IEC 61009-1

Edition 4.0 2024-11

INTERNATIONAL STANDARD

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

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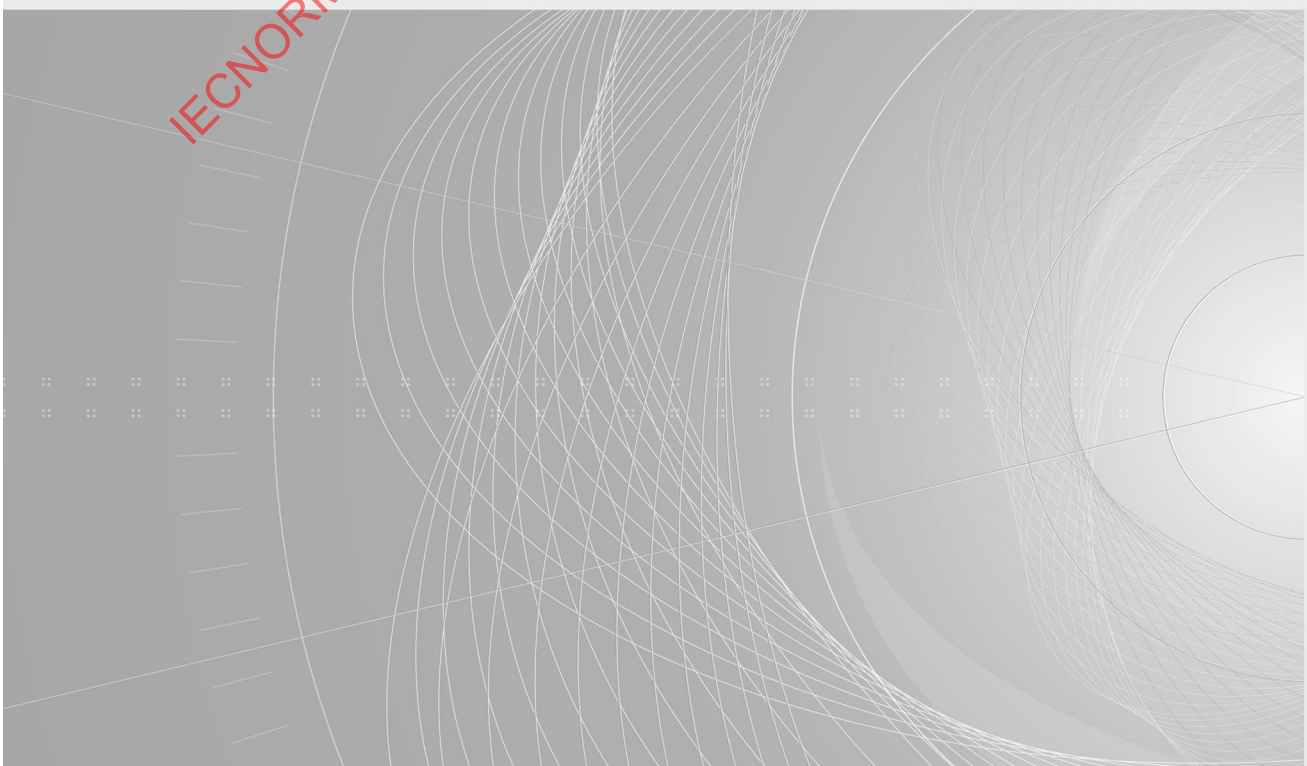

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RESIDUAL CURRENT OPERATED CIRCUIT-BREAKERS WITH INTEGRAL OVERCURRENT PROTECTION FOR HOUSEHOLD AND SIMILAR USES (RCBOs) –

Part 1: General rules

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IEC 61009-1 has been prepared by subcommittee 23E: Circuit-breakers and similar equipment for household use, of IEC technical committee 23: Electrical accessories. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2010, Amendment 1:2012 and Amendment 2:2013. This edition constitutes a technical revision.

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

a) harmonization of all clauses between the IEC 61008, IEC 61009 and IEC 60755 series using blocks and modules approach;

b) harmonization of all tables and figures between the IEC 61008, IEC 61009 and IEC 60755 series;

c) terms and definitions are now referred to IEC 62873-2;

d) modification of Subclause 4.1 for classification according to supply conditions;

e) new Subclauses 8.17 and 9.24 for requirements and tests for the resistance to temporary overvoltages (TOV);

f) improvement of Subclause 9.7 for test of dielectric properties;

g) tests for screwless, flat-quick terminals and aluminium conductors are now referred to in the IEC 62873-3 series.

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

Draft	Report on voting
23E/1373/FDIS	23E/1388/RVD

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

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

This International Standard is to be used in conjunction with the relevant product standard, either IEC 61009-2-1:2024 or IEC 61009-2-2:2024. The chosen standard, IEC 61009-2-1:2024 or IEC 61009-2-2:2024, shall be used consistently throughout the standard.

In order to maintain the same structure throughout the IEC 61008 and IEC 61009 series, some elements that are not applicable to a particular device within the scope of this document are labelled void.

In this document, the following print types are used:

– compliance statements: in *italic* type;

– other statements: in normal type.

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

A list of all parts in the IEC 61009 series, published under the general title *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)*, can be found on the IEC website.

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

- reconfirmed,
- withdrawn, or
- revised.

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INTRODUCTION

The purpose of this document is to harmonize as far as practicable all rules and requirements of a general nature applicable to RCBOs in order to obtain uniformity of requirements and tests and to avoid the need for testing to different standards.

All those parts which can be considered as general have therefore been gathered in this document, e.g., temperature-rise, dielectric properties, etc.

For each type of RCBO, two main documents are used to determine all requirements and tests:

1) this document;
2) the relevant product standard covering RCBOs:
   - IEC 61009-2-1, *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 2-1: RCBOs according to classification 4.1.1*;
   - IEC 61009-2-2, *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 2-2: RCBOs according to classification 4.1.2, 4.1.3, 4.1.4, 4.1.5 and 4.1.6*.

For Type F and Type B RCBOs, IEC 62423 applies in addition to the IEC 61009 series.

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RESIDUAL CURRENT OPERATED CIRCUIT-BREAKERS WITH INTEGRAL OVERCURRENT PROTECTION FOR HOUSEHOLD AND SIMILAR USES (RCBOs) –

Part 1: General rules

1 Scope

This document gives general requirements and tests for residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (hereafter referred to as RCBOs), for rated operational voltages not exceeding 440 V AC, with rated frequencies of 50 Hz, 60 Hz or 50/60 Hz and rated currents not exceeding 125 A and rated short-circuit capacities not exceeding 25 000 A.

RCBOs are intended to provide fault protection (previously referred to as protection against indirect contact), the exposed conductive parts of the installation being connected to an appropriate earth electrode. These devices are also intended to protect against overcurrents in the wiring installations of buildings and similar applications. They are also intended to be used to provide protection against fire hazards due to a persistent earth fault current.

RCBOs having a rated residual operating current not exceeding 30 mA are used for fault protection and additional protection in the case of failure of the protective provisions against electric shock.

This document applies to RCBOs performing simultaneously the functions of detection of the residual current, of comparison of the value of this current with the residual operating value and of opening of the protected circuit when the residual current exceeds this value. These devices also perform the function of making, carrying and breaking overcurrents under specified conditions.

NOTE 1 The requirements for RCBOs are in line with the group safety publication IEC 60755.

NOTE 2 RCBOs of type AC and type A are covered by the IEC 61009 series. RCBOs of type F and type B are covered by IEC 62423 in conjunction with the IEC 61009 series.

NOTE 3 Installation and selection rules for RCBOs are given in the IEC 60364 series.

NOTE 4 The content of this document related to operation under residual current conditions is based on IEC 61008-1. The content of this document related to protection against overcurrents is based on IEC 60898-1.

RCBOs are intended to be operated by ordinary or uninstructed persons and designed not to require maintenance.

The requirements of this document apply for standard conditions (see 7.1). Additional requirements can be necessary for RCBOs used in locations which have severe environmental conditions. RCBOs within the scope of this document are intended for use in an environment with pollution degree 2 (see 7.3).

NOTE 5 For environments with higher pollution degrees, enclosures giving the appropriate degree of protection can be used.

NOTE 6 For RCBOs having a degree of protection higher than IP20 special constructions can be required.

RCBOs are suitable for isolation.

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Special precautions (e.g. surge protective devices) can be necessary when excessive overvoltages are likely to occur on the supply side (for example in the case of supply through overhead lines, see IEC 60364-4-44 and IEC 60364-5-53).

RCBOs, with the exception of those with an uninterrupted neutral, are suitable for use in IT systems.

RCBOs of the general type are resistant to current surges, including the case where surge voltages (as a result of switching transients or induced by lightning) cause loading currents in the installation without occurrence of flashover.

RCBOs of type S are considered to be sufficiently resistant against unwanted tripping even if the surge voltage causes a flashover and a follow-on current occurs.

NOTE 7 Surge protective devices installed downstream of the general type of RCBOs and connected in common mode can cause unwanted tripping.

This document also applies to RCBOs obtained by the assembly of an adaptable residual current device with a circuit-breaker. The mechanical assembly is intended to be effected in the factory by the manufacturer, or on site, in which case the requirements of Annex G apply. It also applies to RCBOs having more than one rated current, provided that the means for changing from one discrete rating to another is not accessible in normal service and that the rating cannot be changed without the use of a tool.

Particular requirements are necessary for RCBOs intended to be used at frequencies other than 50 Hz or 60 Hz.

For RCBOs incorporated in, or intended for association with socket-outlets only, the requirements of this document 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.

NOTE 8 Residual current devices (RCDs) with or without overcurrent protection for socket-outlets for household and similar uses are also covered by IEC 62640.

NOTE 9 In DK, plugs and socket-outlets are in accordance with the requirements of the heavy current regulations section 107.

NOTE 10 In the UK, the plug part associated with an RCBO complies with BS 1363-1 and the socket-outlet(s) associated with an RCBO complies with BS 1363-2. In the UK, the plug part and the socket-outlet(s) associated with an RCBO need not comply with any IEC 60884-1 requirements.

This document does not apply to:

– RCBOs intended to protect motors;
– RCBOs the current setting of which is adjustable without a tool;
– RCBOs including batteries.

A guide for the coordination of RCBOs with fuses is given in Annex F.

This document is not intended to be used alone; it is intended to be used in conjunction with the relevant product standard, IEC 61009-2-1 or IEC 61009-2-2.

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2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

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

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

IEC 60228, *Conductors of insulated cables*

IEC 60417, *Graphical symbols for use on equipment,* available at https://www.graphical-symbols.info/equipment

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

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

IEC 60664-3, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

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

IEC 60898-1:2015, *Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations – Part 1: Circuit-breakers for AC operation*
IEC 60898-1:2015/AMD1:2019

IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 61009-2-1:2024, *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 2-1: RCBOs according to classification 4.1.1*

IEC 61009-2-2:2024 *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) – Part 2-2: RCBOs according to classification 4.1.2, 4.1.3, 4.1.4, 4.1.5 and 4.1.6*

IEC 61032, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 62873-2, *Residual current operated circuit-breakers for household and similar use – Part 2: Residual current devices (RCDs) – Vocabulary*

IEC 62873-3-1, *Residual current operated circuit-breakers for household and similar use – Part 3-1: Particular requirements for devices with screwless-type terminals for external copper conductors*

IEC 62873-3-2, *Residual current operated circuit-breakers for household and similar use – Part 3-2: Particular requirements for devices with flat quick-connect terminations*

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IEC 62873-3-3, *Residual current operated circuit-breakers for household and similar use – Part 3-3: Specific requirements for RCDs with screw-type terminals for external untreated aluminium conductors and with aluminium screw-type terminals for use with copper or with aluminium conductors*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62873-2 and the following apply.

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

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

3.1
live part
<in electrical installations and equipment> conductive part intended to be energized under normal operating conditions, including the neutral conductor and mid-point conductor, but excluding the PEN conductor, PEM conductor and PEL conductor

[SOURCE: IEC 60050-195:2021, 195-02-19]

3.2
functional earth
FE
wire or terminal intended to be connected to the PE to continue to provide a supply to the RCBO when the RCBO is supplied from one phase only

3.3
line to neutral voltage
U_o
voltage between line conductor and neutral conductor

3.4
residual current unit
RC-unit
device performing simultaneously the functions of detection of the residual current and of comparison of the value of this current with the residual operating value, and incorporating the means of operating the tripping mechanism of a circuit-breaker with which it is designed to be assembled

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4 Classification

4.1 According to the supply conditions

4.1.1 RCBO operating correctly on the occurrence of residual current

– within the voltage range 1,1 U_e and zero volt; and

– with any number of supply conductors connected.

The RCBO does not open automatically in the event of loss of supply.

4.1.2 RCBO with 2 or 4 current paths operating correctly on the occurrence of residual current within the voltage range of 1,1 U_e and 85 V

The RCBO does not open automatically in the event of loss of supply.

NOTE 1 In China, the lower limit value of 50 V (line to neutral) is required (for RCBO with $I_{\Delta n} \leq 30$ mA) instead of 85 V.

NOTE 2 Devices according to this classification are not allowed in Germany.

4.1.3 RCBO according to 4.1.2 fitted with a functional earth (FE) and able to continue to provide protection when supplied from just one phase and FE

4.1.3.1 Does not open automatically in the event of loss of supply and continues to provide residual current protection in the event of supply from just one phase and FE

NOTE Devices according to this classification are not allowed in Germany.

4.1.3.2 Does not open automatically in the event of loss of one or more phases and provides protection by opening automatically if supplied from just one phase and FE

NOTE Devices according to this classification are not allowed in Germany.

4.1.4 RCBO with 3 current paths operating correctly on the occurrence of residual current within the voltage range of 1,1 U_e and 0,7 U_e

The RCBO does not open automatically in the event of loss of supply.

These devices are not intended to be supplied from single-phase circuits.

NOTE Devices according to this classification are not allowed in Germany.

4.1.5 RCBO operating correctly on the occurrence of residual current within the voltage range 1,1 U_e and U_x

The device opens automatically, with or without delay, in the event of a supply voltage drop to a value less than U_x.

NOTE Devices according to this classification are not allowed in Germany.

4.1.6 RCBO according to 4.1.5, however reclosing automatically after restoration of the supply voltage

NOTE Devices according to this classification are not allowed in Germany.

4.2 According to the possibility of adjusting the residual operating current

4.2.1 RCBO with a single value of rated residual operating current

4.2.2 RCBO with multiple settings of residual operating current by fixed steps

4.3 According to their operation in response to the type of residual current

4.3.1 RCBO of type AC

NOTE In some countries the use of type AC is not allowed: Germany

4.3.2 RCBO of type A

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4.4 According to time-delay (in the presence of a residual current)

4.4.1 RCBO without time-delay: type for general use

4.4.2 RCBO with time-delay: type S for selectivity

4.5 According to the protection against external influences

4.5.1 Enclosed-type RCBO (not requiring an appropriate enclosure)

4.5.2 Unenclosed-type RCBO (for use with an appropriate enclosure)

4.6 According to the method of mounting

4.6.1 Surface-type RCBO

4.6.2 Flush-type RCBO

4.6.3 Panel board type RCBO, also referred to as distribution board type

NOTE These types can be intended to be mounted on rails.

4.7 According to the method of connection

4.7.1 RCBO for which the electrical connections are not associated with the mechanical mounting

4.7.2 RCBO for which the electrical connections are associated with the mechanical mounting

NOTE Examples of this type are:

- plug-in type;
- bolt-on type;
- screw-in type.

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

4.8 According to the type of terminals

4.8.1 RCBO with screw-type terminals for copper conductors

4.8.2 RCBO with screwless-type terminals for copper conductors

NOTE Related terminal requirements for RCBOs equipped with these types of terminals are given in IEC 62873-3-1.

4.8.3 RCBO with flat quick-connect terminals for copper conductors

NOTE Related terminal requirements for RCBOs equipped with these types of terminals are given in IEC 62873-3-2.

4.8.4 RCBO with screw-type terminals for aluminium conductors

NOTE Related terminal requirements for RCBOs equipped with this type of terminal are given in IEC 62873-3-3.

4.9 According to the number of poles and current paths

4.9.1 Single-pole RCBO with one overcurrent protected pole and uninterrupted neutral (two current paths)

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4.9.2 Two-pole RCBO with one overcurrent protected pole

4.9.3 Two-pole RCBO with two overcurrent protected poles

4.9.4 Three-pole RCBO with three overcurrent protected poles

4.9.5 Three-pole RCBO with three overcurrent protected poles and uninterrupted neutral (four current paths)

4.9.6 Four-pole RCBO with three overcurrent protected poles

4.9.7 Four-pole RCBO with four overcurrent protected poles

NOTE The pole which is not an overcurrent protected pole can be:

– "unprotected", or

– "switched neutral"

4.10 According to the instantaneous tripping current

NOTE This classification applies to RCBOs with integral overcurrent protection based on IEC 60898-1.

4.10.1 B-type

4.10.2 C-type

4.10.3 D-type

4.11 According to the I^2t characteristics

In addition to the I^2t characteristic to be provided by the manufacturer in accordance with Clause 5, RCBOs may be classified according to their I^2t characteristic.

5 Characteristics of RCBOs

5.1 Summary of characteristics

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

– rated voltages (see 5.2.1);

– rated current I_n (see 5.2.2);

– rated frequency (see 5.2.3);

– rated short-circuit capacity I_{cn} (see 5.2.4);

– rated residual operating current $I_{\Delta n}$ (see 5.2.5);

– rated residual non-operating current $I_{\Delta no}$ (see 5.2.6);

– rated residual making and breaking capacity $I_{\Delta m}$ (see 5.2.7);

– time-delay, if applicable (see 5.2.11);

– operating characteristics in the case of residual currents with DC components (see 5.2.10);

– degree of protection (see IEC 60529);

– ranges of overcurrent instantaneous tripping (see 5.3.15).

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5.2 Rated quantities and other characteristics

5.2.1 Rated voltages

5.2.1.1 Rated operational voltage (U_e)

The rated operational voltage of an RCBO is the value of voltage, assigned by the manufacturer, to which its performance is referred.

NOTE The same RCBO can be assigned a number of rated operational voltages and associated performance characteristics.

5.2.1.2 Rated insulation voltage (U_i)

The rated insulation voltage is assumed to be equal to the highest rated operational voltage assigned to the RCBO.

Where the rated insulation voltage assigned by the manufacturer exceeds the highest rated operational voltage of the RCBO, the dielectric test voltages and creepage distances shall be chosen for that rated insulation voltage in accordance with IEC 60664-1.

5.2.1.3 Rated impulse withstand voltage (U_{imp})

The rated impulse withstand voltage of an RCBO shall comply with the standard values given in Table 19.

5.2.2 Rated current (I_n)

The current assigned by the manufacturer which the RCBO can carry in uninterrupted duty, at a specified reference ambient air temperature.

The reference calibration temperature is 30 °C. If a different reference calibration temperature for the RCBO is used, the effect on the overload protection of cables shall be taken into account, since this is also based on an ambient air temperature of 30 °C, according to installation rules (see Clause 523 of IEC 60364-5-52:2009).

5.2.3 Rated frequency

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

NOTE A number of rated frequencies can be assigned to the same RCBO.

5.2.4 Rated short-circuit capacity (I_{cn})

The rated short-circuit capacity of an RCBO is the value of the ultimate short-circuit breaking capacity assigned to that RCBO by the manufacturer.

NOTE An RCBO having a given rated short-circuit capacity (I_{cn}) has a corresponding service short-circuit capacity (I_{cs}) (see Table 41).

5.2.5 Rated residual operating current ($I_{\Delta n}$)

The value of residual operating current, assigned by the manufacturer, at which the RCBO shall operate under specified conditions.

For an RCBO having multiple settings of residual operating current, the highest setting is used to designate it.

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5.2.6 Rated residual non-operating current ($I_{\Delta no}$)

The value of residual non-operating current at which the RCBO does not operate under specified conditions. The standard value of residual non-operating current is defined in 5.3.4.

5.2.7 Rated residual making and breaking capacity ($I_{\Delta m}$)

The RMS value of the AC component of residual prospective current, assigned by the manufacturer, which an RCBO can make, carry and break under specified conditions.

5.2.8 Void

5.2.9 Void

5.2.10 Operating characteristics in response to the type of residual current

5.2.10.1 RCBO type AC

An RCBO for which tripping is ensured for residual sinusoidal alternating currents, whether suddenly applied or slowly rising.

5.2.10.2 RCBO type A

An RCBO for which tripping is ensured:

- as for type AC;
- for residual pulsating direct currents; and
- for residual pulsating direct currents superimposed on a smooth direct current of 0,006 A

with or without phase-angle control, independent of polarity, whether suddenly applied or slowly rising.

