests of this standard, according to the experience gained by the manufacturer.

E.2 Tripping test

The AFDD is connected to a shaker arc test and an adjustable load, as shown in Annex F on Figure F.3.

The value of the resistance having been adjusted to the lowest test current mentioned in Tables 1 and 2 (2,5 A for a 230 V rated voltage AFDD [C⟩ *text deleted* ⟨C]) the AFDD shall trip in less than 1s.

Alternatively any convenient method of verification of the correct tripping is allowed.

E.3 Electric strength test

A voltage of substantially sine-wave form of 1 500 V having a frequency of 50 Hz/60 Hz is applied for 1 s as follows:

a) with the AFDD in the open position, between the terminals which are electrically connected together, when the AFDD is in the closed position;
b) with the AFDD in the open position, either between all incoming terminals of poles in turn or between all outgoing terminals of poles in turn, depending on the position of the electronic components.

No flashover or breakdown shall occur.

Annex F
(informative)

Description of the shaker arc test in 9.10.2

Install two copper studs on two conductive surfaces fixed on a non-conductive vibrating table.

Prepare a copper wire jumper using 300 mm (12 in) lengths and 10 mm^2 (AWG 8) flexible wire terminated on both ends with copper lugs to achieve a gap measurement around 0,3 mm to 0,6 mm as shown in Figure F.1 and F.2.

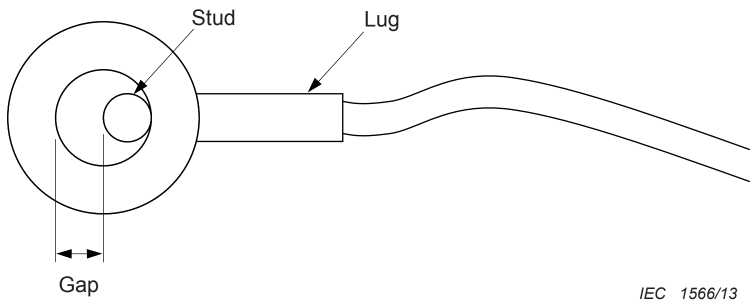


Figure F.1 – Gap Measurement

Loop the wire jumper from stud to terminal in the manner shown in Figure F.2 producing a series connection from one end of the fixture to the other. Tighten a self-locking nut on the studs only until the locking mechanism on the nut fully engages (this nut is only used to ensure that the wire terminal does not vibrate off the stud).

The height between the nut and the base of the stud is around 3 mm. Do not tighten any further.

The wire terminal must remain free to vibrate while making intermittent contact with the stud and self-locking nut.

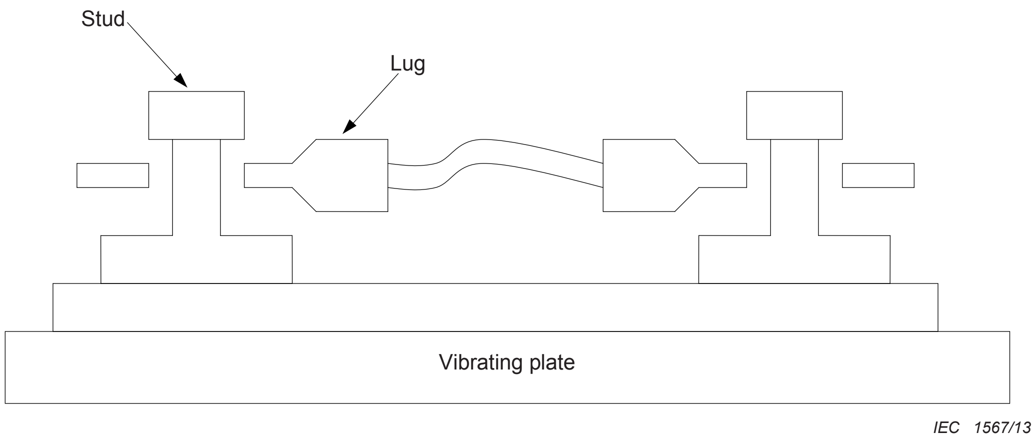


Figure F.2 – Shaker arc test table with Loose Terminals

The frequency of the vibrating plate is in between 30 Hz to 60 Hz.

The AFDD phase terminal is connected to the wire with studs and lugs to the shaker arc test table as shown in Figure F.3.

Before testing, the current is adjusted to half value of the rated current with S1. Then S1 is left open. The arcing will trip the AFDD during the test.

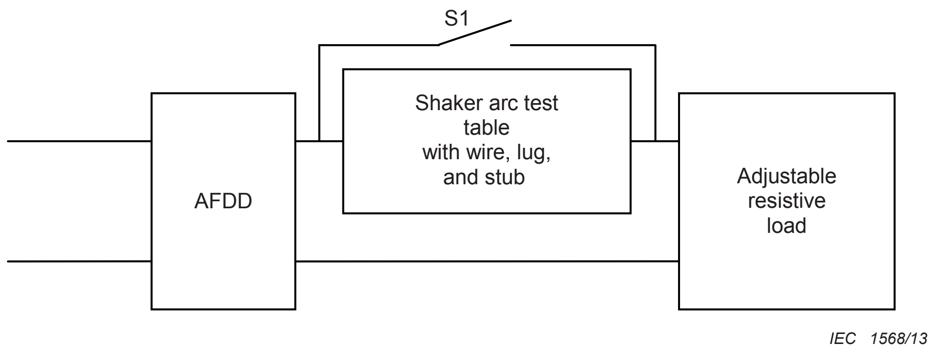


Figure F.3 – AFDD connected to the shaker arc table during test

Annex IA
(informative)

Methods of determination of short-circuit power-factor

IA.1 General

There is no uniform method by which the short-circuit power-factor can be determined with precision. Two examples of acceptable methods are given in this annex.

Method I – Determination from d.c. components

The angle ϕ may be determined from the curve of the d.c. component of the asymmetrical current wave between the instant of the short-circuit and the instant of contact separation as follows:

IA.1 Formula for the d.c. component

The formula for the d.c. component is:

$$i_d = i_{do} \cdot e^{-Rt/L}$$

where

- i_d is the value of d.c. components at the instant t;
- i_{do} is the value of the d.c. component at the instant taken as time origin;
- L/R is the time-constant of the circuit, in seconds;
- t is the time, in seconds, taken from the initial instant;
- e is the base of the Neperian logarithms.

The time-constant L/R can be ascertained from the above formula as follows:

a) measure the value of i_{do} at the instant of short-circuit and the value of i_d at another instant t before the contact separation;

b) determine the value of $e^{-Rt/L}$ by dividing i_d by i_{do};

c) from a table of values of e^{-x} determine the value of –x corresponding to the ratio of i_d/i_{do};

d) the value x represents Rt/L from which L/R is obtained.

IA.2 Determining the angle

Determine the angle from:

$$\phi = \text{arc tan } \omega \text{ L/R}$$

where ω is 2 π times the actual frequency.

This method should not be used when the currents are measured by current transformers.

Methods II – Determination with pilot generator

When a pilot generator is used on the same shaft as the test generator, the voltage of the pilot generator on the oscillogram may be compared in phase first with the voltage of the test generator and then with the current of the test generator.

The difference between the phase angles between pilot generator voltage and main generator voltage on the one hand and pilot generator voltage and test generator current on the other hand gives the phase-angle between the voltage and current of the test generator, from which the power-factor can be determined.

Annex IB
(informative)

Examples of terminal designs

In this annex, some examples of designs of terminals are given (see Figures IB.1 to IB.4).

The conductor location shall have a diameter suitable for accepting solid rigid conductors and a cross-sectional area suitable for accepting rigid stranded conductors (see Table 11 of 9.2).

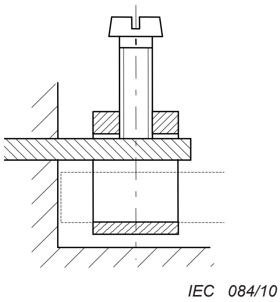


Figure IB.1a – Terminals with stirrup

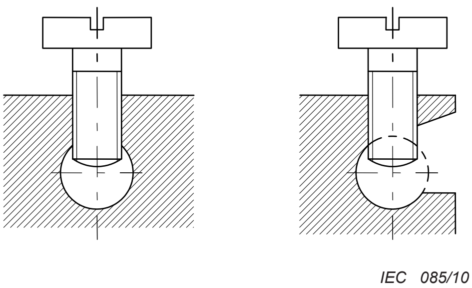


Figure IB.1b – Terminals without pressure plate

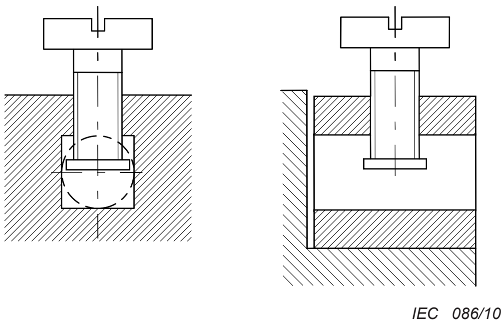


Figure IB.1c – Terminals with pressure plate

The part of the terminal containing the threaded hole and the part of the terminal against which the conductor is clamped by the screw may be two separate parts, as in the case of a terminal provided with a stirrup.