5.2.11 RCBO type S

A time-delay RCBO which complies with the relevant part of Table 11 or Table 12, if applicable.

5.3 Standard and preferred values

5.3.1 Standard values of rated operational voltage (U_e)

Preferred values of rated operational voltage are indicated in Table 46.

5.3.2 Preferred values of rated current (I_n)

Preferred values of rated current are:

6 A – 8 A – 10 A – 13 A – 16 A – 20 A – 25 A – 32 A –
40 A – 50 A – 63 A – 80 A – 100 A – 125 A.

5.3.3 Standard values of rated residual operating current ($I_{\Delta n}$)

Standard values of rated residual operating current are:

0,006 A – 0,01 A – 0,03 A – 0,1 A – 0,3 A – 0,5 A.

NOTE In the Republic of Korea and Japan, 0,015 A, 0,2 A and 1 A are also considered as standard values.

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5.3.4 Standard value of residual non-operating current ($I_{\Delta no}$)

The standard value of residual non-operating current is 0,5 $I_{\Delta n}$.

NOTE For residual pulsating direct currents, residual non-operating currents depend on the phase angle (see Table 14).

5.3.5 Preferred values of rated frequency

Preferred values of rated frequency are 50 Hz, 60 Hz and 50/60 Hz.

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

5.3.6 Standard values of rated impulse withstand voltage (U_{imp})

Table 19 gives the standard values of rated impulse withstand voltages as a function of the nominal voltage of the installation.

5.3.7 Standard limit values of break time and non-actuating time for RCBO of type AC and A

5.3.7.1 Standard limit values of break time and non-actuating time for alternating residual currents (RMS values) of type AC and A

Standard limit values are indicated in Table 11.

NOTE In the USA, where the tripping times are specifically related to current, the following formulas apply:

for $t = \left(\frac{20}{I}\right)^{1,43}$ high-resistance faults and $t = 1,25\left(\frac{10}{I}\right)^{1,43}$ for low-resistance faults.

5.3.7.2 Standard maximum values of break time for half-wave residual currents (RMS values) of type A

Standard limit values are indicated in Table 12.

5.3.8 Void

5.3.9 Void

5.3.10 Void

5.3.11 Minimum value of the rated residual making and breaking capacity ($I_{\Delta m}$)

The minimum value of the rated residual making and breaking capacity ($I_{\Delta m}$) is 10 I_n or 500 A, whichever is the greater.

5.3.12 Void

5.3.13 Void

5.3.14 Values of rated short-circuit capacity

Standard values of rated short-circuit capacities up to and including 10 000 A are given in Table 37.

For values above 10 000 A up to and including 25 000 A, preferred values are 15 000 A and 20 000 A.

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5.3.15 Standard ranges of overcurrent instantaneous tripping

Standard ranges of overcurrent instantaneous tripping are given in Table 38.

6 Marking and other product information

Each RCBO shall be marked according to Table 1, in a durable manner.

The suitability for isolation, which is provided by all RCBOs of this document, may be indicated by the symbol  (IEC 60417-6169-1:2012-08) 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 on the circuit-breaker 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, the device shall comply with it, whichever the method of installation. If the higher degree of protection is obtained only by a specific method of installation or with the use of specific accessories (e.g. terminal covers, enclosures, etc.), this shall be specified in product information.

For RCBOs other than those operated by means of push-button, the open position shall be indicated by the symbol "O" (a circle) IEC 60417-5008:2002-10 and the closed position by the symbol "|" (a short vertical straight line) IEC 60417-5007:2002-10. Additional national symbols can be required for this indication. These indications shall be readily visible when the RCBO is installed.

For RCBOs operated by means of two push-buttons, the push-button designed for the opening operation only shall be in red colour and/or be marked with the symbol "O".

Red colour shall not be used for any other push-button of the RCBO.

If a push-button is used for closing the contacts and is evidently identified as such, its depressed position is sufficient to indicate the closed position.

If a single push-button is used for closing and opening the contacts and is identified as such, the 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.

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

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".

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The markings of non-universal terminals should appear on the device or, if the space available is not sufficient, on the smallest package unit or in the product information.

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

Compliance is checked by inspection and by the test of 9.3.

7 Standard conditions for operation in service and for installation

7.1 Standard conditions

RCBOs shall be capable of operating under the standard conditions shown in Table 47.

7.2 Conditions of installation

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

7.3 Pollution degree

RCBOs are intended for an environment with pollution degree 2, i.e. normally, only non-conductive pollution occurs. However, occasionally, a temporary conductivity caused by condensation may be expected.

8 Requirements for construction and operation

8.1 Mechanical design

8.1.1 General

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

The residual current detection and the residual current release shall be located between the incoming and outgoing terminals of the RCBO.

It shall not be possible to alter the operating characteristics of the RCBO by means of external interventions other than those specifically intended for changing the setting of the residual operating current or of the time delay.

Changing from one setting to another shall not be possible without a tool. It shall not be possible to disable or inhibit the RCBO function by any means.

NOTE 1 In Austria, Australia, Germany, Denmark, Italy, the UK, Ireland and Switzerland, multiple settings are not allowed.

RCBOs with continuously adjustable settings are not allowed.

Provisions for remote tripping of the RCBO, if any, shall:

– not cause any current to the PE;
– not cause any fault voltage when actuated, and
– not impair the isolation function of the RCBO.

RCBOs shall not be operated by introduction of an external connection for the purpose of intentionally creating a residual current to trip the RCBO.

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NOTE 2 This does not preclude the use of an RCBO with a functional earth connection.

NOTE 3 This does not preclude the use of a test instrument.

NOTE 4 This requirement does not apply in Japan.

8.1.2 Mechanism

All poles of multipole RCBOs shall be mechanically coupled so that all poles, except the neutral, if any, make and break substantially together, whether operated manually or automatically.

The neutral pole of four-pole RCBOs shall not close after and shall not open before the other poles.

Compliance is checked by inspection and by manual tests, using any appropriate means (example: indicator lights, oscilloscope, etc.).

If a pole having an appropriate short-circuit making and breaking capacity is used as a neutral pole and the RCBO has an independent manual operation, then all poles, including the neutral pole, may operate substantially together.

RCBOs shall have a trip-free mechanism.

It shall be possible to switch the RCBO on and off by hand. For plug-in RCBOs without an operating handle, this requirement is not considered to be met by the fact that the RCBO can be removed from its base.

RCBOs 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.

RCBOs shall provide in the open position an isolation distance in accordance with the requirements necessary to satisfy the isolating function (see 8.3).

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 US, the colours red and green are not used for contact position indication.

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

RCBOs shall be designed so that the actuator, front plate or cover can only be correctly 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.

Compliance is checked by inspection, in accordance with the instructions of the manufacturer.

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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 RCBO manually before reclosing is possible.

When an indicator light is used, this shall be lit when the RCBO is in the closed position and be of bright colour. The indicator light shall not be the only means to indicate the closed position.

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 RCBO.

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 RCBO is mounted as in normal use, the contacts shall be closed by the up movement.

Compliance is checked by inspection, by manual test and, for the trip-free mechanism, by the tests of 9.9.2.2, 9.11 and 9.15.

8.1.3 Clearances, creepage distances and solid insulation

8.1.3.1 General

The minimum required clearances and creepage distances are given in Table 20 which is based on the RCBO being designed for operating in an environment with pollution degree 2.

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

The insulating materials are classified into material groups based on their comparative tracking index (CTI) according to IEC 60664-1.

NOTE 1 The comparative tracking index (CTI) is declared by the manufacturer based on tests carried out on the insulating material.

NOTE 2 Information on the requirements for design of solid insulation is provided in IEC 60664-1.

For clearances on printed wiring material, footnote c in Table F.2 of IEC 60664-1:2020 applies: "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.5 of IEC 60664-1:2020. A protection by means of a solder resist of high quality is the minimum requirement to allow this clearance reduction".

All measurements required in this Subclause 8.1.3 are carried out in test sequence A on one sample. Tests according to 9.7 are carried out in test sequence B on three samples.

8.1.3.2 Clearances

Compliance for item 1 in Table 20 is checked by measurement and by the tests of 9.7.7.3. The test is carried out with samples not submitted to the humidity treatment described in 9.7.1.

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Compliance for items 2 and 4 in Table 20 is checked by measurement and, if the clearances are reduced, by the tests of 9.7.7.2.

The clearances of items 2 and 4 in Table 20 (except for accessible surface after installation, see below) may be reduced provided that the measured clearances are not shorter than the minimum allowed in IEC 60664-1 for homogenous field conditions. In this case, compliance for items 2 and 4 is always checked by the test of 9.7.7.2.

Accessible surface after installation means any surface accessible by the user when the RCD is installed according to the manufacturer's instructions. The test finger can be applied to determine whether a surface is accessible or not.

Compliance for item 3 in Table 20 is checked by measurement.

8.1.3.3 Creepage distances

Compliance for items 1, 2, 3 and 4 in Table 20 is checked by measurement.

8.1.3.4 Solid insulation

Compliance is checked by the tests according to 9.7.2, 9.7.3, 9.7.4, 9.7.5 and 9.7.7 as applicable.

8.1.3.5 Additional requirements for control circuits connected to the main circuit

Compliance is checked by the test of 9.7.6.

8.1.4 Screws, current-carrying parts and connections

8.1.4.1 Connections

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

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

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

NOTE Screwed connections are also considered to be checked by the tests of 9.8, 9.11, 9.12, 9.13 and 9.21.

Compliance is checked by inspection, by manual test and by the test of 9.4.

8.1.4.2 Screws in engagement with a thread of insulating material

For screws in engagement with a thread of insulating material and which are operated when mounting the RCBO 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.

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.

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8.1.4.3 Electrical connections

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.

8.1.4.4 Current-carrying parts

Current-carrying parts and 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.

If using ferrous alloys or suitably coated ferrous alloys, compliance to resistance to corrosion is checked by a test of resistance to rusting according to 9.23.

The requirements of this Subclause 8.1.4.4 do not apply to contacts, magnetic circuits, heater elements, bimetals, shunts, electronic components, printed circuit boards, nor to screws, nuts, washers, clamping plates, or similar parts of terminals and parts of the test circuit.

8.1.5 Terminals for external conductors

8.1.5.1 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.

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

Compliance is checked by inspection, by the tests of 9.5 for screw-type terminals, by specific tests for plug-in or bolt-on RCBOs included in this document, or by the tests of IEC 62873-3-1, IEC 62873-3-2, or IEC 62873-3-3, as relevant for the type of connection.

8.1.5.2 RCBOs shall be provided with one of the following:

– terminals which shall allow the connection of copper conductors having nominal cross-sectional areas as shown in Table 24; or

NOTE Examples of possible designs of screw-type terminals are given in Annex H.

– screwless type terminals for copper conductors according to IEC 62873-3-1; or
– flat quick-connect terminals for copper conductors according to IEC 62973-3-2; or
– terminals for untreated aluminium conductors and with aluminium screw-type terminals for use with copper or with aluminium conductors according to IEC 62873-3-3.

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Compliance for terminals according to the first indent is checked by inspection, by measurement and by fitting in turn one conductor of the smallest and one of the largest cross-section as specified in Table 24.

8.1.5.3 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.

8.1.5.4 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.

8.1.5.5 Terminals shall have adequate mechanical strength for the intended use.

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 9.5.4.

8.1.5.6 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 9.5.4.

8.1.5.7 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 9.5.4.

8.1.5.8 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 9.5.4.

8.1.5.9 Terminals shall be so fixed or located that, when the clamping screws or nuts are tightened or loosened, their fixings do not work 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 document.

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 document.

Compliance is checked by inspection, by measurement and by the test of 9.4.

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8.1.5.10 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 the use of a tool.

Compliance is checked by manual test.

In general, the designs of terminals of which examples are shown in Annex H 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.

8.1.5.11 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 the thread cutting type.

Compliance is checked by inspection.

8.1.6 Non-interchangeability

For RCBOs intended to be mounted on bases forming a unit therewith (plug-in type or screw-in type) it shall not be possible, without the aid of a tool, to replace an RCBO when mounted and wired as for normal use by another RCBO of the same make having a higher rated current.

Compliance is checked by inspection.

NOTE The expression "as for normal use" implies that the RCBO is mounted according to the manufacturer's instructions.

8.2 Protection against electric shock

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

A part is considered to be "accessible" if it can be touched by the standard test finger (Figure 1).

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

For RCBOs 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 the RCBOs are mounted and wired as in normal use, shall either be of insulating material, or be lined throughout with insulating material.

Linings shall be fixed in such a way that they are not likely to be lost during installation of the RCBOs. 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 RCBOs, 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 RCBOs, from screws or other means for fixing the base to its support and from metal plates used as support.

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

Lacquer and enamel are not considered to provide adequate insulation for the purpose of this Subclause 8.2.

Compliance is checked by inspection and by the test of 9.6.

8.3 Dielectric properties and isolating capability

RCBOs shall have adequate dielectric properties.

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

RCBOs shall ensure isolation.

Compliance is checked by the tests of 9.7.

8.4 Temperature-rise

8.4.1 General

RCBOs shall not suffer damage impairing its functions and its safe use taking into account the ambient air temperature at which they are intended to be used.

Compliance is checked by the tests of 9.8.

8.4.2 Temperature-rise limits

The temperature-rises of the parts of an RCBO specified in Table 28, measured under the conditions specified in 9.8.2, shall not exceed the limiting values stated in Table 28.

8.4.3 Ambient air temperature

The temperature-rise limits given in Table 28 are applicable only if the ambient air temperature remains within the limits given in Table 47.

8.5 Operating characteristics

8.5.1 General

The operating characteristic of RCBOs shall comply with the requirements of 9.9.

RCBOs shall operate according to the requirements of 8.5.2 to 8.5.4, as applicable.

8.5.2 Operation in response to the type of residual current

8.5.2.1 General

The tripping characteristic of RCBOs shall ensure protection against residual current without premature operation.

The tests shall verify the operation of the RCBOs within their voltage range according to the classification.

Compliance is checked by the tests of 9.9.1.

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8.5.2.2 Alternating residual current

RCBOs shall operate in response to a steady increase of alternating residual current of rated frequency within the limits of the non-operating current $I_{\Delta no}$ and the rated residual operating current $I_{\Delta n}$.

8.5.2.3 Pulsating DC residual current

RCBOs type A shall operate in response to a steady increase of pulsating direct residual current of rated frequency within specified limits of the non-operating current and the operating current in accordance with Table 14.

The tripping limits shall be maintained, independent of the polarity of the pulsating direct residual current.

8.5.2.4 Pulsating DC residual current superimposed by smooth direct current of 0,006 A

RCBOs type A shall operate in response to a steady increase of pulsating direct residual current of rated frequency within specified limits of the non-operating current and the operating current in accordance with Table 14 also when a smooth direct current of 0,006 A is superimposed.

The tripping limits of the pulsating direct current shall be maintained, even if the polarity of the pulsating direct residual current and the smooth direct current are the same

8.5.3 Operation in presence of a residual current equal to or greater than $I_{\Delta n}$

Compliance is checked by the tests of 9.9.1.

8.5.4 Operation under overcurrent conditions

8.5.4.1 Standard time-current zone

The tripping characteristic of RCBOs shall ensure protection against overcurrents, without premature operation.

The zone of the time-current characteristic (tripping characteristic) of an RCBO is defined by the conditions and the values stated in Table 39.

Table 39 refers to an RCBO mounted in accordance with the reference conditions (see 9.2) operating at the reference calibration temperature of 30 °C, with a tolerance of $^{+5}_{0}$ °C.

Checking is carried out at any convenient temperature, the results being referred to 30 °C according to the information given by the manufacturer.

Under no circumstances shall the variation of the test current of Table 39 exceed 1,2 % per K of calibration temperature variation.

If the RCBOs are marked for a calibration temperature different from 30 °C, they are tested for that different temperature.

The manufacturer shall be prepared to give information on the variation of the tripping characteristic for calibration temperatures differing from the reference value.

Compliance is checked by the tests specified in 9.9.2.

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8.5.4.2 Conventional quantities

a) Conventional time

The conventional time is 1 h for RCBOs of rated current up to and including 63 A and 2 h for RCBOs of rated current above 63 A.

b) Conventional non-tripping overcurrent (I_{nt})

The conventional non-tripping overcurrent of an RCBO is 1,13 times its rated current.

c) Conventional tripping overcurrent (I_t)

The conventional tripping overcurrent of an RCBO is 1,45 times its rated current.

8.5.4.3 Overcurrent tripping characteristic

The overcurrent tripping characteristic of RCBOs shall be contained within the zone defined in 8.5.4.1.

NOTE Conditions of temperature and mounting different from those specified in 9.2 (e.g. mounting in a special enclosure, grouping of several RCBOs in the same enclosure, etc.) can affect the tripping characteristic of RCBOs.

The manufacturer can provide information on the variation of the tripping characteristic for ambient air temperatures differing from the reference calibration temperature.

8.5.4.4 Effect of the ambient air temperature on the overcurrent tripping characteristic

Ambient air temperatures other than the reference calibration temperature, within the limits of −5 °C and +40 °C, shall not unacceptably affect the overcurrent tripping characteristic of RCBOs.

Compliance is checked by the tests of 9.9.2.3.

8.6 Mechanical and electrical endurance

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

Compliance is checked by the test of 9.10.

8.7 Performance at short-circuit currents

RCBOs 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.

8.8 Resistance to mechanical shock and impact

RCBOs shall have adequate mechanical behaviour to withstand the stresses imposed during installation and use.

Compliance is checked by the test of 9.12.

8.9 Resistance to heat

RCBOs shall be sufficiently resistant to heat.

Compliance is checked by the test of 9.13.

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8.10 Resistance to abnormal heat and to fire

External parts of RCBOs 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 being checked by the other tests of this document.

Compliance is checked by inspection and by the test of 9.14.

8.11 Test device

RCBOs shall be provided with a test device to simulate the passing through the detecting device of a residual current in order to allow a periodic testing of the ability of the residual current device to operate.

NOTE The test device is intended to check the tripping function, not the value at which this function is effective with respect to the rated residual operating current and the break times.

The ampere-turns produced when operating the test device of an RCBO supplied at rated operational voltage or at the highest value of the voltage range, if applicable, shall not exceed 2,5 times the ampere-turns produced, when a residual current equal to $I_{\Delta n}$ is passed through one of the poles of the RCBO.

In the case of RCBOs having several settings of residual operating current (see 4.2.2), the lowest setting for which the RCBOs have been designed shall be used.

The protective conductor of the installation shall not become live when the test device is operated.

It shall not be possible to energize the circuit on the load side by operating the test device when the RCBO is in the open position and connected as in normal use.

The test device shall not be the sole means of performing the opening operation and is not intended to be used for this function.

Compliance is checked by inspection and by the tests of 9.16.

8.12 Void

8.13 Void

8.14 Behaviour of RCBOs in the event of current surges caused by impulse voltages

RCBOs shall adequately withstand the current surges to earth:

– due to the loading of the capacitances of the installation, or
– due to surges of atmospheric origin.

RCBOs of type S shall withstand and shall have adequate resistance against unwanted tripping in the event of surge current to earth:

– due to the loading of the capacitances of the installation, or
– due to surges of atmospheric origin, or
– due to flashovers causing follow currents.

Compliance is checked by the test of 9.19.

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8.15 Reliability

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

Compliance is checked by the tests of 9.20 and 9.21.

8.16 Electromagnetic compatibility (EMC)

RCBOs shall operate reliably, even in the presence of electromagnetic disturbances, and shall comply with relevant EMC requirements.

Compliance is checked by the tests of 9.22.

8.17 Resistance to temporary overvoltages (TOV)

RCBOs shall adequately withstand temporary overvoltages due to various phenomena (such as a fault in the high voltage network, break of neutral, short circuit between line conductor and neutral conductor).

Withstand values of alternating overvoltage levels and duration are given in Table 30.

Compliance with the above requirements is checked by the tests of 9.24.

9 Tests

9.1 General

The characteristics of RCBOs are checked by means of type tests.

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 are provided by IEC 61009-2-1:2024 (RCBOs in accordance with 4.1.1) or IEC 61009-2-2:2024 (RCBOs according to 4.1.2, 4.1.3, 4.1.4, 4.1.5 and 4.1.6), as applicable.

Unless otherwise specified in the relevant test clause, each type test (or sequence of type tests) is carried out on RCBOs in a clean and new condition, the influencing quantities having their normal reference values (see Table 47).

Routine tests to be carried out by the manufacturer on each device are given in Annex D.

Guidance for follow-up testing program for RCBOs is provided in Annex J.

9.2 Test conditions

The RCBO is mounted individually according to the manufacturer's instructions and in free air, at an ambient air temperature equal to 20 °C, unless otherwise specified in the relevant test clause, and is protected against external heating or cooling.

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RCBOs 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 in the relevant test clause, the RCBO is wired with the appropriate cable of cross-section S specified in Table 25 and is fixed on a dull black painted plywood board of not less than 20 mm thickness, the method of fixing being in compliance with the requirements relating to the indications of the manufacturer concerning mounting.

NOTE 2 For AWG copper conductors, see Annex I.

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

During the tests, no maintenance or dismantling of the samples is allowed.

For the tests of 9.8, 9.9, 9.10, 9.20.2 and 9.21, the RCBO 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 up to and including 10 mm^2;
  - 2 m for cross-sections larger than 10 mm^2.

The tightening torques to be applied to the terminal screws are two-thirds of those specified in Table 26.

For RCBOs 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 RCBO 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 RCBO under test.

NOTE 3 In Japan, on request of the manufacturer, a different operating speed can be used for tests in 9.10 and 9.11.

9.3 Test of indelibility of marking

The test is carried out 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, initial boiling point approximately 65 °C, dry point approximately 69 °C and specific gravity of 0,68 g/cm^3.

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

Marking made by impressing, moulding, engraving or laser printing 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 document.

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

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

Compliance with the requirements of 8.1.4 is checked by inspection and, for screws and nuts which are operated when connecting the RCBO, 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 re-inserted each time.

The test is carried out by means of a suitable test screwdriver or spanner applying a torque as shown in Table 26.

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

The test is carried out with rigid conductors only, having the largest connectable cross-section specified in Table 24, solid or stranded, whichever is the more unfavourable. The conductor is moved each time the screw or nut is loosened.

Column I of Table 24 applies to screws without head 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 of Table 24 applies to other screws which are tightened by means of a screwdriver.

Column III of Table 24 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 column II and column III of Table 24 are different, the test is carried out twice, first applying to the hexagonal head the torque specified in column III of Table 24 and then, on another sample, applying the torque specified in column II of Table 24 by means of a screwdriver. If the values in column II and column III of Table 24 are the same, only the test with the screwdriver is carried out.

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

Moreover, enclosures and covers shall not be damaged.

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9.5 Test of reliability of screw-type terminals for external copper conductors

9.5.1 Compliance with the requirements of 8.1.5 is checked by inspection, by the test of 9.4, for which a rigid copper conductor having the largest cross-section specified in Table 24 is placed in the terminal (for nominal cross-sections exceeding 6 mm^2, a rigid stranded conductor is used; for other nominal cross-sections, a solid conductor is used), and by the tests of 9.5.2, 9.5.3 and 9.5.4.

The tests of 9.5.2, 9.5.3 and 9.5.4 are carried out using a suitable test screwdriver or spanner, and applying the torque specified in Table 26.

9.5.2 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 24.

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 conductor 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 50 mm^2, as applicable;
– tests for flexible conductors shall use conductors having cross-sections from 1 mm^2 up to 35 mm^2, as applicable.

NOTE Information on AWG is given in Annex I.

The conductor is inserted into a new terminal for the minimum distance specified or, where no distance is specified, 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 26.

Each conductor is then subjected to a pull of the value, in newtons, shown in Table 27, 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.

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

9.5.3 The terminals are fitted with copper conductors of the smallest and largest cross-sections specified in Table 24, 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 26.

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 work loose and there shall be no damage, such as breakage of screws or damage to the head slots, threads, washers or stirrups, that will impair the further use of the terminal.

9.5.4 The terminals are fitted with the largest cross-section area specified in Table 24, for stranded and/or flexible copper conductor.

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 26.

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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 RCBOs which are exposed to the operator when mounted as for normal use.

The test is carried out with the standard test finger shown in Figure 1 on the RCBO mounted as for normal use (see note of 8.2) and fitted with conductors of the smallest and largest cross-sections which may be connected to the RCBO.

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.

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

RCBOs are subjected for 1 min to a force of 75 N, applied through the tip of a straight unjointed test finger (probe 11 according to IEC 61032). This finger is applied to all places where yielding of insulating material could impair the safety of the RCBO but it 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 RCBOs 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 Resistance to humidity

9.7.1.1 Preparation of the RCBO for test

Parts of the RCBO 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.

9.7.1.2 Test conditions

The humidity treatment is carried out in a humidity cabinet containing air with a relative humidity maintained between 91 % and 95 %.

The temperature of the air in which the sample is placed is maintained within ±1 °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.

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9.7.1.3 Test procedure

The sample is kept in the cabinet for 48 h.

NOTE A relative humidity between 91 % and 95 % can be obtained by 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 a constant circulation of the air within and to use a cabinet which is thermally insulated.

9.7.1.4 Condition of the RCBO after the test

After this treatment, the sample shall show no damage within the meaning of this document and shall withstand the tests of 9.7.2, 9.7.3, 9.7.4, 9.7.6 and 9.7.7.2 (if applicable).

9.7.2 Insulation resistance of the main circuit

The RCBO having been treated as specified in 9.7.1 is then removed from the cabinet.

After an interval of between 30 min and 60 min following this treatment, the insulation resistance is measured 5 s after the application of a DC voltage of approximately 500 V, in the following order:

a) with the RCBO in the open position, between each pair of the terminals which are electrically connected together when the RCBO is in the closed position, in turn on each pole;

b) with the RCBO 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 RCBO in the closed position, between all poles connected together and the frame including a metal foil or part in contact with the outer surface of the housing of insulating material but with the terminal areas kept completely free to avoid flashover between terminals and the metal foil;

d) for RCBOs 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.

The measurement of c) is 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 RCBO 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 RCBO;

– metal parts of operating means referred to in 8.2.

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

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

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The insulation resistance shall not be less than:

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

9.7.3 Dielectric strength of the main circuit

After the RCBO has passed the tests of 9.7.2, the test voltage specified is applied for 1 min between the parts indicated in 9.7.2 with 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 list items a) to c) of 9.7.2;
– 2 500 V for list item d) of 9.7.2.

Initially, not more than half the specified 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 disregarded.

9.7.4 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 list items 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 at a voltage of approximately 500 V DC:

   1) between
      – the auxiliary circuits connected together, and
      – the frame;
   2) between
      – each part of the auxiliary circuit which might be separated from the other parts of the auxiliary circuit in normal service and
      – the other parts of the auxiliary circuit(s) connected together,

   After this voltage has been applied for 1 min, the insulation resistance shall not be less than 2 MΩ.

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

   The voltage values to be applied are specified in Table 21.

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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.

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

In the case of RCBOs in which the auxiliary circuit is not accessible for verification of the requirements given in item b), the tests can be made on specially prepared samples.

Auxiliary circuits do not include the control circuit of RCBOs classified according to 4.1.2, 4.1.3, 4.1.4, 4.1.5 and 4.1.6.

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.

9.7.5 Secondary circuit of detection transformers

The circuit which includes the secondary circuit of the detection transformer is not submitted to any insulation test, provided that the circuit has no connection with accessible metal parts, with a protective conductor, or with live parts.

9.7.6 Capability of control circuits connected to the main circuit to withstand high DC voltages due to insulation measurements

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

A DC voltage source is used with the following characteristics:

– open voltage: 600 V $^{+25}_{0}$ V

– maximum ripple: 5 %

– 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, under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, the RCBO shall trip with a test current of $I_{\Delta n}$. Only one test is carried out, the break time shall comply with Table 11.

9.7.7 Verification of impulse withstand voltages

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 being at least 10 s for impulses of the opposite polarity.

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When performing the impulse voltage test, the attenuation or amplification of the test voltage shall be taken into account. It shall be ensured that the required value of the test voltage is applied across the terminals of the equipment under test.

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

The shape of the impulses is adjusted with the RCBO under test connected to the impulse generator. For this purpose, appropriate voltage dividers and voltage sensors shall be used.

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.

9.7.7.2 Verification of clearances with the impulse withstand voltage

If the measurement of clearances of items 2 and 4 of Table 20 does not show any reduced clearance, this test is not applied.

Where measurements of clearances within the device are not feasible this test may be used to replace measurements of clearances of items 2 and 4 of Table 20.

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

The test impulse voltage values shall be chosen from Table 22 in accordance with the rated impulse withstand voltage of the RCBO as given in Table 19. These values are corrected for barometric pressure and/or altitude at which the tests are carried out, according to Table 22.

Tests are carried out with the RCBO in the closed position, applying the impulse voltage between:

a) in turn between each pole and the others connected together, electronic components connected between current paths being disconnected for the test;
b) between all poles connected together and the frame including a metal foil or part in contact with the outer surface of the housing of insulating material but with the terminal areas kept completely free to avoid flashover between terminals and the metal foil;
c) for RCBOs 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.

NOTE 1 The term "frame" is defined in 9.7.2.

Where applicable, the metal foil is applied in such a way that the sealing compound, if any, is effectively tested.

The test in list item b) above is carried out after having connected all auxiliary circuits to the frame.

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.

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No further disruptive discharge shall occur.

NOTE 2 The expression "disruptive discharge" is used to cover the phenomena associated with the failure of insulation under electric stress, which include a drop in the voltage and the flowing of current.

9.7.7.3 Verification of resistance of the insulation of open contacts against an impulse voltage (suitability for isolation)

The tests of this Subclause 9.7.7.3 are not preceded by the humidity treatment described in 9.7.1, according to Annex A.

The test impulse voltage values shall be chosen from Table 23, in accordance with the rated operational voltage of the installation for which the RCBO is intended to be used as given in Table 19. These values are corrected for barometric pressure and/or altitude at which the tests are carried out according to Table 23.

The series of tests is carried out on an RCBO fixed on a metal support as in normal use and with the contact in open position.

The impulses are applied between the line terminals connected together and the load terminals connected together.

There shall be no disruptive discharges during the test.

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 RCBO at about half its height and at a distance of about 1 m from the RCBO.

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 is passed simultaneously through all the poles of the RCBO 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 per hour.

For four-pole RCBOs, the test is first carried out by passing the specified current through the three-phase poles only.

The test is then repeated by passing the current through the pole intended for the connection of the neutral and the pole adjacent to the neutral.

With the agreement of the manufacturer, the test on four-pole devices may also be replaced by a single test with all poles in series including the N-pole.

During these tests, the temperature-rise shall not exceed the values shown in Table 28.

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9.8.3 Measurement of the temperature of parts

The temperature of the different parts referred to in Table 28 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 Verification of the operating characteristics under residual current conditions

IEC 61009-2-1:2024, 9.9.1 or IEC 61009-2-2:2024, 9.9.1 applies.

9.9.2 Verification of the operating characteristic under overcurrent conditions

9.9.2.1 Test of time-(over)current characteristic

a) a current equal to 1,13 I_n (conventional non-tripping current) is passed for the conventional time through all poles, starting from cold (see Table 39);

   The RCBO shall not trip;

   The current is then steadily increased within 5 s to 1,45 I_n (conventional tripping current);

   The RCBO shall trip within the conventional time.

b) a current equal to 2,55 I_n is passed through all poles, starting from cold.

   The opening time shall be not less than 1 s nor more than

   - 60 s for rated currents up to and including 32 A;
   - 120 s for rated currents greater than 32 A.

9.9.2.2 Test of instantaneous tripping

9.9.2.2.1 General test conditions

For the lower values of the test current of 9.9.2.2.2, 9.9.2.2.3 and 9.9.2.2.4, respectively, the test is carried out once:

– on RCBOs with two and four current paths, connecting all the current paths in series, at any convenient voltage;

– on RCBOs with three current paths, on each combination of two current paths in series, at any convenient voltage.

For the upper value of the test current, the two following tests are carried out:

– at any convenient voltage, one opening operation on each combination of two poles connected in series is performed. The tripping time is measured and shall be within the limits of Table 39;

– at line to neutral voltage U_0 with a power factor between 0,95 and 1 separately on each protected pole of the RCBO, the following sequence of operation is performed:

$$O - t - CO - t - CO - t - CO$$

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the interval t being as defined in 9.11.11.1. The tripping time of the O operation is measured. After each operation the indicating means shall show the open position of the contacts.

9.9.2.2.2 Tests for B type RCBOs

A current equal to 3 I_n is applied, starting from cold.

The opening time shall be not less than 0,1 s.

A current equal to 5 I_n is then applied, again starting from cold.

The RCBO shall trip in a time less than 0,1 s.

9.9.2.2.3 Tests for C type RCBOs

A current equal to 5 I_n is applied, starting from cold.

The opening time shall be not less than 0,1 s.

A current equal to 10 I_n is then applied, again starting from cold.

The RCBO shall trip in a time less than 0,1 s.

9.9.2.2.4 Tests for D type RCBOs

A current equal to 10 I_n is applied, starting from cold.

The opening time shall be not less than 0,1 s.

A current equal to 20 I_n or to the maximum instantaneous tripping current (see Table 1, item T) is then applied, again starting from cold.

The RCBO shall trip in a time less than 0,1 s.

9.9.2.3 Test of effect of ambient air temperature on the tripping characteristic

Compliance is checked by the following tests:

a) The RCBO is placed in an ambient air temperature of (35 ± 2) °C below the ambient air reference temperature until it has attained steady-state temperature.

   A current equal to 1,13 I_n (conventional non-tripping current) is passed through all poles for the conventional time. The current is then steadily increased within 5 s to 1,9 I_n.

   The RCBO shall trip within the conventional time.

b) The RCBO is placed in an ambient air temperature of (10 ± 2) °C above the ambient air reference temperature until it has attained steady-state temperature.

   A current equal to I_n is passed through all poles.

   The RCBO shall not trip within the conventional time.

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9.10 Verification of mechanical and electrical endurance

9.10.1 General test conditions

The RCBO is fixed to a metal support.

The test is carried out at rated operational 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 influence the recovery voltage.

The current shall have a substantially sinusoidal waveform and the power factor shall be between 0,85 and 0,9.

The RCBO is connected to the circuit with conductors of the sizes indicated in Table 25.

9.10.2 Test procedure

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

The RCBO shall be operated as for normal use.

The opening operations shall be carried out as follows:

For RCBOs having $I_{\Delta n}$ > 0,010 A:

– for the first 1 000 operating cycles by using the manual operating means;
– for the following 500 operating cycles by using the test device;
– for the last 500 operating cycles by passing through one pole a residual operating current of value $I_{\Delta n}$.

For RCBOs having $I_{\Delta n}$ ≤ 0,010 A:

– for the first 500 operating cycles by using the manual operating means;
– for the following 750 operating cycles by using the test device;
– for the last 750 operating cycles by passing through one pole a residual operating current of value $I_{\Delta n}$.

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

– 2 000 operating cycles for RCBOs having I_n ≤ 25 A;
– 1 000 operating cycles for RCBOs having I_n > 25 A.

The operating frequency shall be:

– four operating cycles per minute for RCBOs of I_n ≤ 25 A, the ON period having a duration of 1,5 s to 2 s;
– two operating cycles per minute for RCBOs of I_n > 25 A, the ON period having a duration of 1,5 s to 2 s.

For RCBOs having multiple settings, the tests are carried out at the lowest setting.

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9.10.3 Condition of the RCBO after test

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

– 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.

Under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, the RCBO shall trip with a test current of 1,25 $I_{\Delta n}$. Only one test is carried out without measurement of the break time.

The RCBO shall then perform satisfactorily the dielectric strength test in 9.7.3 for 1 min but at a voltage of 900 V without previous humidity treatment.

In addition, the RCBO shall perform satisfactorily the test of 9.9.2.1 b).

9.11 Short-circuit tests

9.11.1 General conditions for test

The short circuit tests shall be performed at a convenient temperature within the range according to 7.1.

The conditions of 9.11.1 to 9.11.12 are applicable to any test intended to verify the behaviour of the RCBOs under short-circuit conditions. However, for the test at rated residual making and breaking capacity, additional requirements are stated in 9.11.13.

For RCBOs having multiple settings of residual operating current, the tests are carried out at the lowest setting.

Standard tests for the verification of the short-circuit performance consist of sequences of making and breaking operations, appropriate to the performance to be verified; these are summarized in Table 40.

All RCBOs are tested:

– at 500 A or 10 I_n, whichever is the higher, according to 9.11.11.2 and 9.11.12.1;
– at 1 500 A, according to 9.11.11.3 and 9.11.12.1;
– at rated residual making and breaking capacity (see 5.2.7) according to 9.11.13.1 and 9.11.13.2.

RCBOs having rated short-circuit capacity above 1 500 A are additionally tested:

– at service short-circuit breaking capacity according to 9.11.11.4 b) and 9.11.12.1; the service short-circuit capacity is obtained by multiplying the rated short-circuit capacity by a factor, k, the values of which are given in Table 41;
– at rated short-circuit capacity (see 5.2.4) according to 9.11.11.4 c) and to 9.11.12.2, if the factor k is less than 1, in which case new samples shall be used.

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9.11.2 Test circuit for short-circuit performance

Figure 5 and Figure 6 give diagrams of the circuits to be used for the tests concerning:

– a single-pole RCBO with two current paths;
– a two-pole RCBO (with one or two overcurrent protected poles);
– a three-pole RCBO;
– a three-pole RCBO with four current paths;
– a four-pole RCBO.

The resistances and reactances of the impedances Z, Z_1 and Z_2 shall be adjustable to satisfy the specified test conditions. The reactors should preferably be air-cored. The reactors shall always be connected in series with the resistors and their value shall be obtained by series coupling of individual reactors; parallel connecting of reactors is permitted 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 7). This resistor may be omitted if agreed by the manufacturer.

If iron-core reactors are used, the iron-core power losses of these reactors shall not exceed the losses that would be absorbed by the resistors connected in parallel with the air-cored reactors.

In each test circuit, the impedances Z are inserted between the supply source S and the RCBO under test.

When tests are carried out with current less than the rated short-circuit capacity, the additional impedances Z_1 shall be inserted on the load side of the RCBO.

For the tests at both the rated and the service short-circuit capacity, and at the rated residual short-circuit making and breaking capacity, the RCBO shall be connected with cables (rigid or flexible) having a length of 0,75 m per pole and the maximum cross-section corresponding to the rated current according to the rigid conductor column of Table 24.

It is recommended that a cable of 0,5 m in length be connected on the supply side and a cable of 0,25 m in length be connected on the load side of the RCBO under test.

The switch S_1 remains open during all the short-circuit tests, except for the tests according to 9.11.13.

A resistor R_2 of about 0,5 Ω is connected in series with a copper wire F, as shown in Figure 5 and Figure 6.

The copper wire F shall be at least 50 mm in length and

– 0,1 mm in diameter for RCBOs to be tested in free air, mounted on a metal support;
– 0,3 mm in diameter for RCBOs to be tested in the smallest individual enclosure specified by the manufacturer.

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. All the conductive parts of the RCBO normally earthed in service, including the metal support on which the RCBO is mounted or any metal enclosure shall be connected to the neutral point of the supply or to a substantially non-inductive artificial neutral.

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Resistors R_1 drawing a current of 10 A per phase are connected on the supply side of the RCBO between the impedances for adjusting the prospective current to the rated short-circuit capacity and the RCBO.

The voltage sensors are connected:

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

The diagram of the test circuit shall be given in the test report.

9.11.3 Values of test quantities

All the tests concerning the verification of the rated short-circuit capacity shall be performed with the values stated by the manufacturer in accordance with the relevant tables of this document.

The value of the applied voltage is that which is necessary to produce the specified power frequency recovery voltage.

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

The value of 105 % (±5 %) of the rated operational voltage is deemed to cover the effect of the variations of the system voltage under normal service conditions. The upper limit value may be increased with the approval of the manufacturer.

9.11.4 Tolerances on test quantities

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: ±5 %
– power factor: $^{0}_{-0,05}$
– voltage (including recovery voltage): ±5 %

9.11.5 Power factor of the test circuit

The power factor of each phase of the test circuit shall be determined according to a method which shall be stated in the test report. Two examples are given in Annex E.

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

The power factor ranges are given in Table 29.

9.11.6 Measurement and verification of I^2t and of the peak current (I_p)

The I^2t and I_p values shall be measured during the tests according to 9.11.11.2, 9.11.11.3 and 9.11.11.4.

In the case of tests of RCBOs in three-phase circuits, the I^2t values shall be measured on each pole.

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The maximum I^2t values measured shall be recorded in the test report and shall not exceed the corresponding values of the I^2t characteristic.

9.11.7 Calibration of the test circuit

9.11.7.1 To calibrate the test circuit, links G_1 and G_2 having negligible impedance compared with those of the test circuit are connected in the positions shown in Figure 5 and Figure 6.

9.11.7.2 To obtain a prospective current equal to the rated short-circuit capacity of the RCBO at the corresponding power factor as stated in Table 29, impedances Z are inserted on the supply side of the links G_1.