Figure IB.1 – Examples of pillar terminals

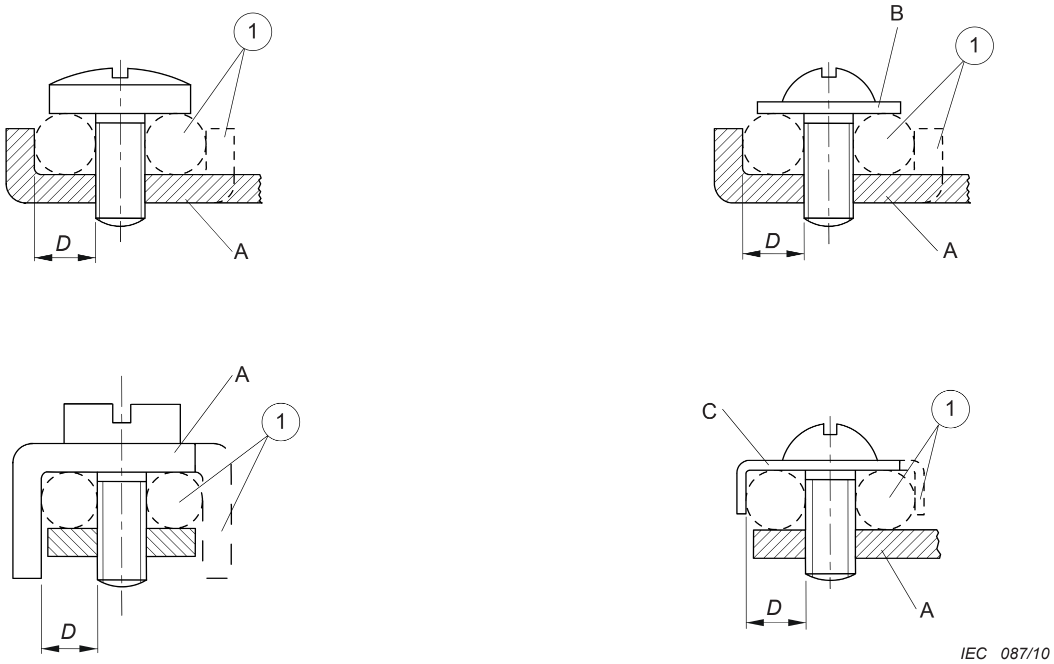


Figure IB.2a – Screw terminals

Screw not requiring washer or clamping plate

Screw requiring washer, clamping plate or anti-spread device

Figure IB.2b – Stud terminals

Key

1 Optional

A Fixed part

B Washer or clamping plate

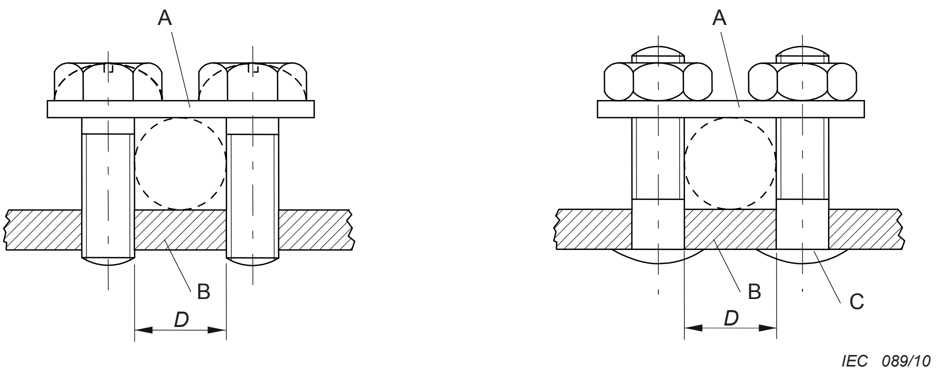
C Anti-spread device

D Conductor space

E Stud

The part which retains the conductor in position may be of insulating material, provided the pressure necessary to clamp the conductor is not transmitted through the insulating material.

Figure IB.2 – Examples of screw terminals and stud terminals



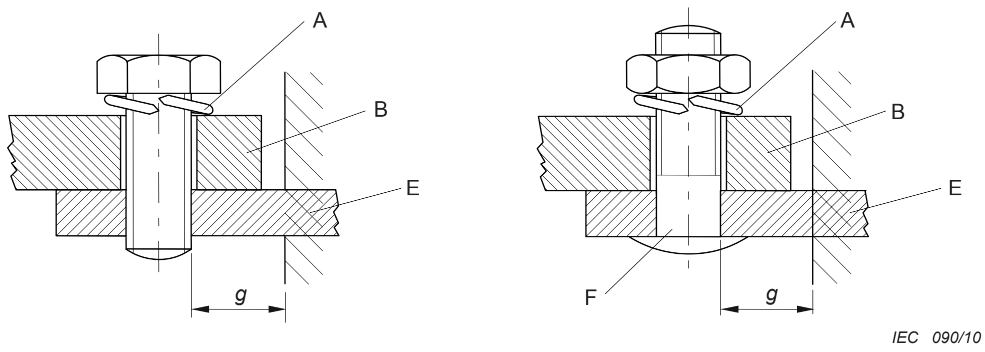
Key

A	Saddle
B	Fixed part
C	Stud
D	Conductor space

The two faces of the saddle may be of different shapes to accommodate conductors of either small or large cross-sectional area, by inverting the saddle.

The terminals may have more than two clamping screws or studs.

Figure IB.3 – Examples of saddle terminals



Key

A	Locking means
B	Cable lug or bar
E	Fixed part
F	Stud

For this type of terminal, a spring washer or equally effective locking means shall be provided and the surface within the clamping area shall be smooth.

For certain types of equipment, the use of lug terminals of sizes smaller than that required is allowed.

Figure IB.4 – Examples of lug terminals

Annex IC
(informative)

Correspondence between ISO and AWG copper conductors

ISO size mm^2	AWG	
	Size	Cross-sectional area mm^2
1,0	18	0,82
1,5	16	1,3
2,5	14	2,1
4,0	12	3,3
6,0	10	5,3
10,0	8	8,4
16,0	6	13,3
25,0	3	26,7
35,0	2	33,6
50,0	0	53,5

In general, ISO sizes apply.

Upon request of the manufacturer, AWG sizes may be used.

Annex ID
(informative)

Follow-up testing program for AFDDs

ID.1 General

In order to guarantee the keeping of the quality level of products, follow-up inspection procedures on the manufacturing process have to be set up by the manufacturers.

This annex gives an example of follow-up procedure to be applied when manufacturing AFDDs.

It may be used as a guide by manufacturers for adapting their specific procedures and organization aiming at keeping the required quality level of the product output.

In particular, any provision of the supplying follow-up as well as the manufacturing follow-up may be taken to guarantee the quality of the manufactured products on which the safe operation of the residual current device depends.

ID.2 Follow-up testing program

The follow-up testing program includes two series of tests.

ID.2.1 Quarterly follow-up testing program

See Table ID.1, test sequence Q.

ID.2.2 Annual follow-up testing program

See Table ID.1, test sequences Y1 to Y3.

The annual follow-up testing may be combined with the quarterly follow-up testing.

Table ID.1 – Test sequences during follow-up inspections

Test sequence	Clause or subclause	Test	Comments
Q	9.9.2.2	Arc detection operating characteristics	
	9.9.2.4	Arc detection operating characteristics	
	9.7.6	Resistance of insulation against impulse voltages	Also carried out between each pole in turn
		Verification of the correct operation of the test button if any	– The AFDD is powered as for normal use, – Then the AFDD is manually closed. Afterward the equipment shall trip when the button is pressed.
Y1	9.9.2.5	Test at the temperature limits	
	9.7	Test of dielectric properties	
	9.10	Mechanical and electrical endurance	
Y2	9.19.1	Reliability (climatic test)	

Test sequence	Clause or subclause	Test	Comments
Y3	9.20	Verification of ageing of electronic components	

ID.2.3 Sampling procedure

ID.2.3.1 Quarterly testing program

For the purpose of the quarterly testing program the following inspection levels are applied:

– normal inspection;

– tightened inspection.

Normal inspection will be used for the first follow-up inspection.

For successive inspections, normal or tightened inspection, or stopping of the production is applied, depending on the results of the on-going tests.

The following criteria for switching over from one level of inspection to another shall be applied:

– Stay at normal level

  When normal inspection is applied, normal level is maintained if all six samples pass the test sequence (see Table ID.2, sequence Q). If five samples pass the test sequence, the subsequent inspection is made one month only after the preceding one with the same number of samples and the same test sequence.

– Normal to tightened

  When normal inspection is applied, tightened inspection shall be applied when only four samples pass the test sequence.

– Normal to production stop

  When normal inspection is applied and less than four samples pass the test sequence, the production shall be discontinued pending action to improve the quality.

– Tightened to normal

  When tightened inspection is applied, normal inspection shall be applied when at least 12 samples pass the test sequence (see Table ID.2).

– Stay at tightened level

  When, being at tightened level, 10 or 11 samples only pass the test sequence, the tightened level is maintained and the subsequent inspection is made one month after the preceding one with the same number of samples and the same test sequence.

– Tightened to production stop

  In the event that four consecutive inspections remain on the tightened level or when less than 10 samples pass the test sequence, the production shall be discontinued pending action to improve the quality.

– Restart production

  The production can restart after appropriate and confirmed corrective action. The restart shall be made under tightened inspection conditions.

ID.2.3.2 Annual testing program

For the purpose of the annual testing program the following inspection levels are applied:

– normal inspection;

– tightened inspection.

Normal inspection will be used for the first follow-up inspection.

For successive inspections, normal or tightened inspections are applied, depending on the results of the on-going tests.

The following criteria for switching over from one level of inspection to another shall be applied.

– Stay at the normal level

  When normal inspection is applied, normal level is maintained if all samples pass the test sequence. If two samples pass the test sequence Y1 and no failure occurs during test sequences Y2 and Y3, the subsequent inspection is made three months after the preceding one with the same number of samples and the same test sequences.

– Normal to tightened

  When normal inspection is applied, tightened inspection shall be applied when either:

  - only one sample passes the sequence Y1;
  - or one failure occurs during any one of test sequences Y2 or Y3.

The subsequent inspection shall be effected within three months of the preceding one, at tightened level for any sequence in which the failure occurred and at normal level for the other test sequences.

– Normal to production stop

  When normal inspection is applied and no sample passes the test sequence Y1, or more than one failure occurs during test sequences Y2 or Y3, the production shall be discontinued pending action to improve the quality.

– Tightened to normal

  When tightened inspection is applied, normal inspection shall be applied when:

  - at least five samples pass the test sequence Y1; and
  - no failure occurs during the test sequence Y2 or Y3.

– Stay at tightened level

  When, being at tightened level, four samples only pass the test sequence Y1 and no failure occurs during test sequences Y2 or Y3, the tightened level is maintained and the following inspection is made three months after the preceding one with the same number of samples and the same test sequences.

– Tightened to production stop

  In the event that four consecutive inspections remain on the tightened level or when during one annual inspection one of the following failures occurs:

  - less than four samples pass test sequence Y1;
  - more than one failure occurs during test sequences Y2 or Y3;

  the production shall be discontinued pending action to improve the quality.

– Restart production

  The production can restart after appropriate and confirmed corrective action. The restart shall be made under tightened inspection conditions.

ID.2.4 Number of samples to be tested

The number of samples for the various inspection levels is given in Table ID.2.