9.11.7.3 To obtain a test current lower than the rated short-circuit capacity of the RCBO, additional impedances Z_1 are inserted on the load side of the links G_2, as shown in Figure 5 and Figure 6.

9.11.7.4 To obtain a prospective current equal to the rated residual making and breaking capacity, at the corresponding power factor as Table 29, an impedance Z_2 is inserted as shown in Figure 5.

9.11.8 Interpretation of records

a) 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 RCBO under test. The applied voltage is evaluated as indicated in Figure 23.

   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.

b) Determination of the prospective short-circuit current.

   The AC component of the prospective current is taken as being equal to the RMS value of the AC component of the calibration current (value corresponding to A_2 of Figure 23).

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

9.11.9 Condition of the RCBO for test

9.11.9.1 General

RCBOs shall be tested in free air according to 9.11.9.2, 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 9.11.9.3 or, with the agreement of the manufacturer, according to 9.11.9.2.

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

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

RCBOs of the plug-in type which are normally mounted on an insulating support are tested in this condition, the insulating support being fixed on a metal support.

9.11.9.2 Test in free air

The RCBO under test is mounted as shown in Figure C.1.

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.

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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).

If the position of the vents is not obvious, or if there are no vents, appropriate information should be provided by the manufacturer. If no information is available, two grids, one above and one below the RCBO, shall be used.

The grid circuit(s) (see Figure B.11) shall be connected to the points B and C as shown in the test circuit diagrams of Figure 5 and Figure 6.

The resistor R' shall have a resistance of 1,5 Ω. The copper wire F' (see Figure B.11) shall have a length of 50 mm and a diameter of 0,12 mm for RCBOs having a rated operational voltage of 230 V and 0,16 mm for RCBOs having a rated operational voltage of 400 V.

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_{cn} 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.

9.11.9.3 Test in enclosures

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

The test shall be performed with the RCBO placed in an enclosure having the most unfavourable configuration.

This means that if other RCBOs (or other devices) are normally fitted in the direction(s) in which the grid(s) would be placed, they should be installed there. These RCBOs (or other devices) should be supplied as in normal use but via F' and R' as defined in 9.11.9.2 and connected as shown in the appropriate Figure 5 and Figure 6.

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.

9.11.10 Behaviour of the RCBO during short-circuit tests

During tests the RCBO shall not endanger the operator.

Furthermore, there shall be no permanent arcing, no flashover between poles or between poles and frame, no blowing of the fuse F and, if applicable, no blowing of the fuse F′.

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9.11.11 Test procedure

9.11.11.1 General

The test procedure consists of a sequence of operations. The following symbols are used for defining the sequence of operations:

O represents an automatic opening;

CO represents a closing operation followed by an automatic opening operation;

t represents the time interval between two successive short-circuit operations which shall be 3 min or longer, as can be required by the thermal release in order to permit the reclosing of the RCBO.

The actual value of t shall be stated in the test report.

After arc extinction, the recovery voltage shall be maintained for a duration of not less than 0,1 s.

Three samples shall be tested for each of the tests of 9.11.11.2, 9.11.11.3 and 9.11.11.4.

9.11.11.2 Test at reduced short-circuit currents

9.11.11.2.1 Tests on all RCBOs

The additional impedances Z_1 (see 9.11.7.3) are adjusted so as to obtain a current of 500 A or 10 I_n, whichever is the higher, at a power factor between 0,93 and 0,98.

Each overcurrent protected pole of the RCBO is subjected separately to a test in a circuit similar to that of Figure 5, but with the impedance Z_1 connected only to the pole to be tested and directly connected to the neutral without passing the current through the N-pole of the RCBO, at a voltage of 105 % of the rated phase to neutral voltage value.

The RCBO is caused to open automatically nine times, the circuit being closed six times by the making switch T and three times by the RCBO itself.

The sequence of operations shall be:

$$O - t - O - t - O - t - O - t - O - t - CO - t - CO - t - CO$$

For the test, the making switch T is synchronized with respect to the voltage wave so that the six points of initiation for the opening operations are equally distributed over the half-wave with a tolerance of ±5°.

9.11.11.2.2 Short-circuit test on RCBOs for verifying their suitability for use in IT systems

This test is carried out on new samples.

The additional impedances Z_1 (see 9.11.7.3) are adjusted so as to obtain a current of 500 A or 1,2 times the upper limit of the standard range of instantaneous tripping given in Table 38, whichever is the higher, but not exceeding 2 500 A, at a power factor between 0,93 and 0,98, at a voltage 105 % of the rated phase to phase voltage value.

According to 5.3.11, the pole marked N, if any, is tested with a current of 500 A or 10 I_n whichever is the greater and at a voltage of 105 % of U_o for the pole marked N, if any.

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For RCBOs having an instantaneous tripping value exceeding $20\,I_n$, the impedances are adjusted so as to obtain a current 1,2 times the upper limit of instantaneous tripping declared by the manufacturer, the 2 500 A limitation being disregarded.

Each pole of RCBOs is subjected individually to a test in a circuit, the connections of which are shown in Figure 6.

The sequence of operations shall be:

$$O - t - CO$$

For the O operation on the first protected pole, the making switch T is synchronized with respect to the voltage wave so that the circuit is closed on the point 0° on the wave for this operation.

For the following O operations on the other protected poles to be tested, this point is shifted each time by 30° with respect to the point on wave of the previous test, with a tolerance of ±5°.

RCBOs with uninterrupted neutral are not subjected to this test.

9.11.11.3 Test at 1 500 A

For RCBOs having rated short-circuit capacity of 1 500 A, the test circuit is calibrated according to 9.11.7.1 and 9.11.7.2 to obtain a current of 1 500 A at a power factor corresponding to this current according to Table 29.

For RCBOs having a rated short-circuit capacity exceeding 1 500 A, the test circuit is calibrated according to 9.11.7.1 and 9.11.7.3 at a power factor corresponding to 1 500 A, according to Table 29.

The RCBOs are tested in a circuit according to Figure 5.

For three-pole RCBOs with three current paths, no connection is made between the neutral of the supply and the common point on the load side of the RCBO.

For four-pole RCBOs with three protected poles, the neutral of the supply is connected through the unprotected pole or the switched neutral pole to the common point on the load side of the RCBO.

If the neutral of a four-pole RCBO is not marked by the manufacturer, the tests are repeated with three new samples, using successively each pole as neutral in turn.

For the test of single-pole and two-pole RCBOs, the making switch T is synchronized with respect to the voltage wave so that the six points of initiation for the opening operations are equally distributed over the half-wave with a tolerance of ±5°.

The sequence of operations shall be as specified in 9.11.11.2.1.

For three-pole and four-pole RCBOs, random point-on-wave testing is acceptable.

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9.11.11.4 Test above 1 500 A

a) Ratio between service short-circuit capacity and rated short-circuit capacity (factor k)

The ratio between the service short-circuit capacity and the rated short-circuit capacity shall be in accordance with Table 41.

b) Test at service short-circuit capacity (I_{cs})

1) The test circuit is calibrated according to 9.11.7.1 and 9.11.7.3, with a power factor accordance with Table 29.

When the supply and load terminals of the RCBOs under test are not marked, two of the samples are connected in one direction and the third sample in the reverse direction.

2) For single-pole and two-pole RCBOs, the sequence of operations is:

$$O - t - O - t - CO$$

For the "O" operations, the making switch T is synchronized with respect to the voltage wave so that the circuit is closed at the point 0° on the wave for the "O" operation on the first sample.

This point is then shifted by 45° for the second "O" operation on the first sample; for the second sample, the two "O" operations shall be synchronized at 15° and 60° and for the third sample at 30° and 75°.

The synchronization tolerance shall be ±5°.

This test procedure is shown in Table 42.

3) For three-pole and four-pole RCBOs the sequence of operations is:

$$O - t - CO - t - CO$$

For the "O" operations, the making switch T is synchronized with respect to the voltage wave so that the circuit is closed on any point x° on the wave for the "O" operation on the first sample.

This point is then shifted by 60° for the "O" operation on the second sample and by a further 60° for the "O" operation on the third sample.

The synchronization tolerance shall be ±5°. The same pole shall be used as reference for the purpose of synchronization for the different samples.

This test procedure is shown in Table 43.

c) Test at rated short-circuit capacity (I_{cn})

The test circuit is calibrated according to 9.11.7.1 and 9.11.7.2.

When the supply and load terminals of the RCBOs under test are not marked, two of the samples are connected in one direction and the third sample in the reverse direction.

The sequence of operations is:

$$O - t - CO$$

For the "O" operations, the making switch T is synchronized with respect to the voltage wave so that the circuit is closed on the point 15° on the wave for the "O" operation on the first sample.

This point is then shifted by 30° for the "O" operation on the second sample and by a further 30° for the "O" operation on the third sample.

The synchronization tolerance shall be ±5°.

For three- and four-pole RCBOs, the same pole shall be used as reference for the purpose of synchronization.

The test procedure is shown in Table 44.

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9.11.12 Verification of the RCBO after short-circuit test

9.11.12.1 After each of the tests according to 9.11.11.2 or 9.11.11.3 or 9.11.11.4 b), the RCBOs shall show no damage impairing their further use and shall be capable, without maintenance, of withstanding the following tests:

a) leakage current across open contacts (suitability for isolation), by applying separately on each pole of the RCBO at a voltage equal to 1,1 times its rated operational voltage, the RCBO being in the open position. The leakage current flowing across the open contacts of each pole is measured after stabilization and shall not exceed 2 mA;

b) 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 500 V less the value specified and without humidity treatment.

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.

Moreover, after the tests of 9.11.11.3 or 9.11.11.4 b), RCBOs shall not trip when a current equal to 0,85 times the conventional non-tripping current is passed through all poles for the conventional time, starting from cold.

At the end of this verification, the current is steadily increased within 5 s to 1,1 times the conventional tripping current.

The RCBOs shall trip within the conventional time.

The polyethylene sheet shall show no holes visible with normal or corrected vision without additional magnification.

9.11.12.2 After the tests according to 9.11.11.4 c), the polyethylene foil shall show no holes visible with normal or corrected vision without additional magnification and the RCBOs shall show no damage impairing their further use and shall, without maintenance, withstand the following tests:

a) leakage current across open contacts (suitability for isolation), supplying the RCBO at a voltage equal to 1,1 times its rated operational voltage, the RCBO being in the open position. The leakage current flowing across the open contacts of each pole is measured and shall not exceed 2 mA;

b) dielectric strength tests according to 9.7.3, carried out between 2 h and 24 h after the short-circuit tests at a voltage of 900 V and without previous humidity treatment.

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

c) moreover, the RCBOs shall trip within the time corresponding to the test c) of Table 39 when a current equal to 2,8 I_n is passed through all poles, the lower time limit being 0,1 s instead of 1 s.

9.11.13 Verification of the rated residual making and breaking capacity ($I_{\Delta m}$)

9.11.13.1 Test procedure

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

The RCBO shall be tested according to the general test conditions specified in 9.11.1 but connected in such a manner that the short-circuit current is a residual current.

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The test is performed on each pole in turn excluding the pole marked N, if any. For the purpose of this test, the impedance Z_1 shall not be used, the circuit being left open.

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

The auxiliary switch S_1 remains closed during this test.

The following sequence of operations is performed:

$$O - t - CO - t - CO.$$

For the breaking operation the making switch T is synchronized with respect to the voltage wave so that the point of initiation is 45° ± 5°.

The same pole shall be used as reference for the purpose of synchronization for the different samples.

9.11.13.2 Verification of the RCBO after residual current making and breaking test

After the test carried out in accordance with 9.11.13.1, the RCBO shall show no damage impairing its further use and shall be capable, without maintenance, of:

– complying with the requirements of 9.7.3, carried out between 2 h and 24 h after the short-circuit tests at a voltage equal to twice its rated operational voltage, for 1 min, without previous humidity treatment; and

– making and breaking one time its rated current at its rated operational voltage.

Under the condition of IEC 61009-2-1:2024, 9.9.1.2.3 1) or IEC 61009-2-2:2024, 9.9.1.2.3 1), as relevant, the RCBO shall trip with a test current of 1,25 $I_{\Delta n}$. Only one test is carried out without measurement of the break time.

The polyethylene sheet shall show no holes visible with normal or corrected vision without additional magnification.

9.12 Verification of resistance to mechanical shock and impact

9.12.1 Mechanical shock

9.12.1.1 Test apparatus

The RCBO is subjected to mechanical shocks using an apparatus as shown in Figure 8. A wooden base A is fixed to a concrete block or equivalent fixing means 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 coiled spring(s) having a total flexion constant of 25 N/mm (±20 %).

The RCBO 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 8. The general tolerance for dimensions given in Figure 8 is ±2 mm.

On C, opposite to the mounting surface of the RCBO, an additional mass is fixed so that the static force on D is 25 N (0, +10 %), in order to ensure that the moment of inertia of the complete system is substantially constant.

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9.12.1.2 Test procedure

With the RCBO 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 RCBO 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 RCBO is 200 mm from the hinge.

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

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

During the tests, the RCBO shall not open.

9.12.2 Mechanical impact

9.12.2.1 General

Compliance is checked on those exposed parts of the RCBO mounted as for normal use (see note in 8.2), which may be subjected to mechanical impact in normal use, by the test of 9.12.2.2, for all types of RCBO and, in addition, by the tests of 9.12.2.3 for RCBOs intended to be mounted on a rail.

NOTE RCBOs intended to be totally enclosed only are not submitted to this test.

9.12.2.2 Test for all RCBOs

The samples are subjected to blows by means of an impact-test apparatus as shown in Figure 9, Figure 10 and Figure 11.

The head of the striking element has a hemispherical face of radius 10 mm and is of 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 ISO 2039-2 or ASTM D 785.

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 RCBOs 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 11.

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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 RCBOs are mounted in a test device, as shown in Figure 12, which is fixed to the mounting support.

Panel mounting-type RCBOs are mounted in a test device, as shown in Figure 13, which is fixed to the mounting support.

Plug-in type RCBOs are mounted in their appropriate sockets, which are fixed on the sheet of plywood or in the test devices according to Figure 12 or Figure 13, as applicable.

RCBOs 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 RCBO, with its covers, if any, is mounted as in normal use on the plywood or in the appropriate test device, as applicable, so that the point of impact lies in the vertical plane 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 26.

The striking element is allowed to fall from a height of 10 cm on the surfaces which are exposed when the RCBO 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 RCBO is subjected to 10 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.

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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 document. In particular, covers which, when broken, make live parts accessible or impair the further use of the RCBO, operating means, linings or barriers of insulating material and the like, shall not show such a damage.

In the 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.

Damage to the appearance, small dents which do not reduce the creepage distances or clearances below the values specified in 8.1.3 as well as small chips which do not adversely affect the protection against electric shock are disregarded.

When testing RCBOs designed for screw fixing as well as for rail mounting, the test is carried out on two sets of RCBOs, one of them being fixed by means of screws and the other being mounted on a rail.

9.12.2.3 Test for RCBOs intended to be mounted on a rail

RCBOs 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 RCBO, immediately followed by an upward vertical force of 50 N for 1 min (Figure 14).

During this test, the RCBO shall not become loose and, after the test, the RCBO shall show no damage impairing its further use.

9.13 Test of resistance to heat

9.13.1 Test on complete RCBOs

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 the 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 non-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.

Under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, the RCBO shall trip with a test current of 1,25 $I_{\Delta n}$. Only one test is carried out without measurement of the break time.

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 document.

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9.13.2 Ball pressure test

External parts of RCBOs made of insulating material are subjected to a ball pressure test by means of the apparatus shown in Figure 15.

The part to be tested, prepared according to 9.13.2 a), is placed on a steel support with the appropriate surface in the horizontal position and tested in a heating cabinet. A steel ball of 5 mm diameter is pressed against this surface with a force of 20 N.

The tests are not carried out on parts of ceramic material.

If two or more of the insulating parts are made of the same material, the test is carried out only on one of these parts.

External parts of RCBOs made of insulating material necessary to retain in position current-carrying parts, or parts serving as a protective conductor, are tested at a temperature of 125 °C ± 2 °C as described in 9.13.2 b).

All other external parts of the RCBO are tested 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 the higher.

For the purpose of the tests of 9.13.2, bases of surface-type RCBOs are considered as external parts.

a) Test specimen

A test specimen is cut from the end product in such a way that a piece at least 2,5 mm thick with approximately parallel upper and lower surfaces is obtained. If necessary, the thickness may be obtained by stacking two or more sections so long as there is no noticeable movement between the surfaces prior testing. If it is not possible to cut a test specimen with parallel surfaces, it is recommended to support the area of the test specimen directly under the pressure ball. The test specimen shall be at least 10 mm in length and 10 mm in width or a circle with a diameter of at least 10 mm.

If it is impracticable to use a test specimen from the end product, then a plaque of identical material may be used. The dimensions of the planar sections of the test specimens shall be at least 10 mm in length and 10 mm in width, or a circle with a diameter of at least 10 mm and shall be provided in a thickness of 3,0 mm ± 0,5 mm.

The test specimen shall be stored for at least 24 h in an atmosphere having a temperature between 15 °C and 35 °C and a relative humidity between 45 % and 75 %.

b) Setup and test procedure

The tolerance for the steel ball diameter shall not exceed ±1 % to ensure comparable results.

The specimen support shall be a metal block of steel, with a diameter at least ≥ 50 mm and a height of ≥ 100 mm.

The test shall be conducted in air, in a heating cabinet at the specified temperature (within a tolerance of ±2 °C) measured within 50 mm of the approximate centre of the test specimen.

Before introducing the test specimen, the test apparatus and the test specimen support shall be maintained in the heating cabinet at the required test temperature for 24 h or until equilibrium conditions are reached, whichever occurs sooner. The latter condition may be verified by means of a thermocouple inserted in the test specimen support.

NOTE It has been found useful to mount a separate thermocouple in the centre of the test specimen support approximately 3 mm below the surface to check that the temperature of the test specimen support does not significantly deviate from the test temperature.

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When thermal equilibrium conditions are reached, the test specimen is placed on the approximate centre of the support so that its upper surface is horizontal. The pressure ball is then gently lowered on to the approximate centre of the test specimen so as not to move other than in a downward direction.

The installation of the test specimen shall be performed in a time as short as practicable, but not exceeding 30 s. The test chamber shall return to the specified temperature (±2 °C) within 5 min and without any temperature overshoot exceeding +5 °C.

After the ball pressure apparatus has been applied for 60 min $\frac{+2}{0}$ + 2/−0 min, the test specimen shall be removed and cooled down by immersion, within 10 s, in ambient temperature water (20 °C ± 5 °C) for 6 min ± 2 min.

After removal from the water, the diameter of the indentation caused by the pressure ball shall be measured.

The dimension to be considered shall be the largest distance that can be measured across the indentation from one clearly defined edge of the indentation to another.

The dimension shall exclude any upward deformation and shall not exceed 2,0 mm.

9.14 Test of resistance to abnormal heat and to fire

The glow-wire test is performed on a complete RCBO in accordance with IEC 60695-2-10 under the following conditions:

– for external parts of RCBOs made of insulating material necessary to retain in position current-carrying parts and parts serving as a protective conductor, by the test carried out at a temperature of 960 °C ± 15 °C;

– for all other external parts made of insulating material, by the test carried out at a temperature of 650 °C ± 10 °C.

For the purpose of this test, bases of surface-type RCBOs are considered as external parts.

Small parts, where each surface lies completely within a circle of 15 mm diameter, or where any part of the surface lies outside a 15 mm diameter circle and it is not possible to fit a circle of 8 mm diameter on any of the surfaces, are not subjected to the test of this Subclause 9.14 (see Figure 27 for diagrammatic representation).

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 carried out 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 the 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, points of application of glow-wire test being different from one sample to another one.

The glow-wire cannot be applied directly to the 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 coming into contact 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.

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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 permitted to remove the relevant identified internal part(s) of insulation material from a new sample. Then, the glow wire test shall be repeated at the same place on this new sample.

The sample is regarded as having passed the glow-wire test if:

– either 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

IEC 61009-2-1:2024, 9.15 or IEC 61009-2-2:2024, 9.15 applies in accordance with classification 4.1.

9.16 Verification of the operation of the test device at the limits of rated operational voltage

The operation of the test device at the limits of rated operational voltage is verified as follows:

a) the RCBO being supplied with a voltage equal to 0,85 times the rated operational voltage, the test device is momentarily actuated 25 times at intervals of 5 s, the RCBO being reclosed before each operation;
b) test a) is then repeated at 1,1 times the rated operational voltage;
c) test b) is then repeated, but only once, the operating means of the test device being held in the closed position for 30 s.

For each test, the RCBO shall operate. After the test, the sample shall show no change impairing its further use.

In order to check that the number of ampere-turns due to the actuation of the test device is less than 2,5 times the ampere-turns produced by a residual current equal to $I_{\Delta n}$ at the rated operational voltage, the impedance of the circuit of the test device is measured and the test current is calculated, taking into account the configuration of the circuit of the test device.

If, for such verifications, the dismantling of the RCBO is necessary, a separate sample shall be used.

NOTE The verification of the endurance of the test device is considered as being covered by the tests of 9.10.

9.17 Void

9.18 Void

9.19 Verification of the behaviour of RCBOs in the event of current surges caused by impulse voltages

9.19.1 Current surge test for all RCBOs (0,5 µs/100 kHz ring wave test)

The RCBO is tested using a surge generator capable of delivering a damped oscillator current wave as shown in Figure 16. An example of a circuit diagram for the connection of the RCBO is shown in Figure 17.

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One pole of the RCBO, chosen at random, shall be submitted to 10 applications of the surge current. The polarity of the surge 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 RCBO of the same type with the same I_n and the same $I_{\Delta n}$, to meet the following requirements:

– peak value:	200 A $^{+10}_{0}$ %
	or 25 A $^{+10}_{0}$ % for RCBOs with $I_{\Delta n} \leq$ 10 mA
– virtual front time:	0,5 µs ± 30 %
– period of the following oscillatory wave:	10 µs ± 20 %
– each successive reverse peak:	about 60 % of the preceding peak

During the tests, the RCBO shall not trip.

After the test, under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, the RCBO shall trip with a test current of $I_{\Delta n}$. Only one test is carried out, the break time shall comply with Table 11.

9.19.2 Verification of the behaviour at surge currents up to 3 000 A (8/20 µs surge current test)

9.19.2.1 Test conditions

The RCBO is tested using a current generator capable of delivering a damped surge current 8/20 µs in accordance with IEC 60060-2 as shown in Figure 18. An example of a circuit diagram for the connection of the RCBO is shown in Figure 19.

One pole of the RCBO, 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 RCBO of the same type with the same I_n and the same $I_{\Delta n}$, 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 and the same $I_{\Delta n}$, the reverse current, if any, should not exceed 30 % of the peak value.

9.19.2.2 Test results for S type RCBOs

During the tests, the RCBO shall not trip.

After the test, under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, the RCBO shall trip with a test current of $I_{\Delta n}$. Only one test is carried out, the break time shall comply with Table 11.

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9.19.2.3 Test results for RCBOs of the general type

During the tests, the RCBO can trip. After any tripping, the RCBO shall be re-closed.

After the test, under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, the RCBO shall trip with a test current of $I_{\Delta n}$. Only one test is carried out, the break time shall comply with Table 11.

9.20 Verification of reliability

9.20.1 Climatic test

9.20.1.1 Testing chamber

The test is based on IEC 60068-2-30 taking into account IEC 60068-3-4.

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 repurified. 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 ± 1,0. During the test, the resistivity should be not less than 100 Ωm and the pH value should remain within 7,0 ± 1,0.

9.20.1.2 Severity

The cycles are effected under the following conditions:

– upper temperature: 55 °C ± 2 °C;
– number of cycles: 28.

9.20.1.3 Test procedure

For RCBOs having multiple settings, the tests shall be carried out at the lowest setting.

The test procedure shall be in accordance with IEC 60068-2-30:2005, Clause 4 and with IEC 60068-3-4.

a) Initial verification

An initial verification is made by submitting the RCBO to the test according to IEC 61009-2-1:2024, 9.9.1.2.3 1) or IEC 61009-2-2:2024, 9.9.1.2.3 1), but only at $I_{\Delta n}$.

b) Conditioning

1) The RCBO is mounted and wired as for normal use is introduced into the chamber.
2) Stabilizing period (see Figure 20).

The temperature of the RCBO shall be stabilized at 25 °C ± 3 °C:

i) either by placing the RCBO in a separate chamber before introducing it into the test chamber;

ii) or by adjusting the temperature of the test chamber to 25 °C ± 3 °C after the introduction of the RCBO 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 specified for standard atmospheric conditions for testing (see Table 47).

During the final hour of the test, with the RCBO in the test chamber, the relative humidity shall be increased to not less than 95 % at an ambient air temperature of 25 °C ± 3 °C.

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3) Description of the 24 h cycle (see Figure 21)

i) The temperature of the chamber shall be progressively raised to the appropriate upper temperature specified in 9.20.1.2.

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 21.

During this period, the relative humidity shall not be less than 95 %. Condensation shall occur on the RCBO during this period.

The condition that condensation occurs implies that the surface temperature of the RCBO is below the dew point of the atmosphere. This means that the relative humidity is 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.

ii) The temperature shall then be maintained at a substantially constant value within the specified limits of ±2 °C, for the upper temperature, for 12 h with a tolerance of ±30 min from the beginning of the cycle.

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 RCBO during the last 15 min.

iii) 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 21, 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 %.

iv) 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.

During the 28 cycles, the RCBO shall remain in the closed position.

9.20.1.4 Recovery

At the end of the cycles, the door of the test chamber shall be opened and the temperature regulation and humidity regulation are stopped.

A period of 4 h to 6 h shall then elapse to permit the ambient conditions (temperature and humidity) to be re-established.

The RCBO shall not be removed from the test chamber and shall remain in the closed position before the final verification is carried out.

9.20.1.5 Final verification

Under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, the RCBO shall trip with a test current of 1,25 $I_{\Delta n}$. Only one test is carried out without measurement of the break time.

9.20.2 Test with temperature of 40 °C

For RCBOs having multiple settings, the tests shall be carried out at the lowest setting.

The RCBO is mounted as for normal use on a dull black painted plywood wall, about 20 mm thick.

For each pole, a conductor, as specified in 9.2, is connected to each terminal of the RCBO. The assembly is placed in a heating cabinet.

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The RCBO is loaded with a current equal to the rated current and is subjected, at an ambient air 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 RCBO being not operated.

For four-pole RCBOs with four overcurrent protected poles or with three overcurrent protected poles, only three protected poles are loaded.

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 RCBO in the cabinet is allowed to cool down to approximately room temperature without current passing.

Under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, the RCBO shall trip with a test current of 1,25 $I_{\Delta n}$. Only one test is carried out without measurement of the break time.

9.21 Verification of withstand against ageing

The RCBO is placed for a period of 168 h in an ambient air temperature of 40 °C ± 2 °C and loaded with the rated current.

For four-pole RCBOs, only three poles are loaded.

After this test, the RCBO in the cabinet is allowed to cool down to approximately room temperature without current passing. The electronic parts shall show no damage.

Under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, the RCBO shall trip with a test current of 1,25 $I_{\Delta n}$. Only one test is carried out without measurement of the break time.

9.22 Electromagnetic compatibility (EMC)

IEC 61009-2-1:2024, 9.22 or IEC 61009-2-2:2024, 9.22, as relevant, applies according to classification 4.1.

9.23 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 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 carried out without previous removal of the grease.

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9.24 Verification of the behaviour of the RCBO under temporary overvoltage (TOV) conditions

9.24.1 General

The source of the test voltage shall be capable of supplying a short-circuit current of at least 0,2 A, but not exceeding 1 A.

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

The voltage is applied to the supply terminals. However, if the supply side is not indicated, two samples are tested on one side; a third sample is tested on the opposite side.

Verification is carried out according to the tests of 9.24.2 and 9.24.3.

After the test, the RCBO shall be verified according to 9.24.4.

9.24.2 TOV test for all RCBOs

This test does not apply to three-pole RCBO with three overcurrent protected poles.

The RCBO being in the closed position, a voltage of $\sqrt{3} \times U_o$ is applied for 1 h between neutral and one pole, a different pole being tested per sample.

During the test, the RCBO can trip automatically; if this occurs, the test is ended. No flashover or breakdown shall occur. Glow discharges without drop in voltage are ignored.

After the test, under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, as relevant, the RCBO shall trip with a test current of 1,25 $I_{\Delta n}$. Only one test is carried out without measurement of the break time.

9.24.3 Additional tests for RCBOs with a terminal intended to be connected to the PE

The tests of this Subclause 9.24.3 are not applicable for single-pole RCBO with two current paths and for three-pole RCBO with four current paths.

During the test, the RCBO can trip automatically; if this occurs the test is ended. No flashover or breakdown shall occur. Glow discharges without drop in voltage are ignored.

The RCBO is supplied as for normal use and being in the closed position, an additional voltage is applied between earth and all poles including neutral, if any, at the following voltage values:

a) U_{TOV} = 1 200 V AC is applied for 5 s according to Figure 24;

b) U_{TOV} = 250 V AC is applied for 1 h according to Figure 24.

Immediately after tests of 9.24.3 b), under the conditions of IEC 61009-2-1:2024, 9.9.1.2.3 or IEC 61009-2-2:2024, 9.9.1.2.3, as relevant, the RCBO shall trip with a test current of 1,25 $I_{\Delta n}$. Only one test is carried out without measurement of the break time.

9.24.4 Verification after the tests

After the tests, the RCBO is then supplied at rated operational voltage and closed. The RCBO is then opened with the test device and the RCBO shall show no visible damage.

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Table 1 – Marking

	Marking or information item	Position of the marking or information		
		Visible on product when installed	On the product	In the product information
A	Manufacturer's name or trade mark		X	
B	Type designation, catalogue number or serial number		X	
C	Rated operational voltage(s)		X	
D [a]	Rated current	X		
E	Rated frequency according to the preferred values of 5.3.5 Rated frequency different from the preferred values of 5.3.5		X	X
F	Rated residual operating current	X		
G	Settings of residual operating current for RCBOs with multiple residual operating currents	X		
H	Rated short-circuit capacity (in amperes) for RCBO		X	
I	Reference calibration temperature, if different from 30 °C			X
J [b]	Rated residual making and breaking capacity		X	
K	Degree of protection (only if different from IP 20)			X
L	Position of use, if necessary		X	
M	Letter symbol S (S in a square) for type S devices	X		
N	Marking according to classification of 4.1			X
O	Operating means of the test device, by the letter T	X		
P [d]	Wiring diagram unless the connection is evident		X	
Q [c, e]	Operating characteristic in presence of residual currents with DC components	X		
R	Value for U_x (if any) for devices according to 4.1.5 and 4.1.6		X	
S	Reference to the product standard (IEC 61009-2-1 or IEC 61009-2-2)		X	
T	For type D RCBOs: the maximum instantaneous tripping current, if higher than 20 I_n (see Table 38 and Table 39)		X	
U	If it is necessary to distinguish between the supply and the load terminals, they shall be clearly marked (e.g. by the words "line" and "load" placed near the corresponding terminals or by arrows indicating the direction of power flow)		X	
V	Terminals specifically intended for the connection of the neutral shall be indicated by the symbol N		X	
W	Terminals intended for the FE shall be marked with the symbol (IEC 60417-5018:2011-07) 		X	

[a] For RCBOs: rated current without symbol "A", preceded by the symbol of overcurrent instantaneous tripping (B, C or D), for example B 16

[b] To be marked if different from the rated short circuit capacity

[c] One of the following markings apply:

– RCBOs of type AC with the symbol (IEC 60417-6148:2012-01) 

– RCBOs of type A with the symbol (IEC 60417-6149:2012-01) 

[d] This information may be on the inside of any cover which has to be removed in order to connect the supply wires

[e] It is not necessary for the symbol for Type AC to be visible after installation, but it shall be marked on the product

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Table 2 – Void

Table 3 – Void

Table 4 – Void

Table 5 – Void

Table 6 – Void

Table 7 – Void

Table 8 – Void

Table 9 – Void

Table 10 – Void

Table 11 – Standard limit values of break time and non-actuating time for alternating residual currents (RMS values) for type AC and A

			Standard limit values of break time and non-actuating time(s) for type AC and A in the event of alternating residual currents (RMS values)						
Type	**I_n A**	**$I_{\Delta n}$ A**	**$I_{\Delta n}$**	**2 $I_{\Delta n}$**	**5 $I_{\Delta n}$**	**5 $I_{\Delta n}$ or 0,25 A [a]**	**5 A to 200 A [b]**	**500 A or $I_{\Delta t}$ [c]**	
General	any	≤ 0,03	0,3	0,15		0,04	0,04	0,04	Maximum break times
		> 0,03	0,3	0,15	0,04		0,04	0,04	
S	≥ 25	> 0,03	0,5	0,2	0,15		0,15	0,15	
		> 0,03	0,13	0,06	0,05		0,04	0,04	Minimum non-actuating times

[a] Value for this test to be decided by the manufacturer.

[b] The tests are only carried out during the verification of the correct operation according to IEC 61009-2-1:2024, 9.9.1.2.4 or IEC 61009-2-2:2024, 9.9.1.2.4. For RCBOs, values exceeding the lower limit of the overcurrent instantaneous tripping range are not tested.

[c] For RCBOs, the test is carried out with a current $I_{\Delta t}$ equal to the lower limit of the overcurrent instantaneous tripping range according to type B, C or D, as applicable. For the tests of IEC 61009-2-1:2024, 9.9.1.2.5 and 9.9.1.2.6 2) or IEC 61009-2-2:2024, 9.9.1.2.5 and 9.9.1.2.6 2), the current $I_{\Delta t}$ is established so that the vector sum $I_{\Delta t}$ + I_n is equal to the lower limit of the overcurrent instantaneous tripping range, according to type B, C or D, as applicable.

Table 12 – Standard maximum values of break time for half-wave residual currents (RMS values) for type A

			Standard maximum values of break time for type A in the event of half-wave pulsating residual currents (RMS values) equal to							
Type	**I_n A**	**$I_{\Delta n}$ A**	**1,4 $I_{\Delta n}$**	**2 $I_{\Delta n}$**	**2,8 $I_{\Delta n}$**	**4 $I_{\Delta n}$**	**7 $I_{\Delta n}$**	**0,35 A**	**0,5 A**	**350 A [a]**
General	Any	< 0,03		0,3		0,15			0,04	0,04
		0,03	0,3		0,15			0,04		0,04
		> 0,03	0,3		0,15		0,04			0,04
S	≥ 25	> 0,03	0,5		0,2		0,15			0,15

[a] For RCBOs, this value shall be limited to the lower limit of the overcurrent instantaneous tripping ranges according to type B, C or D, as applicable.

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Table 13 – Void

Table 14 – Tripping current limits

Phase angle	Tripping current		
	Lower limit	Upper limit	
		$I_{\Delta n}$ < 30 mA	$I_{\Delta n}$ ≥ 30 mA
0°	0,35 $I_{\Delta n}$	2 $I_{\Delta n}$	1,4 $I_{\Delta n}$
90°	0,25 $I_{\Delta n}$	2 $I_{\Delta n}$	1,4 $I_{\Delta n}$
135°	0,11 $I_{\Delta n}$	2 $I_{\Delta n}$	1,4 $I_{\Delta n}$

Table 15 – Void

Table 16 – Void

Table 17 – Void

Table 18 – Void

Table 19 – Rated impulse withstand voltage as a function of the nominal voltage of the installation

Rated impulse withstand voltage U_{imp}	Nominal voltage of the installation	
	Three-phase systems	Single-phase system with mid-point earthed
kV	V	V
2,5 [a]		120/240 [b]
4 [a]	230/400	120/240, 240 [c]

NOTE 1 For test voltages to check the insulation, see Table 22.

NOTE 2 For test voltages to check the isolation distance across open contacts, see Table 23.

[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 20 and Table 23).

[b] For installation practice in Japan.

[c] For installation practice in North American countries.

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Table 20 – Minimum clearances and creepage distances

	Minimum clearances mm			Minimum creepage distances [e, f] mm											
				Group IIIa [h] (175 ≤ CTI < 400) [d]				Group II (400 ≤ CTI < 600) [d]				Group I (600 ≤ CTI) [d]			
	Rated operational voltage V			Working voltage [e] V											
	U_{imp}														
	2,5 kV	4 kV	4 kV												
Description/ Item	120/ 240 120	120/ 240 240	230/ 400 230 400	> 25 ≤ 50[i]	120	250	400	> 25 ≤ 50[i]	120	250	400	> 25 ≤ 50[i]	120	250	400
1. Between live parts which are separated when the main contacts are in the open position [a, j]	2,0	4,0	4,0	1,2	2,0	4,0	4,0	0,9	2,0	4,0	4,0	0,6	2,0	4,0	4,0
2. Between live parts of different polarity [a, k]	1,5	3,0	3,0	1,2	1,5	3,0	4,0	0,9	1,5	3,0	3,0	0,6	1,5	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 operational voltage V											
				120 / 240		230 / 400		120 / 240		230 / 400		120 / 240		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 RCBO – surface on which the RCBO is mounted [b] – screws or other means for fixing the RCBO [b] – metal covers or boxes [b] – other accessible metal parts [c] – metal frames supporting flush-type RCBOs	1,5	3,0	3,0	1,5		4,0		1,5		3,0		1,5		3,0	

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

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

[a] For auxiliary and control contacts, the values are given in IEC 62019.

[b] The values shall be doubled if clearances and creepage distances between live parts of the device and the metallic screen or the surface on which the RCBO is mounted are not dependent on the design of the RCBO only.

[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 (test probe 11 of IEC 61032).

[d] See IEC 60112.

[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 taken from the tables. For determination of creepage distances, Annex B applies.

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

[g] To cover all different voltages including ELV (see IEC 60364-4-41:2005, 414) in an auxiliary contact.

[h] For material group IIIb (100 ≤ CTI < 175) 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.

[j] The clearance and creepage distances between the metal parts within the arc chamber may be less than 1 mm, provided that the sum of distances is greater than that specified in item 1 of this Table 20.

[k] In general this also applies to clearances and creepage distances between live parts and any surfaces adjacent to the RCBO when installed. If any surfaces adjacent to the RCBO do not meet the clearance and creepage distance requirements, appropriate information shall be provided for installation. In this case at least half the required distances shall be provided.

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Table 21 – Test voltage of auxiliary circuits

Rated voltage of auxiliary circuits (AC or DC) 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

Table 22 – Test voltage for verification of rated impulse withstand voltage

Rated impulse withstand voltage U_{imp} kV	Test voltages at corresponding altitude $U_{1,2/50}$ peak kV				
	Sea level	**200 m**	**500 m**	**1 000 m**	**2 000 m**
2,5	2,9	2,8	2,8	2,7	2,5
4	4,9	4,8	4,7	4,4	4,0

Table 23 – Test voltage for verifying the suitability for isolation, with reference to the rated impulse withstand voltage of the RCBO and the altitude where the test is carried out

Nominal voltage of the installation V	Test voltages at corresponding altitude				
	$U_{1,2/50}$ peak kV				
	Sea level	200 m	500 m	1 000 m	2 000 m
Single-phase system with mid-point earthed 120/240 [a]	3,5	3,5	3,4	3,2	3,0
Single-phase system 120/240 240 [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.

Table 24 – Connectable cross-sections of copper conductors for screw-type terminals

Rated current [a] A		Range of nominal cross-section to be clamped [b] mm^2					
Greater than	Up to and including	Rigid (solid or stranded [c]) 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
80	100	16	to	35	16	to	25
100	125	25	to	50	25	to	35

NOTE Information on AWG is given in Annex I.

[a] A range of RCBOs having the same fundamental design and having the same 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.

[b] 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.

[c] Rigid stranded conductors shall be used for conductors having cross-sections from 1,5 mm^2 up to 50 mm^2 and shall be in compliance with Class 2 of IEC 60228, related to stranded conductors for single-core.

Table 25 – Test copper conductors corresponding to the rated currents

Rated current I_n A	$I_n \leq 6$	$6 < I_n \leq 13$	$13 < I_n \leq 20$	$20 < I_n \leq 25$	$25 < I_n \leq 32$	$32 < I_n \leq 50$	$50 < I_n \leq 63$	$63 < I_n \leq 80$	$80 < I_n \leq 100$	$100 < I_n \leq 125$
S mm^2	1	1,5	2,5	4	6	10	16	25	35	50

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Table 26 – 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

Table 27 – 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

Table 28 – 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 RCBO, 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 RCBO in direct contact with the mounting surface	60

[a] No value is specified for the contact since the design of most RCBOs 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 9.20) 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 RCBO shall not be impaired.