Table ID.2 – Number of samples to be tested

Inspection sequence	Number of samples for normal inspection	Number of samples for tightened inspection
Q	6	13
Y1, Y2, Y3	3 each	6 each

Out of each series of AFDDs of the same fundamental design only one set of samples need be tested, irrespective of the ratings.

For the purpose of this follow-up testing program, AFDDs are considered to be of the same fundamental design if they belong to the same classification according to 4.1, and:

– the arc current operating means have identical tripping mechanism and identical relay or solenoid, except for:
  • the number of turns and cross-sectional area of the windings;
  • the sizes and material of the core of the differential transformer;
  • the rated residual current; and
– the electronic part, if any, is of the same design and uses the same components, except for variations so as to achieve different arc current operating value.

Annex IE
(informative)

SCPDs for short-circuit tests

IE.1 Introduction

For the verification of the minimum I^2t and I_p values to be withstood by the AFDD as given in Table 18 of 9.11.2.1, short-circuit tests have to be performed. The short-circuit tests shall be made by the use of the declared protective device or a silver wire using the test apparatus shown in Figure IE.1or by the use of any other means producing the required I^2t and I_p values.

IE.2 Silver wires

For the purpose of verifying the minimum I^2t and I_p values to be withstood by the AFDD, in order to obtain reproducible test results, the SCPD, if any, may be a silver wire using the test apparatus shown in Figure IE.1.

For silver wires with at least 99,9 % purity, Table IE.1 gives an indication of the diameters according to the rated current I_n and the conditional short-circuit currents I_{nc} .

Table IE.1 – Indication of silver wire diameters as a function of rated currents and short-circuit currents

I_{nc}	I_n A					
	≤ 16	**≤ 20**	**≤ 25**	**≤ 32**	**≤ 40**	**≤ 63**
	Silver wire diameter[a] mm					
500	0,30	0,35	0,35	0,35		
1 000	0,30	0,35	0,40	0,50		
1 500	0,35	0,40	0,45	0,50	0,65	0,85
3 000	0,35	0,40	0,45	0,50	0,60	0,80
4 500	0,35	0,40	0,45	0,50	0,60	0,80
6 000	0,35	0,40	0,45	0,50	0,60	0,75
10 000	0,35	0,40	0,45	0,50	0,60	0,70

[a] The silver wire diameter values are essentially based on peak current (I_p) considerations (see Table 18).

The silver wire shall be inserted in the appropriate position of the test apparatus shown in Figure IE.1, horizontally and stretched. The silver wire shall be replaced after each test.

IE.3 Declared protective devices

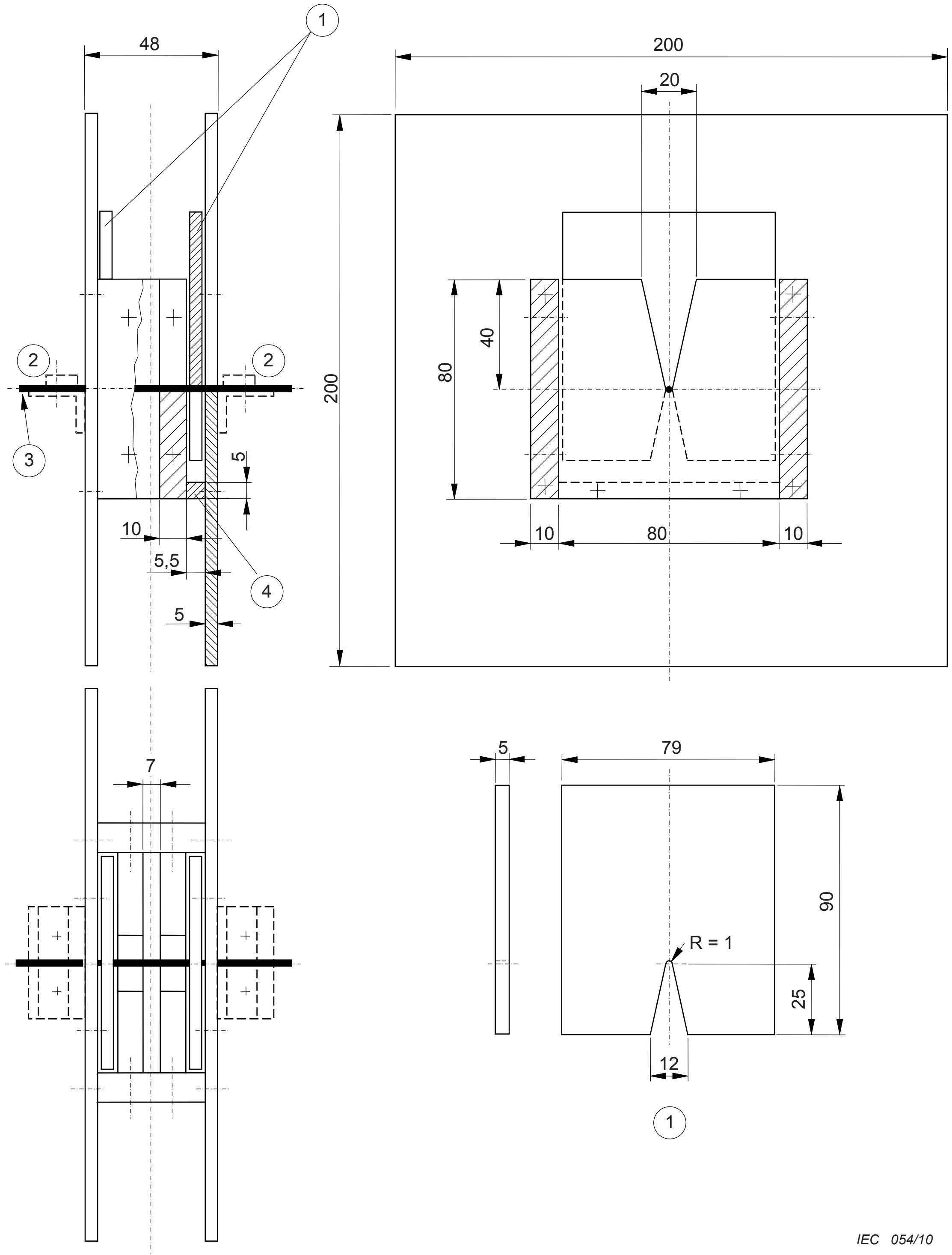
For the purpose of verifying the minimum I^2t and I_p values to be withstood by the AFDD, in order to obtain reproducible test results, the SCPD, if any, may be the declared protective device.

The rating of the declared protective device must not be smaller than the rating of the AFDD. Higher ratings of declared protective devices may be used to obtain the I^2t and I_p values of Table 18.

NOTE In case of fuse intermediate values can be achieved by adding fuses in parallel.

IE.4 Other means

Other means may be used provided that the values of Table 18 are fulfilled.



Key

1 Gliding plate
2 Terminal
3 Silver wire
4 Stop for gliding plate

Figure IE-1 – Test apparatus for the verification of the minimum I^2t and I_p values to be withstood by the AFDD

Annex J
(normative)

Particular requirements for AFDDs with screwless type terminals for external copper conductors

J.1 Scope

This annex applies to AFDDs within the scope of Clause 1, equipped with screwless terminals, for current not exceeding 20 A primarily suitable for connecting unprepared (see J.3.6) copper conductors of cross-section up to 4 mm^2.

NOTE In AT, CZ, DE, DK, NL, NO and CH the upper limit of current for use of screwless terminals is 16 A.

In this annex, screwless terminals are referred to as terminals and copper conductors are referred to as conductors.

J.2 Normative references

Clause 2 of this standard applies.

J.3 Terms and definitions

As a complement to Clause 3 of this standard, the following definitions apply for the purpose of this annex.

J.3.1
clamping units
parts of the terminal necessary for mechanical clamping and the electrical connection of the conductors including the parts which are necessary to ensure correct contact pressure

J.3.2
screwless-type terminal
terminal for the connection and subsequent disconnection obtained directly or indirectly by means of springs, wedges or the like

Note 1 to entry: Examples are given in Figure J.2.

J.3.3
universal terminal
terminal for the connection and disconnection of all types of conductors (rigid and flexible)

Note 1 to entry: In the following countries only universal screwless type terminals are accepted: AT, BE, CN, DK, DE, ES, FR, IT, PT, SE and CH.

J.3.4
non-universal terminal
terminal for the connection and disconnection of a certain kind of conductor only

EXAMPLE Rigid-solid conductors only or rigid-(solid or stranded) conductors only.

J.3.5
push-wire terminal
non-universal terminal in which the connection is made by pushing-in rigid (solid or stranded) conductors

J.3.6
unprepared conductor
conductor which has been cut and the insulation of which has been removed over a certain: length for insertion into a terminal

Note 1 to entry: A conductor the shape of which is arranged for introduction into a terminal or of which the strands are twisted to consolidate the end, is considered to be an unprepared conductor.

Note 2 to entry: The term "unprepared conductor" means conductor not prepared by soldering of the wire, use of cable lugs, formation of eyelets, etc., but includes its reshaping before introduction into the terminal or, in the case of flexible conductor, by twisting it to consolidate the end.

J.4 Classification

Clause 4 of this standard applies.

J.5 Characteristics of AFDDs

Clause 5 of this standard applies.

J.6 Marking

In addition to Clause 6 of this standard, the following requirements apply:

Universal terminals:

– no marking.

Non-universal terminals:

– terminals declared for rigid-solid conductors shall be marked by the letters "sol";
– terminals declared for rigid (solid and stranded) conductors shall be marked by the letter "r";
– terminals declared for flexible conductors shall be marked by the letter "f".

The markings should appear on the AFDD or, if the space available is not sufficient, on the smallest package unit or in technical information.

An appropriate marking indicating the length of insulation to be removed before insertion of the conductor into the terminal shall be shown on the AFDD.

The manufacturer shall also provide information, in his literature, on the maximum number of conductors which may be clamped.

J.7 Standard conditions for operation in service

Clause 7 of this standard applies.

J.8 Constructional requirements

J.8.1 General

Clause 8 of this standard applies, with the following modifications.

In 8.2.5 only 8.2.5.1, 8.2.5.2, 8.2.5.3, 8.2.5.6 and 8.2.5.7 apply.

Compliance is checked by inspection and by the tests of J.9.1 and J.9.2 of this annex, instead of 9.4 and 9.5.

In addition the following requirements apply.

J.8.2 Connection or disconnection of conductors

The connection or disconnection of conductors shall be made

– by the use of a general purpose tool or by a convenient device integral with the terminal to open it and to assist the insertion or the withdrawal of the conductors (e.g. for universal terminals);

or, for rigid conductors

– by simple insertion. For the disconnection of the conductors an operation other than a pull on the conductor shall be necessary (e.g. for push-wire terminals).

Universal terminals shall accept rigid (solid or stranded) and flexible unprepared conductors.

Non-universal terminals shall accept the types of conductors declared by the manufacturer.

Compliance is checked by inspection and by the tests of J.9.1 and J.9.2.

J.8.3 Dimensions of connectable conductors

The dimensions of connectable conductors are given in Table J.1.

The ability to connect these conductors shall be checked by inspection and by the tests of J.9.1 and J.9.2.

Table J.1 – Connectable conductors

Connectable conductors and their theoretical diameter									
Metric					**AWG**				
Rigid			**Flexible**		**Rigid**			**Flexible**	
	Solid	**Stranded**				**Solid**[a]	**Class B stranded**[a]		**Classes I, K, M, stranded**[b]
mm²	∅ mm	∅ mm	mm²	∅ mm	gauge	∅ mm	∅ mm	gauge	∅ mm
1,0	1,2	1,4	1,0	1,5	18	1,02	1,16	18	1,28
1,5	1,5	1,7	1,5	1,8	16	1,29	1,46	16	1,60
2,5	1,9	2,2	2,5	2,3	14	1,63	1,84	14	2,08
4,0	2,4	2,7	4,0	2,9	12	2,05	2,32	12	2,70

NOTE Diameters of the largest rigid and flexible conductors are based on Table 1 of IEC 60228:2004, and, for AWG conductors, on ASTM B 172-71, and ICEA publications S-19-81, S-66-524 and S-68-516.

[a] Nominal diameter + 5 %.

[b] Largest diameter + 5 % for any of the three classes I, K and M.

J.8.4 Connectable cross-sectional areas

The nominal cross-sections to be clamped are defined in Table J.2.

Table J.2 – Cross-sections of copper conductors connectable to screwless-type terminals

Rated current A	**Nominal cross-sections to be clamped** mm^2
Up to and including 13	1 up to and including 2,5
Above 13 up to and including 20	1,5 up to and including 4

Compliance is checked by inspection and by the tests in *J.9.2 and J.9.3.*

J.8.5 Insertion and disconnection of conductors

The insertion and disconnection of the conductors shall be made in accordance with the manufacturer's instructions.

Compliance is checked by inspection.

J.8.6 Design and construction of terminals

Terminals shall be so designed and constructed that:

– each conductor is clamped individually;
– during the operation of connection or disconnection the conductors can be connected or disconnected either at the same time or separately;
– inadequate insertion of the conductor is avoided.

It shall be possible to clamp securely any number of conductors up to the maximum provided for.

Compliance is checked by inspection and by the tests of J.9.2 and J.9.3.

J.8.7 Resistance to ageing

The terminals shall be resistant to ageing.

Compliance is checked by the test of J.9.4.

J.9 Tests

J.9.1 General

Clause 9 of this standard applies, by replacing 9.4 and 9.5 by the following tests:

J.9.2 Test of reliability of screwless terminals

J.9.2.1 Reliability of screwless system

The test is carried out on three terminals of poles of new samples, with copper conductors of the rated cross sectional area in accordance with Table J.2. The types of conductors shall be in accordance with J.8.2.

The connection and subsequent disconnection shall be made five times with the smallest diameter conductor and successively five times with the largest diameter conductor.

New conductors shall be used each time, except for the fifth time, when the conductor used for the fourth insertion is clamped at the same place. Before insertion into the terminal, wires of stranded rigid conductors shall be re-shaped and wires of flexible conductors shall be twisted to consolidate the ends.

For each insertion, the conductors are either pushed as far as possible into the terminal or shall be inserted so that adequate connection is obvious.

After each insertion, the conductor being inserted is rotated 90° along its axis at the level of the clamped section and subsequently disconnected.

After these tests, the terminal shall not be damaged in such a way as to impair its further use.

J.9.2.2 Test of reliability of connection

Three terminals of poles of new samples are fitted with new copper conductors of the type and of the rated cross sectional area according to Table J.2.

The types of conductors shall be in accordance with J.8.2.

Before insertion into the terminal, wires of stranded rigid conductors and flexible conductors shall be reshaped and wires of flexible conductors shall be twisted to consolidate the ends.

It shall be possible to fit the conductor into the terminal without undue force in the case of universal terminals and with the force necessary by hand in the case of push-wire terminals.

The conductor is either pushed as far as possible into the terminal or shall be inserted so that adequate connection is obvious.

After the test, no wire of the conductor shall have escaped outside the terminal.

J.9.3 Tests of reliability of terminals for external conductors: mechanical strength

For the pull-out test three terminals of poles of new samples are fitted with new conductors of the type and of the minimum and maximum cross-sectional areas according to Table J.2.

Before insertion into the terminal, wires of stranded rigid conductors and flexible conductors shall be reshaped and wires of flexible conductors shall be twisted to consolidate the ends.

Each conductor is then subjected to a pull force of the value shown in Table J.3. The pull is applied without jerks for 1 min in the direction of the axis of the conductor.

Table J.3 – Pull forces

Cross-sectional area mm^2	**Pull force** N
1,0	35
1,5	40
2,5	50
4,0	60

During the test the conductor shall not slip out of the terminal.

J.9.4 Cycling test

The test is made with new copper conductors having cross section according to Table 12.

The test is carried out on new samples (a sample is one pole), the number of which is defined below, according to the type of terminals:

– universal terminals for rigid (solid and stranded) and flexible conductors: 3 samples each (6 samples in total);
– non-universal terminals for solid conductors only: 3 samples;
– non-universal for rigid (solid and stranded) conductors: 3 samples each (6 samples);

NOTE In case of rigid conductors, solid conductors can be used (if solid conductors are not available in a given country, stranded conductors can be used).

– non-universal for flexible conductors only: 3 samples.

A conductor having the cross section defined in Table 12 is connected in series as in normal use to each of the three samples as defined on Figure J.1.

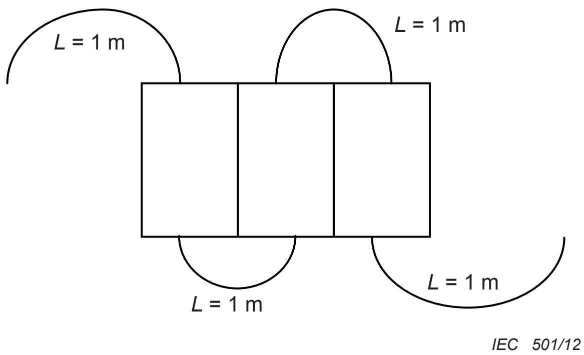


Figure J.1 – Connecting samples

The sample is provided with a hole (or equivalent) in order to measure the voltage drop on the terminal.

The whole test arrangement, including the conductors, is placed in a heating cabinet which is initially kept at a temperature of (20 ± 2) °C.

To avoid any movement of the test arrangement until all the following voltage drop tests have been completed it is recommended that the poles are fixed on a common support.

Except during the cooling period, a test current corresponding to the rated current of the circuit breaker is applied to the circuit.

The samples shall be then subjected to 192 temperature cycles, each cycle having a duration of approximately 1 h, as follows:

The air temperature in the cabinet is raised to 40 °C in approximately 20 min. It is maintained within ± 5 °C of this value for approximately 10 min.

The samples are then allowed to cool down in approximately 20 min to a temperature of approximately 30 °C, forced cooling being allowed. They are kept at this temperature for approximately 10 min and, if necessary for measuring the voltage drop, allowed to cool down further, to a temperature of (20 ± 2) °C.

The maximum voltage drop, measured at each terminal, at the end of the 192nd cycle, with the nominal current shall not exceed the smaller of the two following values:

- either 22,5 mV,
- or 1,5 times the value measured after the 24th cycle.

The measurement shall be made as near as possible to the area of contact on the terminal.

If the measuring points cannot be positioned closely to the point of contact, the voltage drop within the part of the conductor between the ideal and the actual measuring points shall be deducted from the voltage drop measured.

The temperature in the heating cabinet must be measured at a distance of at least 50 mm from the samples.

After this test an inspection with the naked eye, by normal or corrected vision, without additional magnification, shall show no changes evidently impairing further use, such as cracks, deformations or the like.