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

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Table 29 – Power factor ranges of the test circuit

Test current I_{cc} A	Corresponding power factor range
I_{cc} ≤ 1 500	0,93 to 0,98
1 500 < I_{cc} ≤ 3 000	0,85 to 0,90
3 000 < I_{cc} ≤ 4 500	0,75 to 0,80
4 500 < I_{cc} ≤ 6 000	0,65 to 0,70
6 000 < I_{cc} ≤ 10 000	0,45 to 0,50
10 000 < I_{cc} ≤ 25 000	0,20 to 0,25

Table 30 – Withstand values and duration of temporary overvoltages

TOV		
Occurrence	**Voltage**	**Duration**
Between neutral and all other poles	$\sqrt{3} \times U_o$	1 h
Between earth and all poles including neutral, if any [a, b]	1200 V + U_o	5 s
Between earth and all poles including neutral, if any [a, b]	250 V + U_o	1 h
[a] Only for RCBO with a terminal intended to be connected to the PE [b] Not applicable for single-pole RCBO with two current paths and three-pole RCBO with four current paths		

Table 31 – Void

Table 32 – Void

Table 33 – Void

Table 34 – Void

Table 35 – Void

Table 36 – Void

Table 37 – Standard values of rated short circuit capacity

1 500 A
3 000 A
4 500 A
6 000 A
10 000 A

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Table 38 – Ranges of overcurrent instantaneous tripping

Type	Range
B	Above 3 I_n up to and including 5 I_n
C	Above 5 I_n up to and including 10 I_n
D	Above 10 I_n up to and including 20 I_n [a]
[a] For special cases, values up to 50 I_n are also used.	

Table 39 – Time-current operating characteristics

Test	Type	Test current	Initial condition	Limits of tripping or non-tripping time	Results to be obtained	Remarks
a)	B, C, D	1,13 I_n	Cold [a]	$t \leq 1$ h (for $I_n \leq 63$ A) $t \leq 2$ h (for $I_n > 63$ A)	No tripping	
b)	B, C, D	1,45 I_n	Immediately following test a)	$t < 1$ h (for $I_n \leq 63$ A) $t < 2$ h (for $I_n > 63$ A)	Tripping	Current steadily increased within 5 s
c)	B, C, D	2,55 I_n	Cold [a]	1 s < t < 60 s (for $I_n \leq 32$ A) 1 s < t < 120 s (for $I_n > 32$ A)	Tripping	
d)	B C D	3 I_n 5 I_n 10 I_n	Cold [a]	$t \leq 0{,}1$ s	No tripping	Current established by closing an auxiliary switch
e)	B C D	5 I_n 10 I_n 20 I_n [b]	Cold [a]	$t < 0{,}1$ s	Tripping	Current established by closing an auxiliary switch
[a] The term "cold" means without previous loading, at the reference calibration temperature. [b] 50 I_n for special cases.						

Table 40 – List of short-circuit tests

Short-circuit tests	RCBOs to be tested	Verification after short-circuit test according to subclause
Test at reduced short-circuit currents (9.11.11.2)	All RCBOs	9.11.12.1
Test at 1 500 A (9.11.11.3)		
Test at rated residual making and breaking capacity (9.11.13.1)		9.11.13.2
Test at service short-circuit capacity (9.11.11.4 b))	RCBOs having I_{cn} > 1 500 A	9.11.12.1
Test at rated short-circuit capacity (9.11.11.4 c))		9.11.12.2

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Table 41 – Ratio between service short-circuit capacity (I_{cs}) and rated short-circuit capacity (I_{cn}) – (factor k)

I_{cn}	k
≤ 6 000 A	1
> 6 000 A ≤ 10 000 A	0,75 [a]
> 10 000 A	0,5 [b]
[a] Minimum value of I_{cs}: 6 000 A. [b] Minimum value of I_{cs}: 7 500 A.	

Table 42 – Test procedure for I_{cs} in the case of single- and two-pole RCBOs

Operation	Sample		
	1	2	3
1	O (0°)	O (15°)	O (30°)
2	O (45°)	O (60°)	O (75°)
3	CO	CO	CO

Table 43 – Test procedure for I_{cs} in the case of three- and four-pole RCBOs

Operation	Sample		
	1	2	3
1	O (x°)	O (x° + 60°)	O (x° + 120°)
2	CO	CO	CO
3	CO	CO	CO

Table 44 – Test procedure for I_{cn}

Operation	Sample		
	1	2	3
1	O (15°)	O (45°)	O (75°)
2	CO	CO	CO

Table 45 – Void

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Table 46 – Standard values of rated operational voltage

RCBOs	Circuit supplying the RCBO	Rated operational voltage of RCBOs for use in systems 230 V or 230/400 V or 400 V V	Rated operational voltage of RCBOs for use in systems 120/240 V or 240 V V
Single-pole (with two current paths)	Single-phase (phase to earthed middle conductor or phase to neutral)	230	120
Two-pole	Single-phase (phase to neutral or phase to phase or phase to earthed middle conductor)	230	120
	Single-phase (phase to phase)	400	240
	Single-phase (phase to phase, three-wire)		120/240
	Three-phase 230/400 V-system phase to neutral (four-wires) or 230 V-system phase to phase (three-wires)	230	
Three-pole (with three or four current paths)	Three-phase (three-wire or four-wire) (400 V or 230/400 V or 240 V system	400	240
Four-pole	Three-phase (four-wire) (230/400 V system)	400	

NOTE 1 The value of 230/400 V is the result of the evolution of 220/380 V and 240/415 V systems which has been completed in Europe and many other countries. However, 220/380 V and 240/415 V systems still exist.

NOTE 2 Wherever in this document there is a reference to 230 V or 400 V, they can be read as 220 V or 240 V, 380 V or 415 V, respectively.

NOTE 3 Wherever in this document there is a reference to 120 V or 120/240 V or 240 V, they can be read as 100 V or 100/200 V or 200 V, respectively.

NOTE 4 Wherever in this document there is a reference to 240 V three phases, it can be read as 100 V or 120/208 V.

NOTE 5 In Japan, phase to neutral conductor and phase to earthed conductor (grounded conductor) is thought of differently because a single-phase two-wire system supplied from two-wire system source does not have a neutral point.

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Table 47 – Values of influencing quantities

Influencing quantity	Conditions of use	Reference values for tests	Test tolerances [e]
Ambient air temperature [a]	−5 °C to +40 °C	See 9.2	±5 °C
Altitude	Not exceeding 2 000 m		
Relative humidity maximum value at 40 °C	50 % [b]		
External magnetic field	Not exceeding 5 times the earth's magnetic field in any direction	Earth's magnetic field	[c]
Position	As stated by the manufacturer with a tolerance of 5° in any direction [d]	As stated by the manufacturer	2° in any direction
Frequency	Reference value ±5 %	Rated value	±5 %
Sinusoidal wave distortion	Not exceeding 5 %	Zero	5 %

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

[b] Higher relative humidifies are admitted at lower temperatures (for example 90 % at 20 °C).

[c] When an RCBO is installed in proximity to strong magnetic field, supplementary requirements may be necessary.

[d] The device shall be fixed in such a way that it does not cause deformation liable to impair its functions.

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

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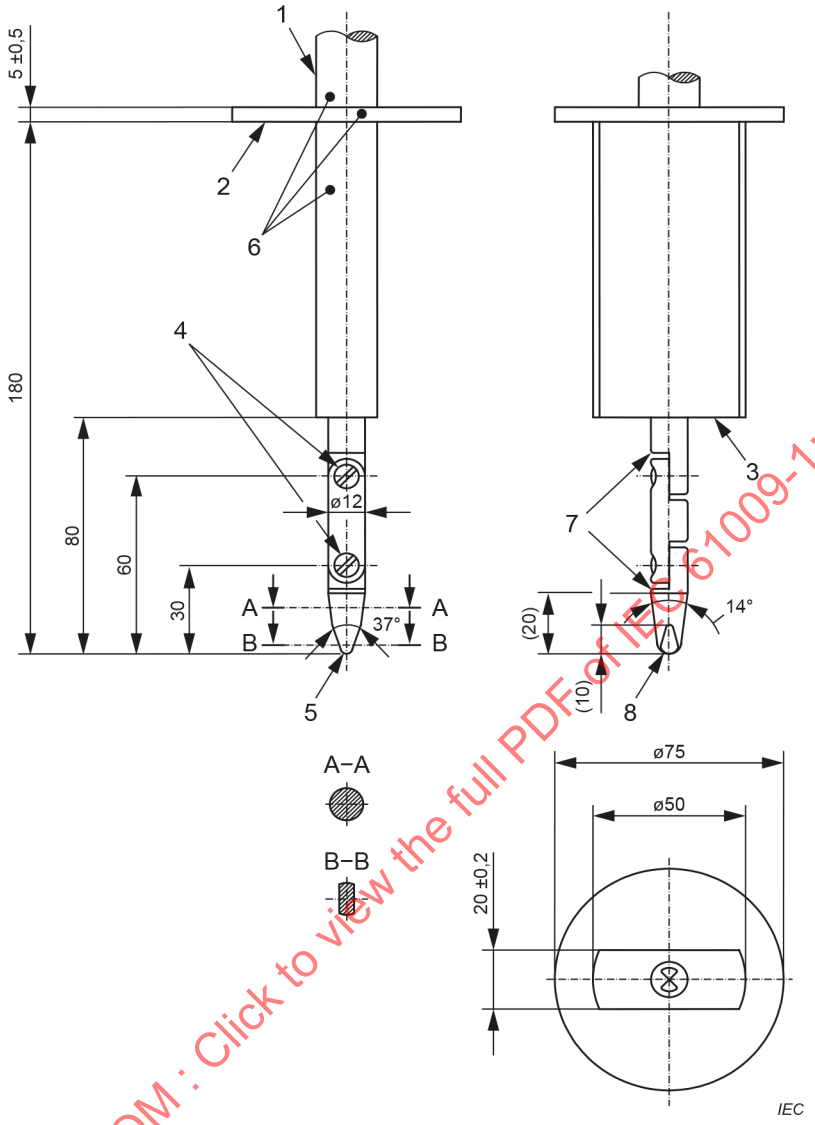
Dimensions in millimetres



Key

1	Handle	5	R_z ±0,05 cylindrical
2	Guard	6	Insulating material
3	Stop face	7	Chamfer all edges
4	Joints	8	R_4 ±0,05 spherical

Material: metal, except where otherwise specified in this figure.

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 tolerance of $^{+10}_{0}$.

Figure 1 – Standard test finger

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Figure 2 – Void

Figure 3 – Void

Figure 4 – Void

Explanation of letter symbols used in Figure 5, Figure 6 and Figure 7:

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 should 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
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, Ur_2, Ur_3	=	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)
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)
P	=	Short circuit protective device

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 voltage sensors Ur_1, Ur_2 and Ur_3 are connected between phase and neutral, as necessary.

The adjustable load Z may be located at the high-voltage side of the supply circuit.

Resistance R_1 may be omitted with the agreement of the manufacturer.

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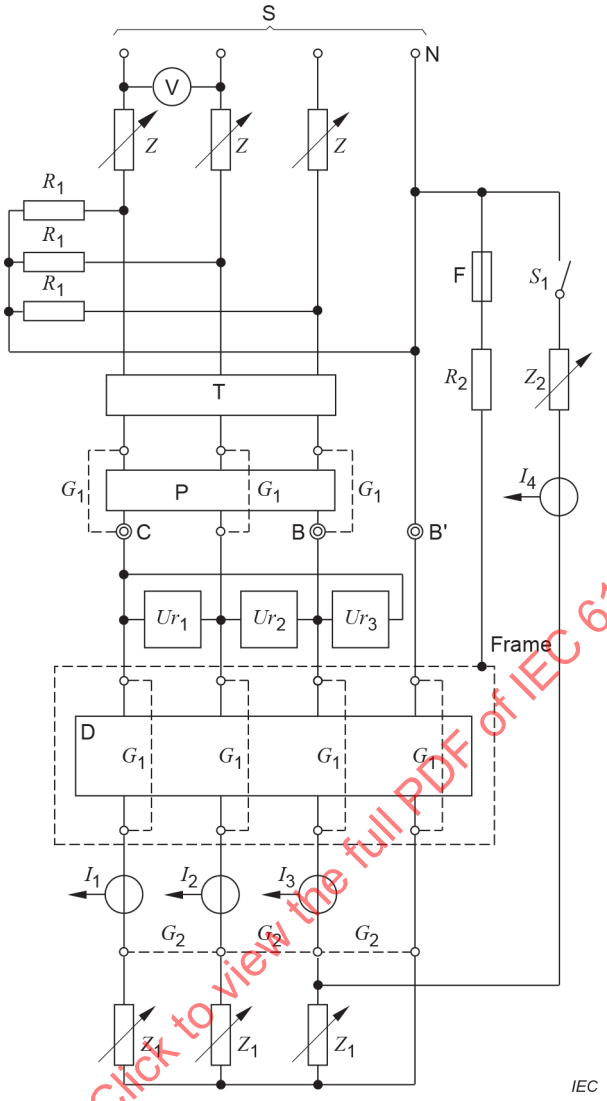

Figure 5 – Typical diagram for all short circuit tests except for the verification of the suitability in IT systems

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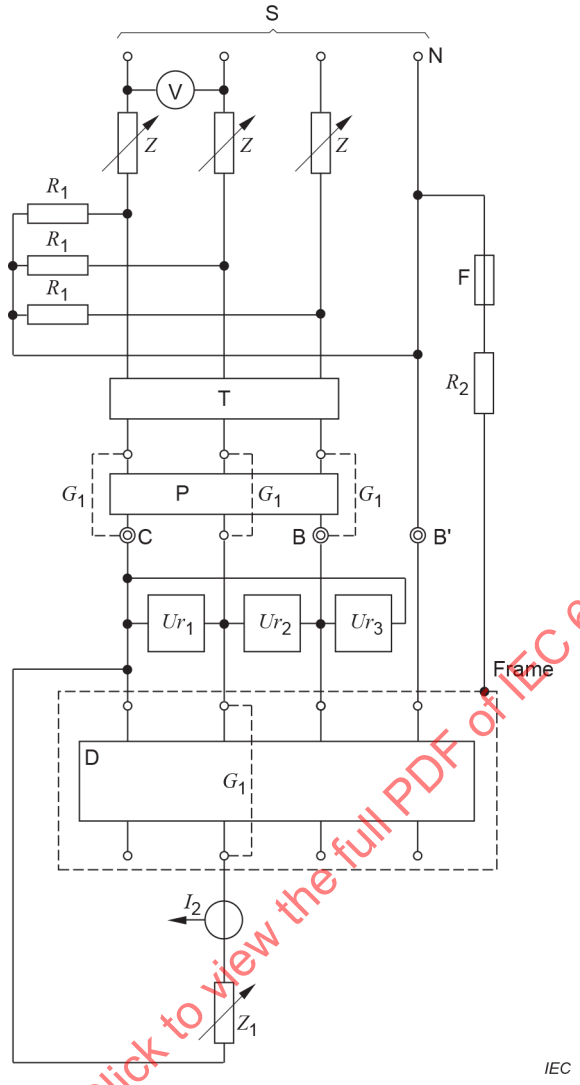

Figure 6 – Typical diagram for the verification of the suitability in IT systems

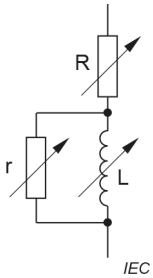

Figure 7 – Detail of impedances Z, Z_1 and Z_2

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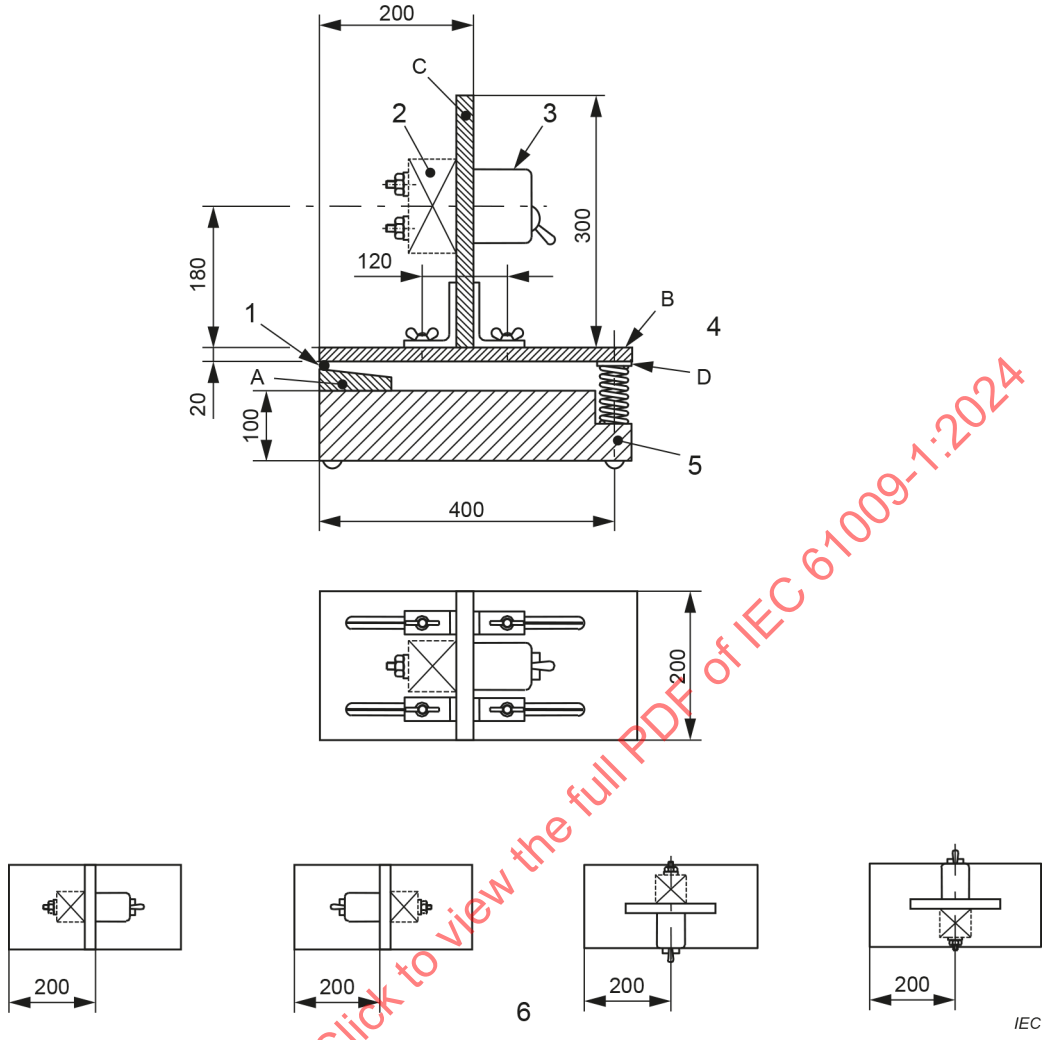
Dimensions in millimetres



Key

1 Hinge
2 Additional mass
3 Sample
4 Metal stop plate
5 Concrete block
6 Consecutive test positions

Figure 8 – Mechanical shock test apparatus

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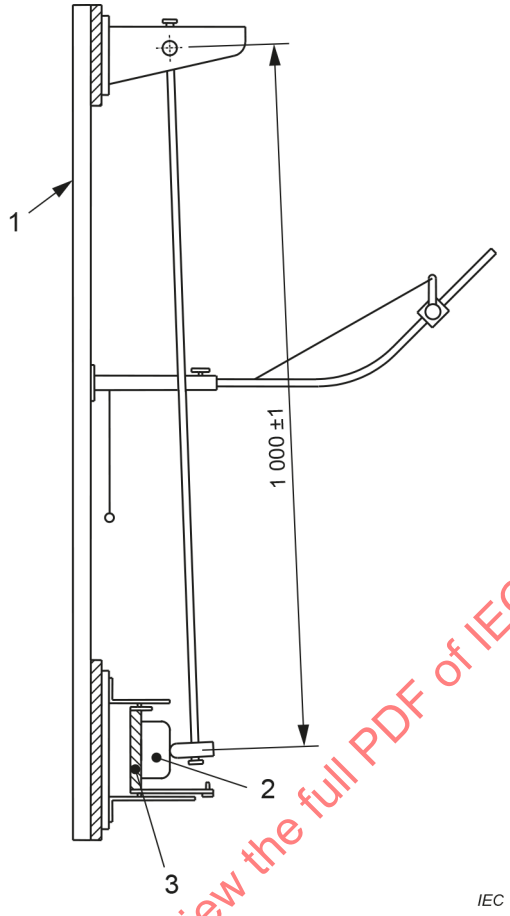
Dimensions in millimetres