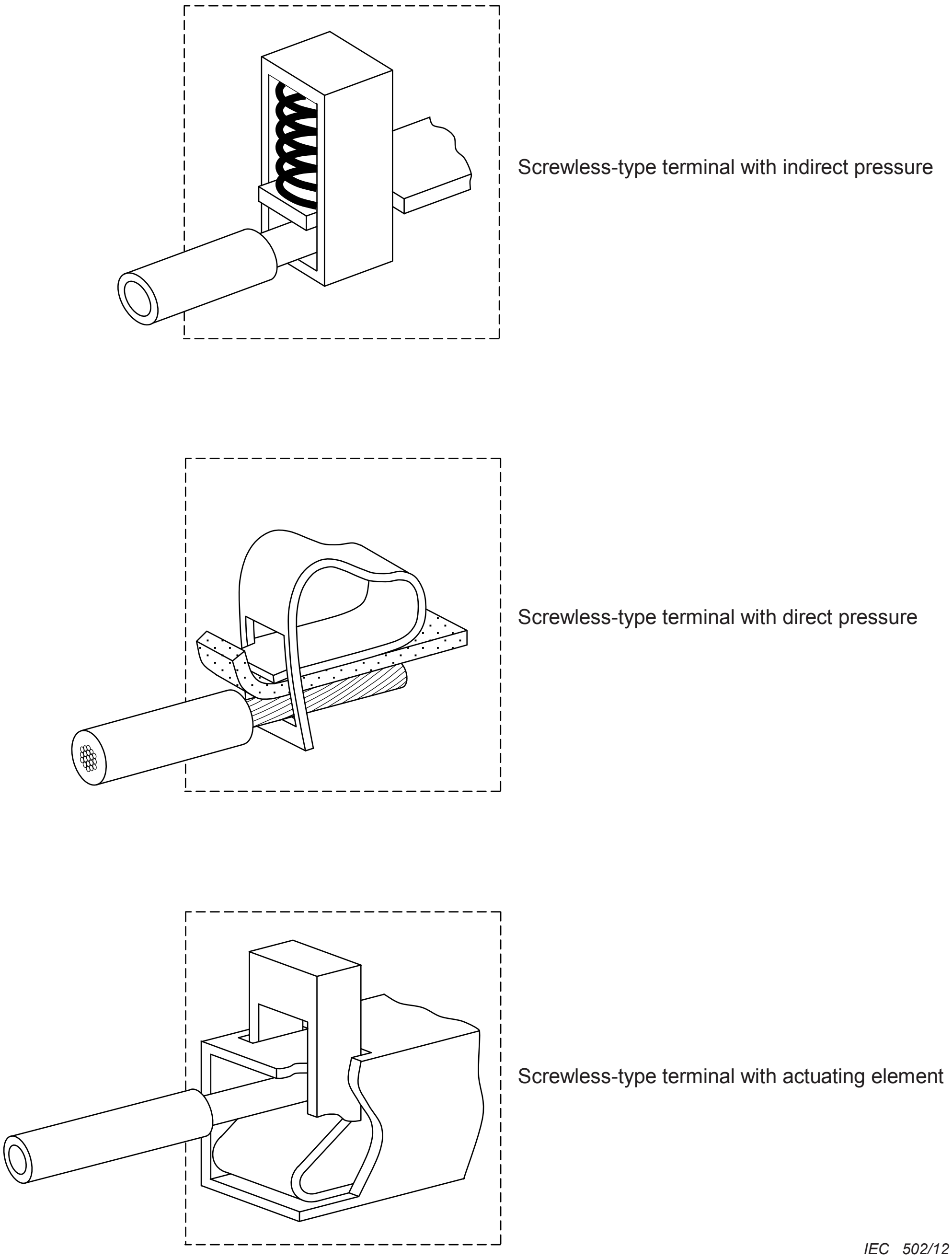


Figure J.2 – Examples of screwless-type terminals

J.10 Reference documents

IEC 60228:2004, *Conductors of insulated cables*

IEC 60998-1:2002, *Connecting devices for low voltage circuits for household and similar purposes – Part 1: General requirements*

IEC 60998-2-2:2002, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units*

IEC 60999 (all parts), *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units*

Annex K
(normative)

Particular requirements for AFDDs with flat quick-connect terminations

K.1 Scope

This annex applies to AFDDs within the scope of Clause 1 of this standard, equipped with flat quick-connect terminations consisting of a male tab (see K.3.2) with nominal width 6,3 mm and thickness 0,8 mm, to be used with a mating female connector for connecting electrical copper conductors according to the manufacturer's instructions, for rated currents up to and including 16 A.

NOTE The use of AFDDs with flat quick-connect terminations for rated currents up to and including 20 A is accepted in BE, FR, IT, ES, PT and US.

The connectable electrical copper conductors are flexible, having a cross-sectional area up to and including 4 mm^2, or rigid stranded, having a cross-sectional area up to and including 2,5 mm^2 (AWG equal to or greater than 12).

This annex applies exclusively to AFDDs having male tabs as an integral part of the device.

K.2 Normative references

As a complement to Clause 2 of this standard, the following normative reference applies:

IEC 61210, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

K.3 Terms and definitions

As a complement to Clause 3 of this standard, the following definitions apply for the purpose of this annex.

K.3.1
flat quick-connect termination
electrical connection consisting of a male tab and a female connector which can be pushed into and withdrawn with or without the use of a tool

K.3.2
male tab
portion of a quick-connect termination which receives the female connector

K.3.3
female connector
portion of a quick-connect termination which is pushed onto the male tab

K.3.4
detent
dimple (depression) or hole in the male tab which engages a raised portion on the female connector to provide a latch for the mating parts.

K.4 Classification

Clause 4 of this standard applies.

K.5 Characteristics of AFDDs

Clause 5 of this standard applies.

K.6 Marking

The whole of Clause 6 of this standard applies, with the following addition after the lettered item k).

The following information regarding the female connector according to IEC 61210 and the type of conductor to be used shall be given in the manufacturers' instructions:

k) manufacturer’s name or trade mark;

l) type reference;

m) information on cross-sections of conductors and colour code of insulated female connectors (see Table K.1 below);

n) the use of only silver or tin-plated copper alloys.

Table K.1 – Informative table on colour code of female connectors in relationship with the cross section of the conductor

Cross-section of the conductor mm^2	**Colour code of the female connector**
1	Red
1,5	Red or blue
2,5	Blue or yellow
4	Yellow

K.7 Standard conditions for operation in service

Clause 7 of this standard applies.

K.8 Constructional requirements

K.8.1 General

Clause 8 of this standard applies, with the following exceptions:

Replace 8.2.3 by:

K.8.2 Clearances and creepage distances (see Annex B)

8.2.3 applies, the female connectors being fitted to the male tabs of the AFDD.

Replace 8.2.5 by:

K.8.3 Terminals for external conductors

K.8.3.1 Male tabs and female connectors shall be of a metal having mechanical strength, electrical conductivity and resistance to corrosion adequate for their intended use.

NOTE Silver or tin plated copper alloys are examples of suitable solutions.

K.8.3.2 The nominal width of the male tab is 6,3 mm and the thickness 0,8 mm, applicable to rated currents up to and including 16 A.

NOTE The use for rated currents up to and including 20 A is accepted in BE, FR, IT, PT, ES and US.

The dimensions of the male tab shall comply with those specified in Table K.3 and in Figures K.2, K.3, K.4 and K.5, where the dimensions A, B, C, D, E, F, J, M, N and Q are mandatory.

The dimensions of the female connector which may be fitted-on are given in Figure K.6 and in Table K.4.

NOTE 2 The shapes of the various parts can deviate from those given in the Figures, provided that the specified dimensions are not influenced and the test requirements are complied with, for example: corrugated tabs, folded tabs, etc.

Compliance is checked by inspection and by measurement.

K.8.3.3 Male tabs shall be securely retained.

Compliance is checked by the mechanical overload test in K.9.2.

K.9 Tests

K.9.1 General

Clause 9 of this standard applies, with the following modifications:

Replace 9.5 by:

K.9.2 Mechanical overload-force

This test is carried out on 10 terminals of AFDDS, mounted as in normal use when wiring takes place.

The axial push force, and successively the axial pull force specified in the following Table K.2, are gradually applied to the male tab integrated in the AFDD, once only with a suitable test apparatus.

Table K.2 – Overload test forces

Push N	**Pull** N
96	88

No damage which could impair further use shall occur to the tab or to the AFDD in which the tab is integrated.

Addition to 9.8.3:

Fine-wire thermocouples shall be placed in such a way as not to influence the contact or the connection area. An example of placement is shown in Figure K.1.

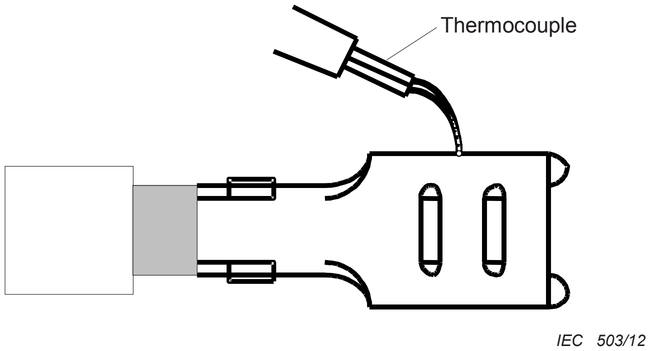


Figure K.1 – Example of position of the thermocouple for measurement of the temperature-rise

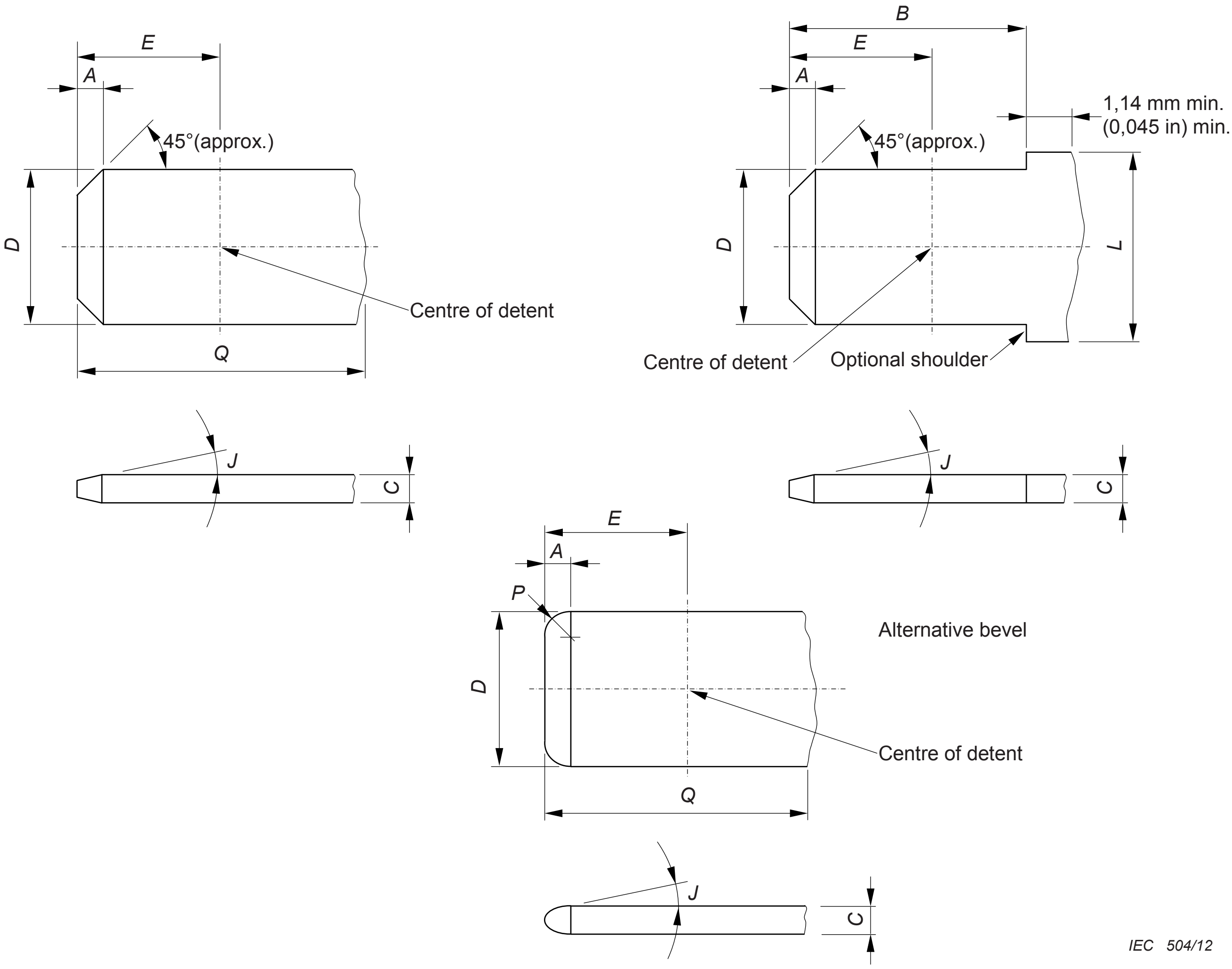
Table K.3 – Dimensions of tabs

Dimensions in millimetres

Nominal size		***A***	***B* min**	***C***	***D***	***E***	***F***	***J***	***M***	***N***	***P***	***Q* min**
6,3 × 0,8	Dimple	1,0		0,84	6,40	4,1	2,0	12°	2,5	2,0	1,8	
		0,7	7,8	0,77	6,20	3,6	1,6	8°	2,2	1,8	0,7	8,9
	Hole	1,0		0,84	6,40	4,7	2,0	12			1,8	
		0,5	7,8	0,77	6,20	4,3	1,6	8°			0,7	8,9

NOTE 1 For the dimensions *A* to *Q* refer to Figures K.2 to K.5.