Key

1 Frame

2 Sample

3 Mounting support

Figure 9 – Mechanical impact test apparatus

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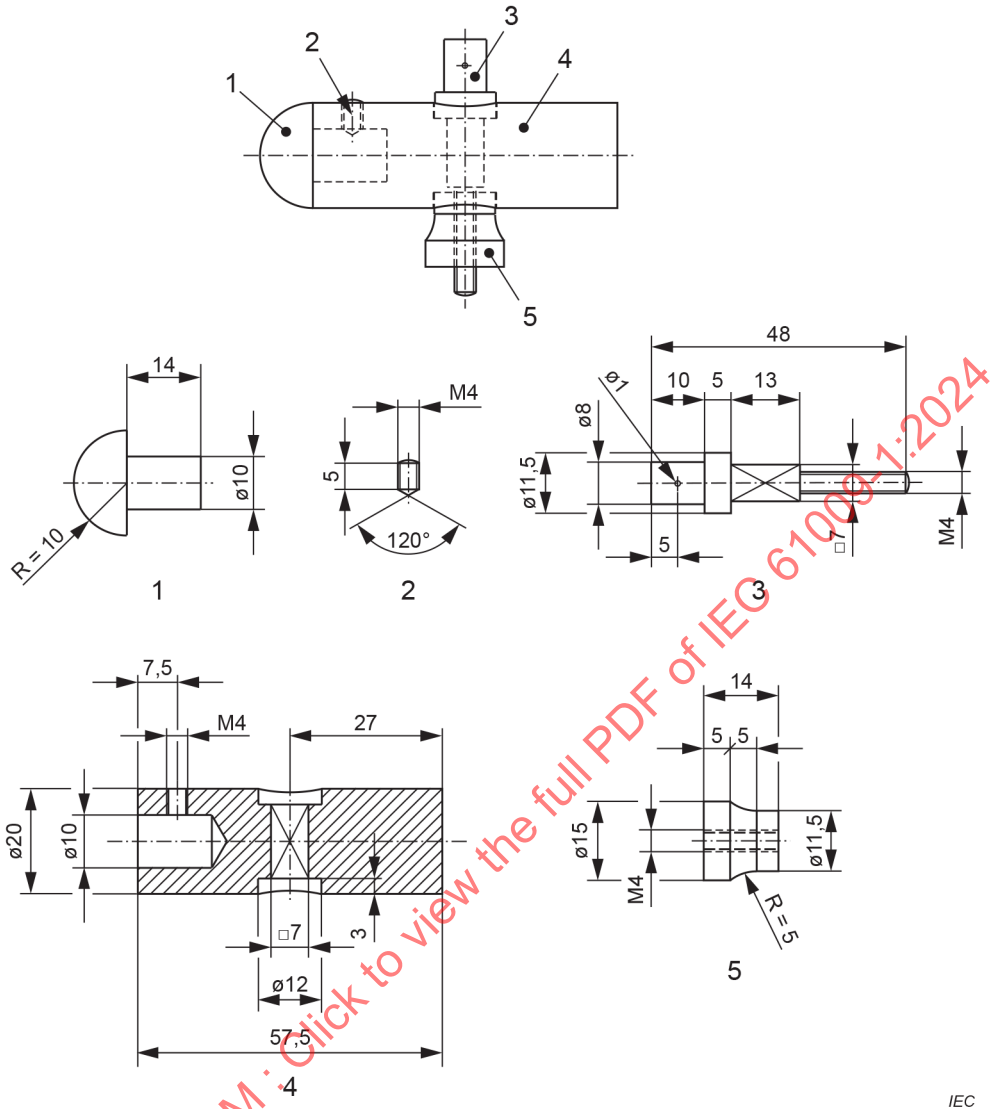
Dimensions in millimetres



Key

1	Polyamide
2, 3, 4, 5	Steel, Fe 360

Figure 10 – Striking element for pendulum impact test apparatus

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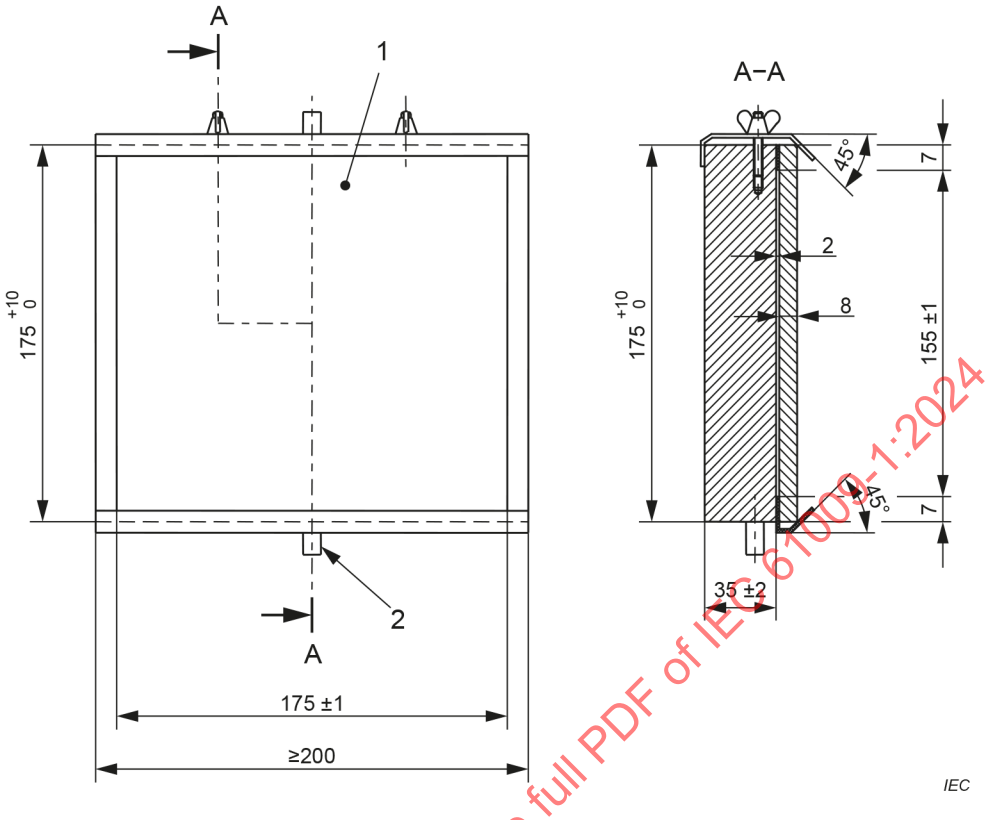
Dimensions in millimetres



Key

1 Sheet of plywood

2 Pivot

Figure 11 – Mounting support for sample for mechanical impact test

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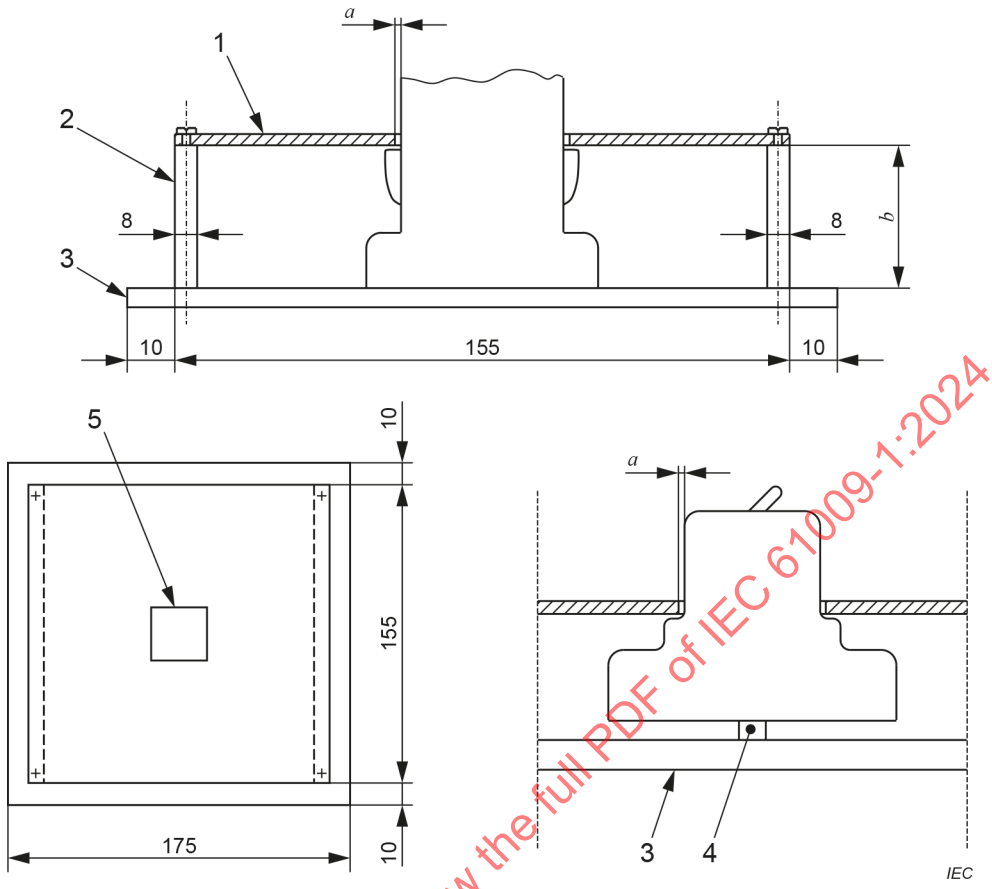
Dimensions in millimetres



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 RCBO designed to be mounted on a rail

5 Cut-out for the RCBO in the steel plate

a The distance between the edges of the cut-out and the faces of the RCBO 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 RCBO if the RCBO 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 12 – Example of mounting an unenclosed or flush-type RCBO for mechanical impact test

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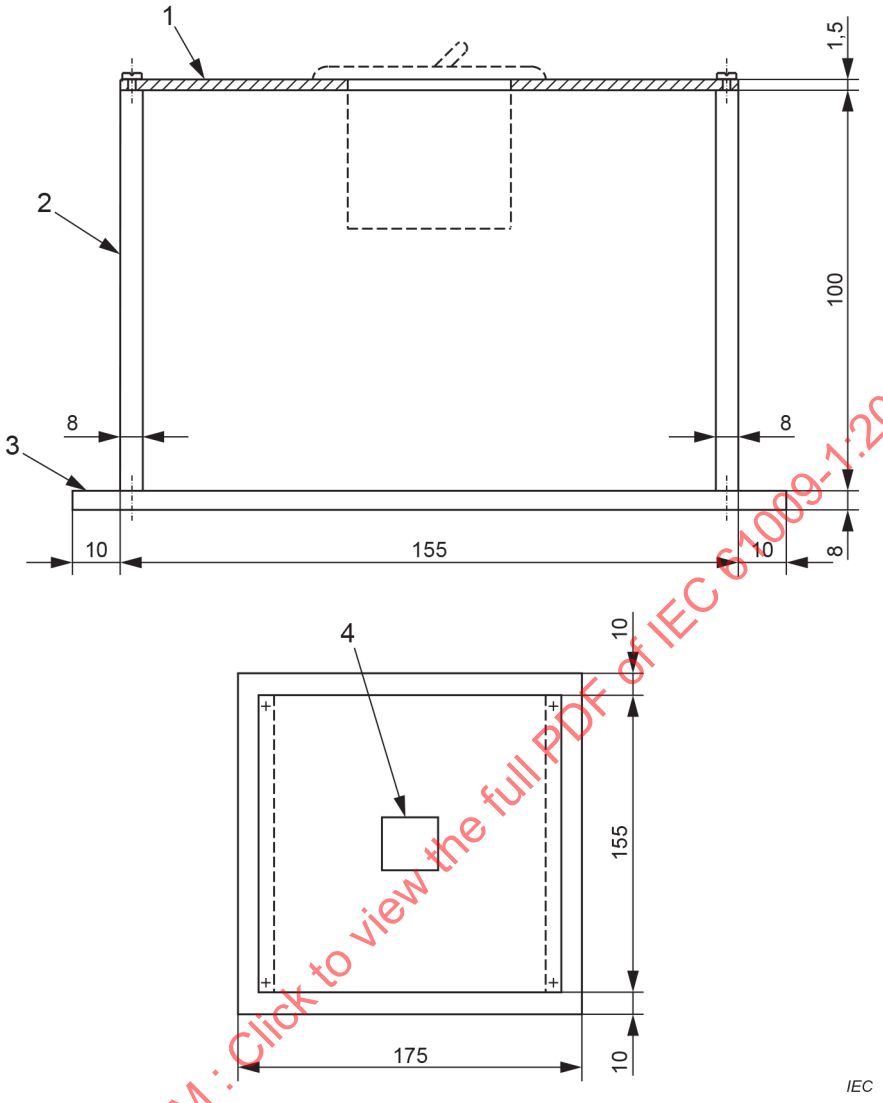
Dimensions in millimetres



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Key

1 Interchangeable steel plate with a thickness of 1,5 mm

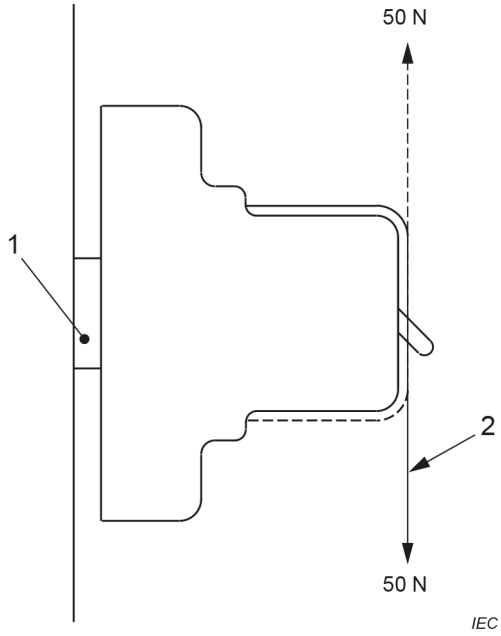
2 Aluminium plates with a thickness of 8 mm

3 Mounting plate

4 Cut-out for the RCBO in the steel plate

In particular cases, the dimensions may be increased.

Figure 13 – Example of mounting of panel mounting type RCBO for the mechanical impact test



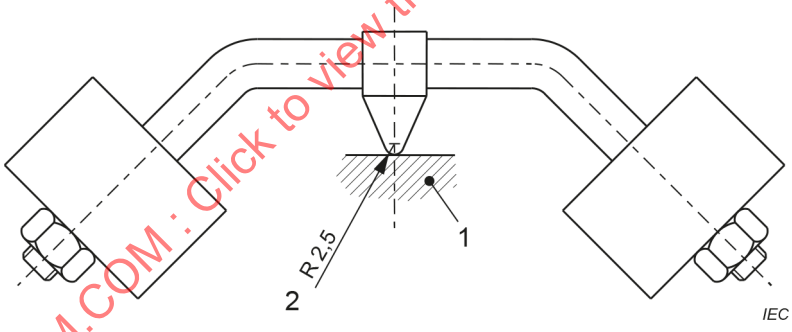
Key

1 Rail

2 Cord

Figure 14 – Application of force for mechanical test of rail mounted RCBO

Dimensions in millimetres



Key

1 Sample

2 Spherical

Figure 15 – Ball-pressure test apparatus

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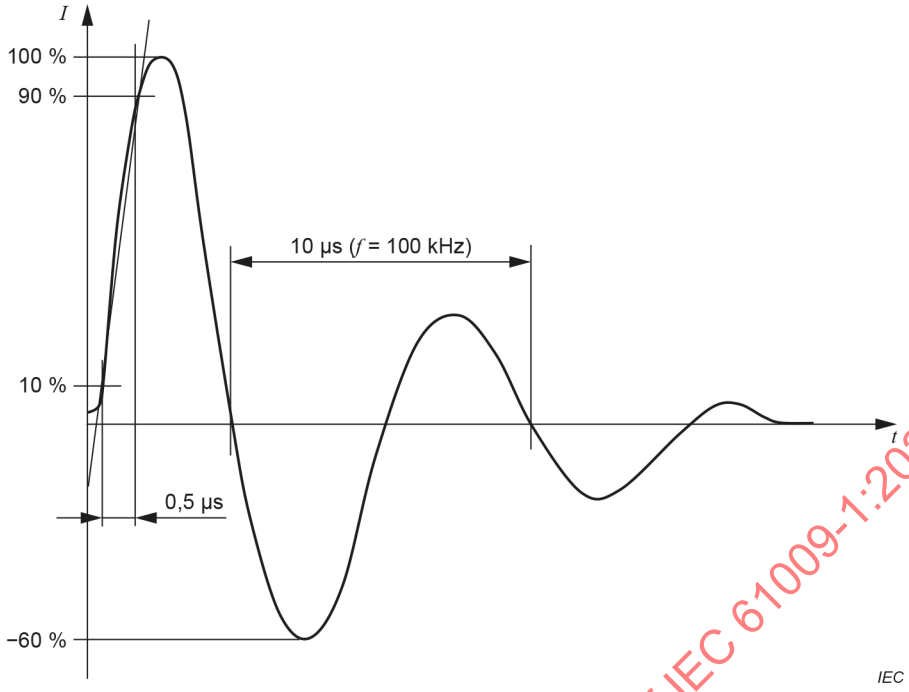
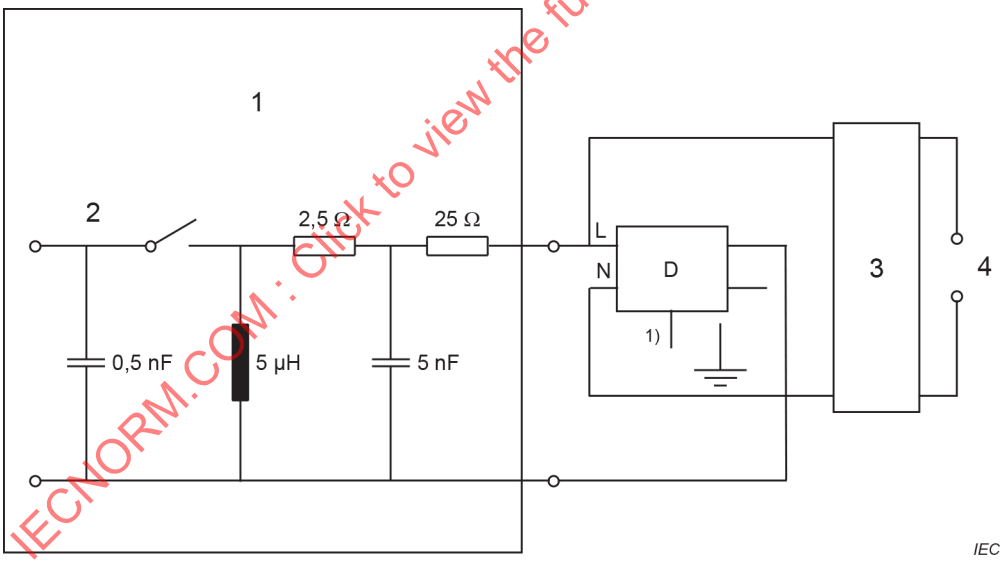


Care should be taken that the oscillating wave is guaranteed at least up to the fifth full period (50 µs).

Figure 16 – Current ring wave 0,5 µs/100 kHz



Key

D Device under test
1 Ring wave generator 0,5 µs/100 kHz
2 Trigger
3 Filter
4 Supply
1) If the RCBO has an earthing terminal, it shall be connected to the neutral terminal, if any, or, failing that, to any phase terminal.