NOTE 2 Where two values are shown in one column, they give the maximum and the minimum dimension.



NOTE 1 Bevel *A* of 45° need not be a straight line if it is within the confines shown.

NOTE 2 Dimension *L* is not specified and can vary by the application (for example fixing).

NOTE 3 Dimension *C* of tabs may be produced from more than one layer of material provided that the resulting tab complies in all respects with the requirements of this standard.

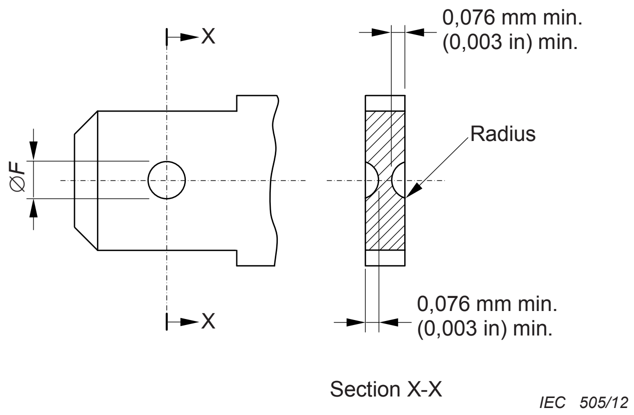
A radius on the longitudinal edge of the tab is permissible.

NOTE 4 The sketches are not intended to govern the design except with regard to the dimensions shown.

NOTE 5 The thickness *C* of the male tab can vary beyond *Q* or beyond *B* + 1,14 mm (0,045 in).

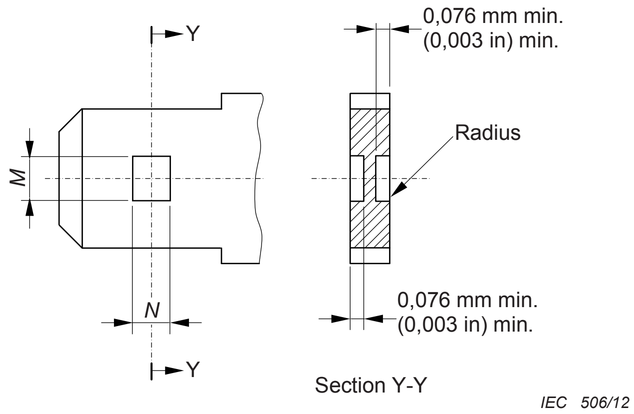
NOTE 6 All portions of the tabs are flat and free of burrs or raised plateaus, except that there may be a raised plateau over the stock thickness of 0,025 mm (0,001 in) per side, in an area defined by a line surrounding the detent and distant from it by 1,3 mm (0,051 in).

Figure K.2 – Dimensions of male tabs



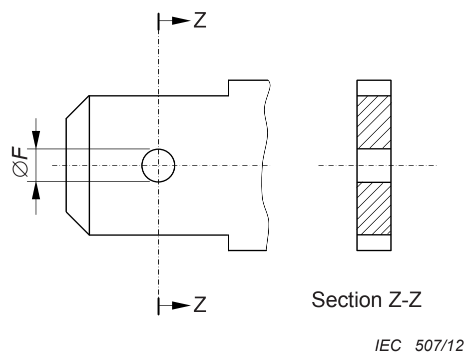
Detent shall be located within 0,076 mm (0,003 in) of the centre-line of the tab.

Figure K.3 – Dimensions of round dimple detents (see Figure K.2)



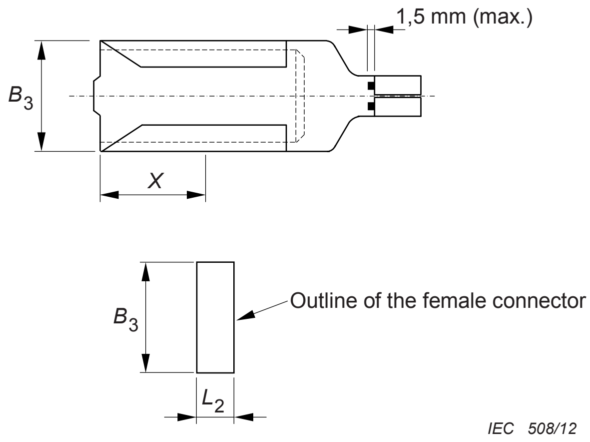
Detent shall be located within 0,13 mm (0,005 in) of the centre-line of the tab.

Figure K.4 – Dimensions of rectangular dimple detents (see Figure K.2)



Detent shall be located within 0,076 mm (0,003 in) of the centre-line of the tab.

Figure K.5 – Dimensions of hole detents



Dimensions *B*3 and *L*2 are mandatory.

NOTE 1 For determining female connector dimensions varying from *B*3 and *L*2 it is necessary to refer to the tab dimensions in order to ensure that in the most onerous conditions the engagement (and detent, if fitted) between tab and female connector is correct.

NOTE 2 If a detent is provided, the dimension *X* is at manufacturer's discretion in order to meet the requirements of the performance clauses.

NOTE 3 Female connectors should be so designed that undue insertion of the conductor into the crimping area is visible or prevented by a stop in order to avoid any interference between the conductor and a fully inserted tab.

NOTE 4 The sketches are not intended to govern the design except as regards the dimensions shown.

Figure K.6 – Dimensions of female connectors

Table K.4 – Dimensions of female connectors

Tab size mm	**Dimensions of female connector** mm	
	***B*3 max**	***L*2 max**
6,3 × 0,8	7,80	3,50

Annex L
(normative)

Specific requirements for AFDDs with screw-type terminals for external untreated aluminium conductors and with aluminium screw-type terminals for use with copper or with aluminium conductors

L.1 Scope

This annex applies to AFDDs within the scope of this standard, equipped with screw-type terminals of copper – or of alloys containing at least 58 % of copper (if worked cold) or at least 50 % of copper (if worked otherwise), or of other metal or suitably coated metal, no less resistant to corrosion than copper and having mechanical properties no less suitable – for use with untreated aluminium conductors, or with screw-type terminals of aluminium material for use with copper or aluminium conductors.

In this annex copper-clad and nickel-clad aluminium conductors are considered as aluminium conductors.

NOTE In AT, AU and DE, the use of aluminium screw-type terminals for use with copper conductors is not allowed.

– In AT, CH and DE, terminals for aluminium conductors only are not allowed.
– In SP, the use of aluminium conductors is not allowed for final circuits in household and similar installations e.g. offices, shops.
– In DK, the minimum cross-sectional area for aluminium conductors is 16 mm^2.

L.2 Normative references

Clause 2 of this standard applies.

L.3 Terms and definitions

As a complement to Clause 3 of this standard, the following definitions apply for the purpose of this annex.

L.3.1
treated conductor
contact area of a conductor that has had its oxide layer on the outside strands scraped away and/or has had a compound added to improve connectability and/or prevent corrosion

L.3.2
untreated/unprepared conductor
conductor which has been cut and the insulation of which has been removed for insertion into a terminal

Note 1 to entry: A conductor, the shape of which is arranged for introduction into a terminal or the strands of which are twisted to consolidate the end, is considered to be an unprepared conductor.

L.3.3
equalizer
arrangement used in the test loop to ensure an equipotentiality point and uniform current density in a stranded conductor, without adversely affecting the temperature of the conductor(s)

L.3.4
reference conductor
continuous length of the same type and size conductor as that used in the terminal unit under test and connected in the same series circuit

Note 1 to entry: It enables the reference temperature and, if required, reference resistance to be determined

L.3.5
stability factor
Sf
measure of temperature stability of a terminal unit during the current cycling test

L.4 Classification

Clause 4 of this standard applies.

L.5 Characteristics of AFDDs

Clause 5 of this standard applies.

L.6 Marking

In addition to Clause 6 of this standard, the following requirements apply:

The terminal marking defined in Table L.1 shall be marked on the AFDD, near the terminals.

The other information concerning the number of conductors, the screw torque values (if different from Table 12) and the cross-sections shall be indicated on the AFDD.

Table L.1 – Marking for terminals

Conductor types accepted	Marking
Copper only	None
Aluminium only	Al
Aluminium and copper	Al/Cu

The manufacturer shall state in his catalogue that, for the clamping of an aluminium conductor the tightening torque shall be applied with appropriate means.

L.7 Standard conditions for operation in service

Clause 7 of this standard applies.

L.8 Constructional requirements

Clause 8 of this standard applies, with the following exceptions:

8.2.5.2 is completed by:

For the connection of aluminium conductors, AFDDS shall be provided with screw-type terminals allowing the connection of conductors having nominal cross-sections as shown in Table L.2.

Terminals for the connection of aluminium conductors and terminals of aluminium for the connection of copper or aluminium conductors shall have mechanical strength adequate to withstand the tests in 9.4, with the test conductors tightened with the torque indicated in Table 13, or with the torque specified by the manufacturer, which shall never be lower than that specified in Table 13.

Table L.2 – Connectable cross-sections of aluminium conductors for screw-type terminals

Rated Current [a] A	**Range of nominal cross-sections**[b] **to be clamped** mm^2
Up to and including 13	1 to 4
Above 13 up to and including 16	1 to 6
Above 16 up to and including 25	1,5 to 10
Above 25 up to and including 32	2,5 to 16
Above 32 up to and including 50	4 to 25
Above 50 up to and including 80	10 to 35
Above 80 up to and including 100	16 to 50
Above 100 up to and including 125	25 to 70

[a] It is required that, for current ratings up to and including 50 A, terminals be designed to clamp solid conductors as well as rigid stranded conductors; the use of flexible conductors is permitted. Nevertheless, it is permitted that terminals for conductors having cross-sections from 1 mm^2 up to 10 mm^2 be designed to clamp solid conductors only.

[b] Maximum wire sizes of Table 7, increased according to Table D.2 of IEC 61545:1996.

Compliance is checked by inspection, by measurement and by fitting in turn one conductor of the smallest and one of the largest cross-section areas as specified.

8.1.5.4 *The text of 8.2.5.4 is replaced by:*

Terminals shall allow the conductors to be connected without special preparation.

Compliance is checked by inspection and the tests of L.9.

L.9 Tests

L.9.1 General

Clause 9 of this standard applies, with the following modifications/additions:

For the tests which are influenced by the material of the terminal and the type of conductor that can be connected, the test conditions of Table L.3 are applied.

Additionally, the test of L.9.3 is carried out on terminals separated from the AFDD.

Table L.3 – List of tests according to the material of conductors and terminals

Material of terminals	**Material according to 8.1.4.4 [a]**	**Al [a]**	
Material of conductor (Table L.1)	Al Use Tables L.2 and L.5	Cu Use Tables 6 and 10	Al Use Tables L.2 and L.5
9.4 Reliability of screws	Use Tables L.2, L.5 and 13	Use Tables 6, 10 and 13	Use Tables L.2, L.5 and 13
9.5.1 Pull-out test [b]	Use Tables L.2, L.5 and 13	Use Tables 8, 12 and 13	Use Tables L.2, L.5 and 13
9.5.2 Damage of the conductor	Use Tables L.2, L.5 and 13	Use Tables 8, 12 and 13	Use Tables L.2, L.5 and 13
9.5.3 Insertion of the conductor	Use Table L.4	Use Table 15	Use Table L.4
9.8 Temperature rise	Use Table L.5	Use Table 12	Use Table L.5
9.19 Verification of reliability	Use Table L.5	Use Table 12	Use Table L.5
L.9.3 Cycling test	Use Table 13	Use Table 13	Use Table 13

[a] Use test sequences A and B and number of samples defined in Annex C. For AFDDs which are able to be connected to Al or Cu conductors, the test sequences and number of samples have to be doubled (one for the Cu conductor and one for the Al conductor)

[b] For the pull-out test 9.5.1, the value for 70 mm² wire is under consideration.

Table L.4 – Connectable conductors and their theoretical diameters

Metric					**AWG**				
Rigid			**Flexible (copper only)**		**Rigid**			**Flexible (copper only)**	
S	**Solid**	**Stranded**	**S**			**Solid [a]**	**Class B stranded [a]**		**Classes [b] I, K, M stranded**
mm²	**Ø** mm	**Ø** mm	mm²	**Ø** mm	Gauge	**Ø** mm	**Ø** mm	Gauge	mm
1,0	1,2	1,4	1,0	1,5	18	1,07	1,23	18	1,28
1,5	1,5	1,7	1,5	1,8	16	1,35	1,55	16	1,50
2,5	1,9	2,2	2,5	2,3[c]	14	1,71	1,95	14	2,08
4,0	2,4	2,7	4,0	2,9 [c]	12	2,15	2,45	12	2,70
6,0	2,9	3,3	4,0	2,9 [c]	10	2,72	3,09		
10,0	3,7	4,2	6,0	3,9	8	3,43	3,89	10	3,36
16,0	4,6	5,3	10,0	5,1	6	4,32	4,91	8	4,32
25,0		6,6	16,0	6,3	4	5,45	6,18	6	5,73
35,0		7,9	25,0	7,8	2	6,87	7,78	4	7,25
					1	7,72	8,85		
50,0		9,1	35	9,2	0	8,51	9,64		12,08
70,0		12,0	50	12	0	9,266	10,64		

NOTE Diameters of the largest rigid and flexible conductors are based on IEC 60228:2004, Table 1 and, for AWG conductors, on ASTM B 172-71, ICEA S-19-81, ICEA S-66-524, ICEA S-68-516.

[a] Nominal diameter + 5 %.

[b] Largest diameter + 5 % for any of the three classes I, K, M.

[c] Dimensions for class 5 flexible conductors only, according to IEC 60228.

L.9.2 Test conditions

Subclause 9.1 of this standard applies, except that the Al conductors to be connected are taken from Table L.5.

Table L.5 – Cross sections (*S*) of aluminium test conductors corresponding to the rated currents

S mm^2	I_n A
1,5	$I_n \leq 6$
2,5	$6 < I_n \leq 13$
4	$13 < I_n \leq 20$
6	$20 < I_n \leq 25$
10	$25 < I_n \leq 32$
16	$32 < I_n \leq 50$
25	$50 < I_n \leq 63$
35	$63 < I_n \leq 80$
50	$80 < I_n \leq 100$
70	$100 < I_n \leq 125$

L.9.3 Current cycling test

L.9.3.1 General

This test verifies the stability of the screw-type terminal by comparing the temperature performance with that of the reference conductor under accelerated cycling conditions.

This test is carried out on separate terminals.

L.9.3.2 Preparation

The test is performed on four specimens, each one made by a couple of terminals, assembled in a manner which represents the use of the terminals in the AFDD (see examples shown in Figures L.2 to L.6). The screw-type terminals which have been removed from the product shall be attached to the conducting parts of the same cross-section, shape, metal and finish as that on which they are mounted on the product. The screw-type terminals shall be fixed to the conducting parts in the same manner (position, torque, etc.) as on the product. If one specimen fails during the test, four other specimens shall be tested and no other failures are admitted.

L.9.3.3 Test arrangement

The general arrangement of the samples shall be as shown in Figure L.1.

Ninety per cent of the value of torque stated by the manufacturer or, if not stated, selected in Table 13 shall be used for the test specimens.

The test is carried out with conductors according to Table L.5. The length of the test conductor from the point of entry to the screw-type terminal specimens to the equalizer (see L.3.3) shall be as in Table L.6.

Table L.6 – Test conductor length

Conductor cross section mm²	Conductor wire size AWG	Minimum conductor length mm
S ≤ 10,0	≤ 8	200
16,0 ≤ S ≤ 25,0	6 to 3	300
35,0 ≤ S ≤ 70,0	2 to 00	460

Test conductors are connected in series with a reference conductor of the same cross-section.

The length of the reference conductor shall be approximately at least twice the length of the test conductor.

Each free end of the test and reference conductor(s) not connected to a screw-type terminal specimen shall be welded or brazed to a short length of an equalizer of the same material as the conductor and of cross section not greater than that given in Table L.7. All strands of the conductor shall be welded or brazed to make an electrical connection with the equalizer.

Tool-applied compression type terminations without welding may be used for the equalizer if acceptable to the manufacturer and if the same performance is provided.

Table L.7 – Equalizer and busbar dimensions

Range of test current A	Maximum cross section mm²	
	Al	Cu
0 – 50	45	45
51 – 125	105	85
126 – 225	185	155

The separation between the test and reference conductors shall be at least 150 mm.

The test specimen shall be suspended either horizontally or vertically in free air by supporting the equalizer or busbar by non-conductive supports so as not to subject the screw-type terminal to a tensile load. Thermal barriers shall be installed midway between the conductors which shall extend 25 mm ± 5 mm widthways and 150 mm ± 10 mm lengthways beyond the screw-type terminals (see Figure L.1). Thermal barriers are not required provided the specimens are separated by at least 450 mm. The specimens shall be located at least 600 mm from the floor, wall or ceiling.

The test specimens shall be located in a substantially vibration-free and draught-free environment and at an ambient temperature between 20 °C and 25 °C. Once the test is started, the maximum permissible variation is ± 1 K provided the range limitation is not exceeded.

L.9.3.4 Temperature measurement

Temperature measurements are made by means of thermocouples, using a wire having a cross-section of not more than 0,07 mm² (approximately 30 AWG).

For screw-type terminals, the thermocouple shall be located on the conductor entry side of the screw-type terminal, close to the contact interface.

For the reference conductor, the thermocouples shall be located midway between the ends of the conductor, and under its insulation.

Positioning of the thermocouples shall not damage the screw-type terminal or the reference conductor.

NOTE 1 Drilling of a small hole and subsequent fastening of the thermocouple is an acceptable method, provided that the performance is not affected and that it is agreed by the manufacturer.

The ambient temperature shall be measured with two thermocouples in such a manner as to achieve an average and stable reading in the vicinity of the test loop without undue external influence. The thermocouples shall be located in a horizontal plane intersecting the specimens, at a minimum distance of 600 mm from them.

NOTE 2 A satisfactory method for achieving a stable measurement is, for example, to attach the thermocouple to unplated copper plates approximately 50 mm × 50 mm, having a thickness between 6 mm and 10 mm.

L.9.3.5 Test method and acceptance criteria

NOTE 1 Evaluation of performance is based on both the limit of screw-type terminal temperature rise and the temperature variation during the test.

The test loop shall be subjected to 500 cycles of 1 h current-on and 1 h current-off, starting at an a.c. current equal to 1,12 times the test current value determined in Table L.8. Near the end of each current-on period of the first 24 cycles, the current shall subsequently be adjusted to raise the temperature of the reference conductor to 75 °C.

At the 25th cycle the test current shall be adjusted for the last time and the stable temperature shall be recorded as the first measurement. There shall be no further adjustment of the test current for the remainder of the test.

Temperatures shall be recorded for at least one cycle of each working day, and after approximately 25, 50, 75, 100, 125, 175, 225, 275, 350, 425, and 500 cycles.

The temperature shall be measured during the last 5 min of the current-on time. If the size of the set of test specimens or the speed of the data acquisition system is such that not all measurements can be completed within 5 min, the current-on time shall be extended as necessary to complete such measurements.

After the first 25 cycles the current-off time may be reduced to a time 5 min longer than the time necessary to all terminal assemblies for cooling down to a temperature between ambient temperature T_a and T_a + 5 K during the current-off period. Forced-air cooling may be employed to reduce the off time, if acceptable to the manufacturer. In that case it shall be applied to the entire test loop and the resulting temperature of the forced air shall not be lower than the ambient air temperature.

The stability factor Sf for each of the 11 temperature measurements is to be determined by subtracting the average temperature deviation *D* from the 11 values of the temperature deviation *d*.

The temperature deviation d for the 11 individual temperature measurements is obtained by subtracting the associated reference conductor temperature from the screw-type terminal temperature.

NOTE 2 The value of *d* is positive if the screw-type temperature is higher than that of the reference conductor and negative if it is lower.

For each screw-type terminal

– the temperature rise shall not exceed 110 K;

– the stability factor Sf shall not exceed ± 10 °C.

An example of calculation for one screw-type terminal is given in Table L.9.

Table L.8 – Test current as a function of rated current

Metric sizes		
Rated current A	**Al conductor size** mm^2	**Test current** A
$0 \le I_n \le 15$	2,5	26
$15 < I_n \le 20$	4	35
$20 < I_n \le 25$	6	46
$25 < I_n \le 32$	10	60
$32 < I_n \le 50$	16	79
$50 < I_n \le 65$	25	99
$65 < I_n \le 80$	35	137
$80 < I_n \le 100$	50	171
$100 < I_n \le 125$	70	190

AWG		
Rated current A	**Al conductor size** N°	**Test Current** A
$0 < I_n \le 15$	12	30
$15 < I_n \le 25$	10	40
$25 < I_n \le 40$	8	53
$40 < I_n \le 50$	6	69
$50 < I_n \le 65$	4	99
$65 < I_n \le 75$	3	110
$75 < I_n \le 90$	2	123
$90 < I_n \le 100$	1	152
$100 < I_n \le 120$	0	190

Table L.9 – Example of calculation for determining the average temperature deviation *D*

Temperature measurement	**Cycle Number**	**Temperatures**		**Temperature deviation** ***d* = *a* – *b*** K	**Stability factor** ***Sf* = *d* – *D*** K
		Screw-type terminal *a* °C	**Reference conductor *b*** °C		
1	25	79	78	1	0,18
2	50	80	77	3	2,18
3	75	78	78	0	−0,82
4	100	76	77	−1	−1,82
5	125	77	77	0	−0,82
6	175	78	77	1	0,18
7	225	79	76	3	2,18
8	275	78	76	2	1,18
9	350	77	78	−1	−1,82
10	425	77	79	−2	−2,82
11	500	81	78	3	2,18

Average temperature deviation $D = \frac{\Sigma d}{\text{number of measurements}} = \frac{9}{11} = 0{,}82$

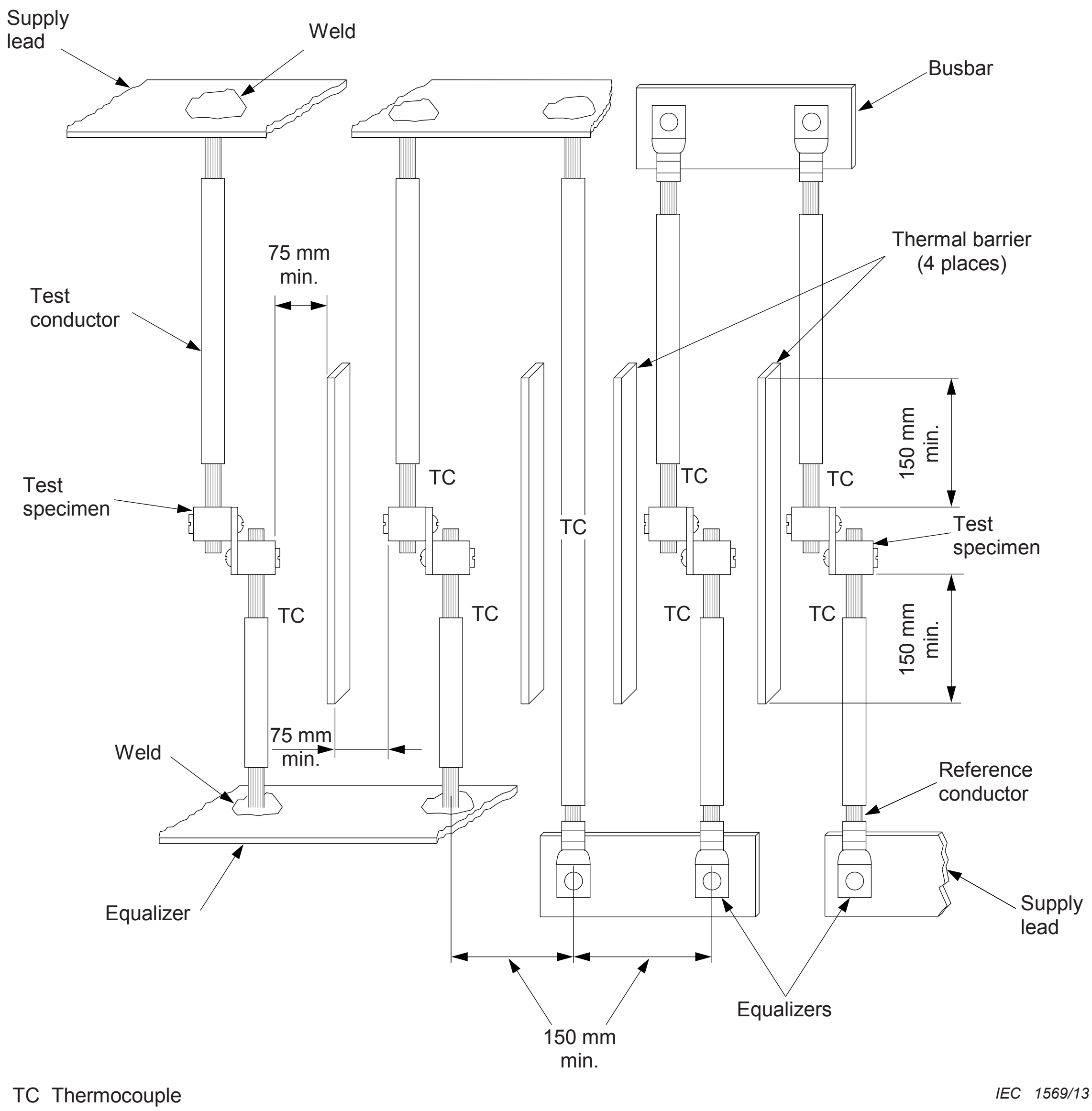
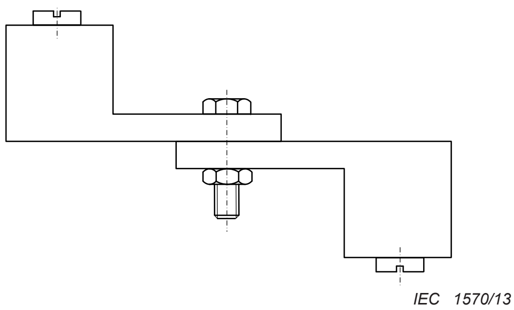


Figure L.1 – General arrangement for the test



The conducting part may be bolted, soldered or welded.

Figure L.2 – Example for the use of the terminals in the AFDD

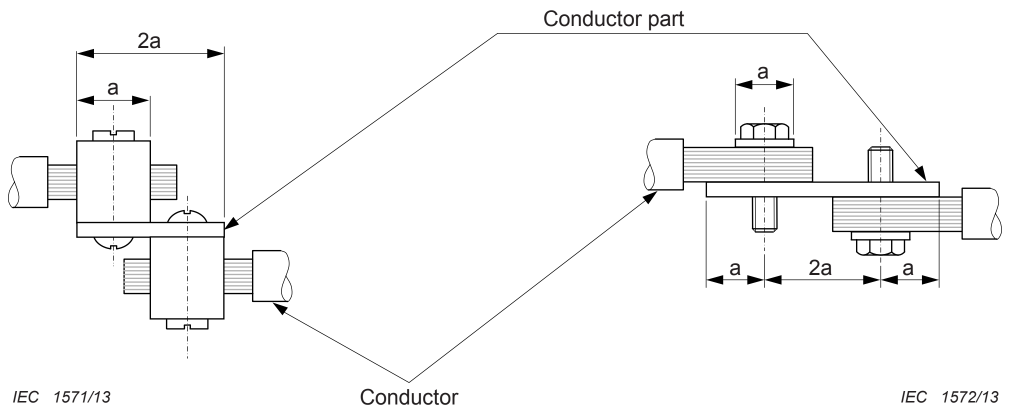


Figure L.3 – Example for the use of the terminals in the AFDD

Figure L.4 – Example for the use of the terminals in the AFDD

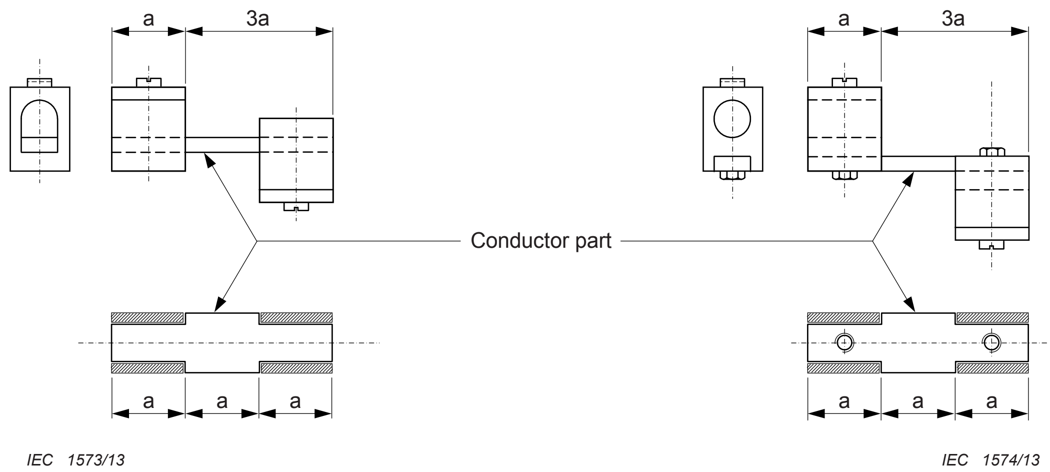


Figure L.5 – Example for the use of the terminals in the AFDD

Figure L.6 – Example for the use of the terminals in the AFDD

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