Figure 17 – Test circuit for the ring wave test on RCBOs

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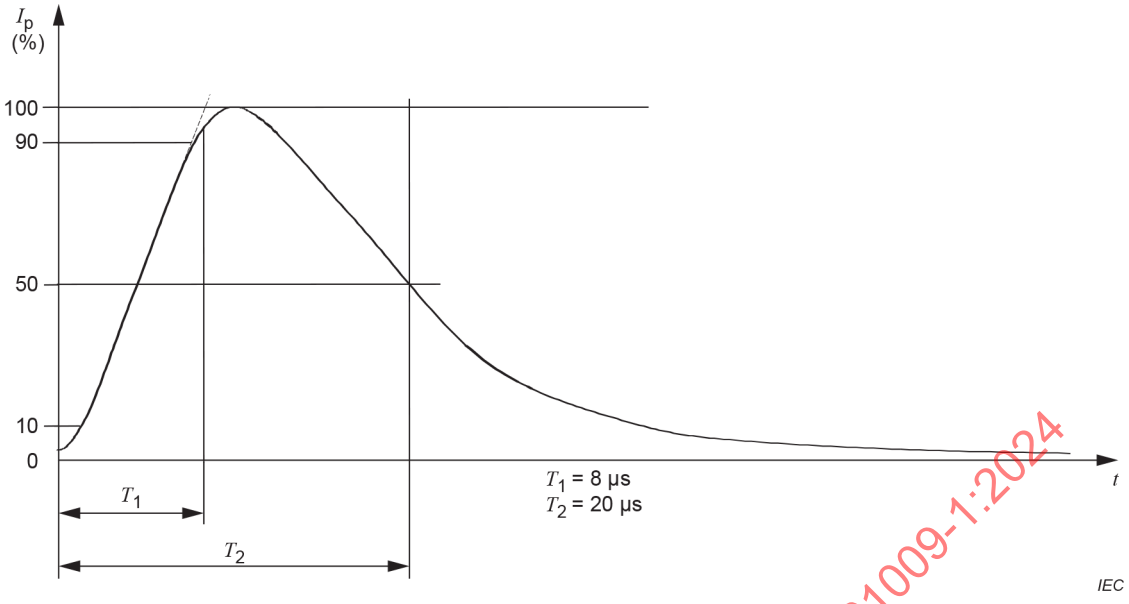
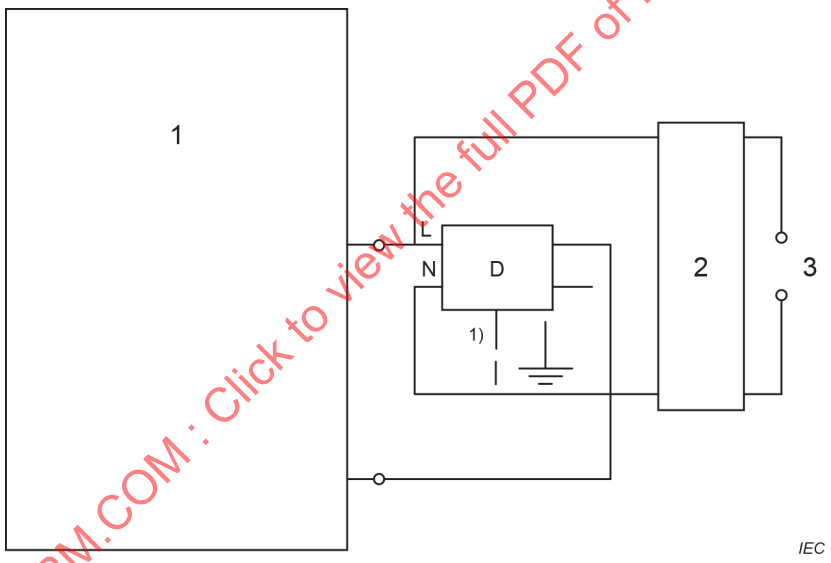


Figure 18 – Surge current impulse 8/20 µs



Key

D Device under test

1 Surge current generator 8/20 µs

2 Filter

3 Supply

1) If the RCBO has an earthing terminal, it shall be connected to the neutral terminal, if any, or, failing that, to any phase terminal.

Figure 19 – Test circuit for the surge current test of RCBOs

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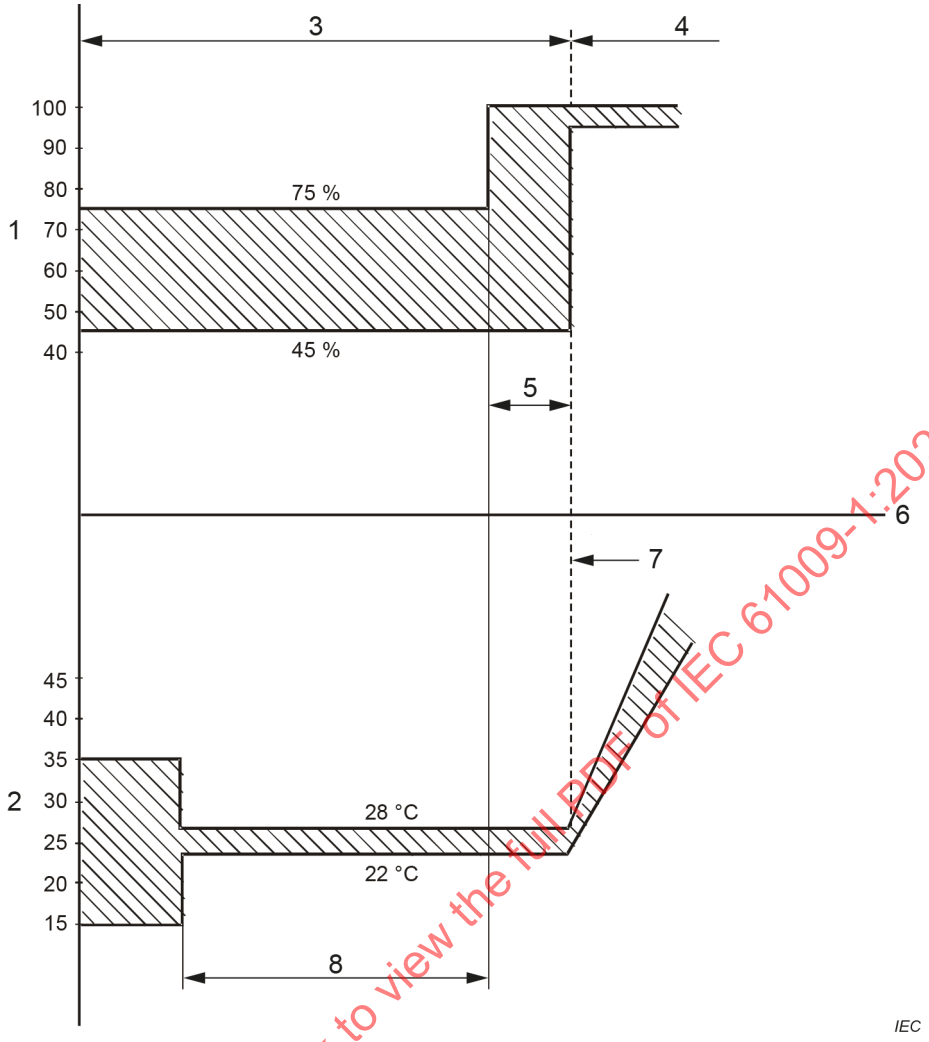

Key

1 Relative humidity (%)
2 Ambient temperature (°C)
3 Stabilizing period
4 First cycle
5 Time required to reach 95 % to 100 % relative humidity (not exceeding 1 h)
6 Time
7 Start of the first cycle
8 Time required for test specimen to reach temperature stability

Figure 20 – Stabilizing period for reliability test

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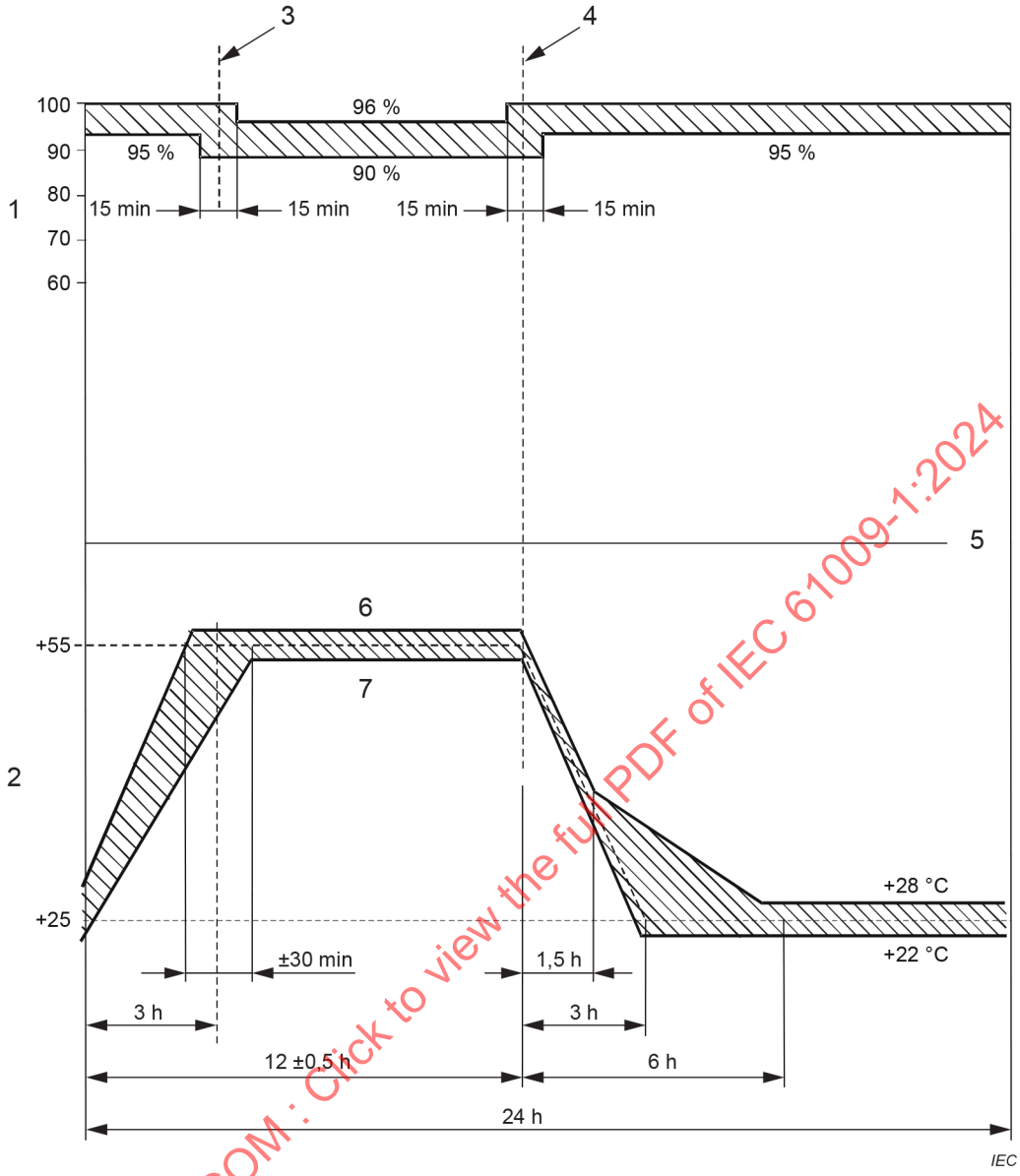

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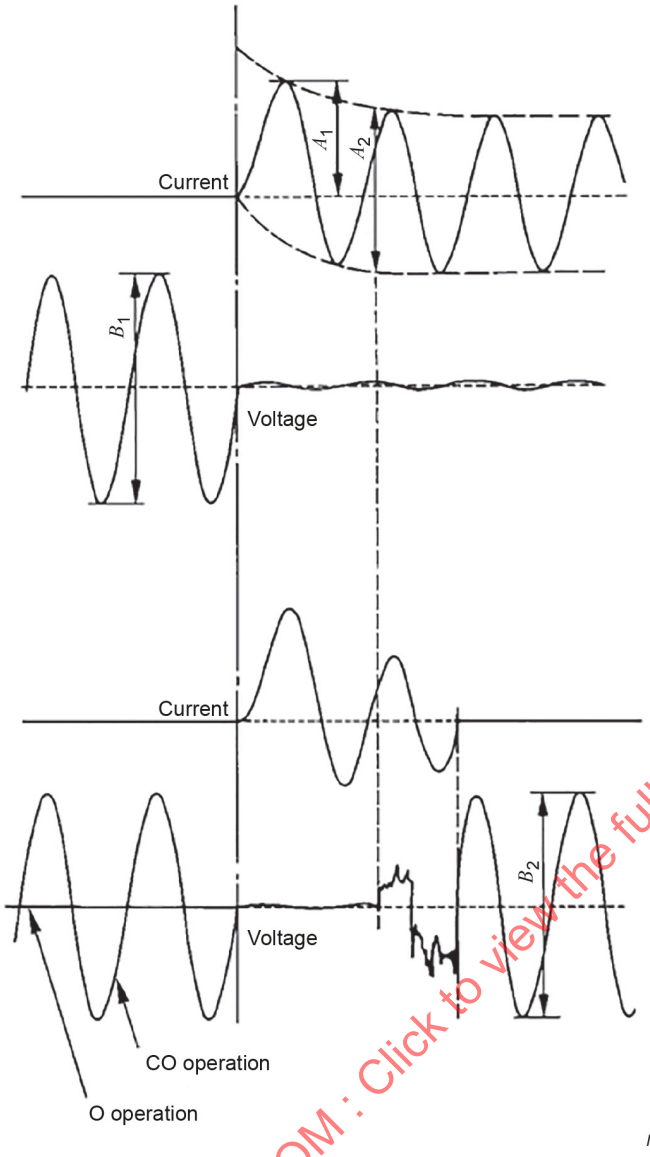
Key

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 21 – Reliability test cycle

Figure 22 – Void



a) = *Calibration of circuit*

A_1 = Prospective peak making current

$\frac{A_2}{2\sqrt{2}}$ = Prospective symmetrical breaking current (RMS value)

$\frac{B_1}{2\sqrt{2}}$ = Applied voltage (RMS value)

b) = *O or CO operation*

$\frac{B_2}{2\sqrt{2}}$ = Recovery voltage (RMS value)

NOTE The amplitude of the voltage trace, after initiation of the test current, varies according to the relative positions of the closing device, the adjustable impedances, the voltage sensing devices, and according to the test diagram.

Figure 23 – Example of records for short-circuit tests

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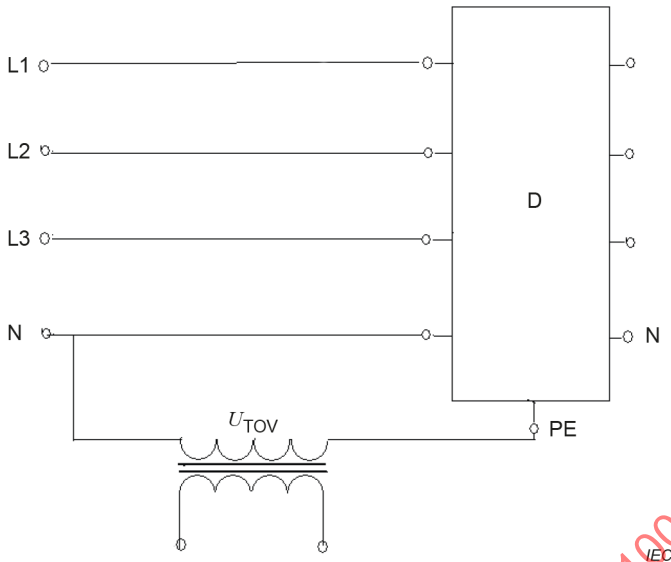

Key

D RCBO under test

N Neutral pole of the supply and of the RCBO under test

PE Terminal of RCBO intended to be connected to the PE

Figure 24 – Test circuit for the verification of the behaviour under temporary over voltage (TOV) conditions for RCBOs with a terminal intended to be connected to the PE

Figure 25 – Void

Figure 26 – Void

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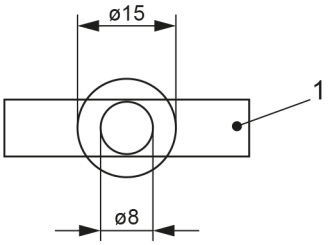
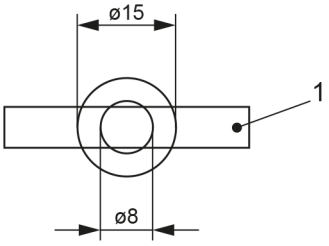


To be tested

At least one of the surfaces covers the 8 mm diameter circle completely while at least one other dimension is > 15 mm



No test is required

At least one of the surfaces does NOT cover the 8 mm circle completely while any other dimension is > 15 mm

IEC

Key

1 Sample

Figure 27 – Diagrammatic representation for glow-wire test

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Annex A
(normative)

Test sequence and number of samples to be submitted for certification purposes

IEC 61009-2-1:2024, Annex A or IEC 61009-2-2:2024, Annex A (as relevant) applies.

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Annex B
(normative)

Determination of clearances and creepage distances

B.1 General

Clearances and creepage distances shall be determined in accordance with this Annex B.

If necessary, the manufacturer shall indicate the intended orientation of the equipment or component in order that creepage distances are not 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 into 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 IEC 60664-1:2020, 6.8 (see also Example 11 in Figure B.11).

B.4 Measurement of creepage distances and clearances

In determining creepage distances according to IEC 60664-1, the dimension X, specified in the following examples, has a minimum value of 1,0 mm for pollution degree 2.

Requirements for arc chambers are covered by Table 20, footnote j).

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 Figure B.1 to Figure B.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 in Figure B.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 in Figure B.2);

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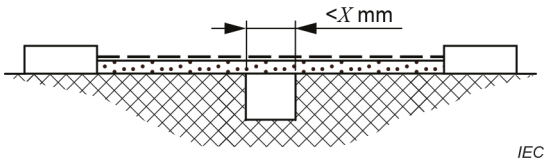
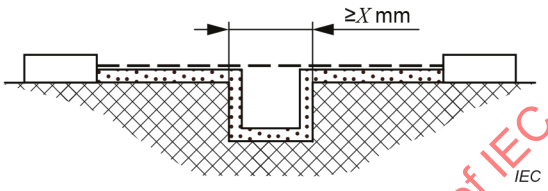
– creepage distances and clearances, measured between parts which can assume different positions in relation to each other, are measured when these parts are in their most unfavourable position.



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.

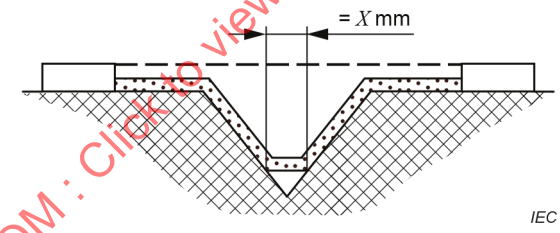
Figure B.1 – Measuring creepage distances and clearances: Example 1



Condition: Path under consideration includes a parallel-sided groove of any depth and with a width equal to or more than X mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove.

Figure B.2 – Measuring creepage distances and clearances: Example 2



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.

Figure B.3 – Measuring creepage distances and clearances: Example 3

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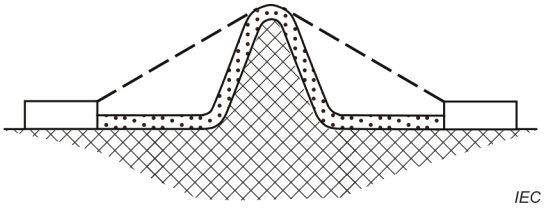
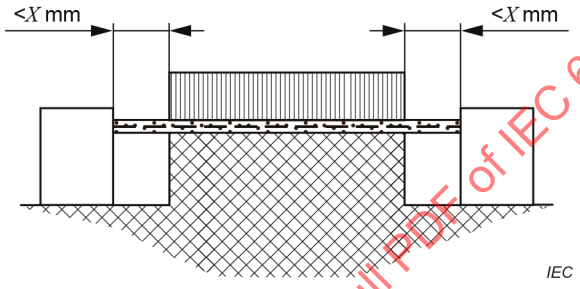


Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib.

Clearance Creepage distance

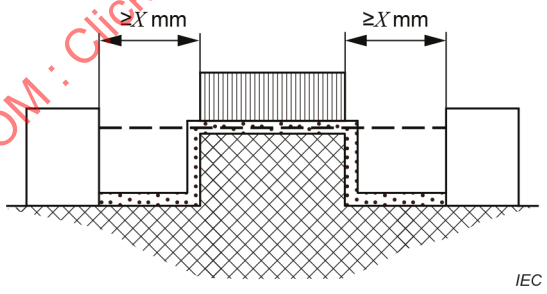
Figure B.4 – Measuring creepage distances and clearances: Example 4



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.

Figure B.5 – Measuring creepage distances and clearances: Example 5



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.

Figure B.6 – Measuring creepage distances and clearances: Example 6

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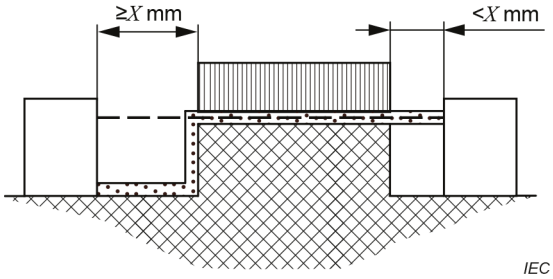
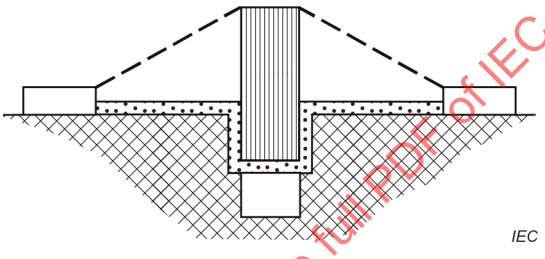


Condition: Path under consideration includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage paths area as shown.

Clearance Creepage distance

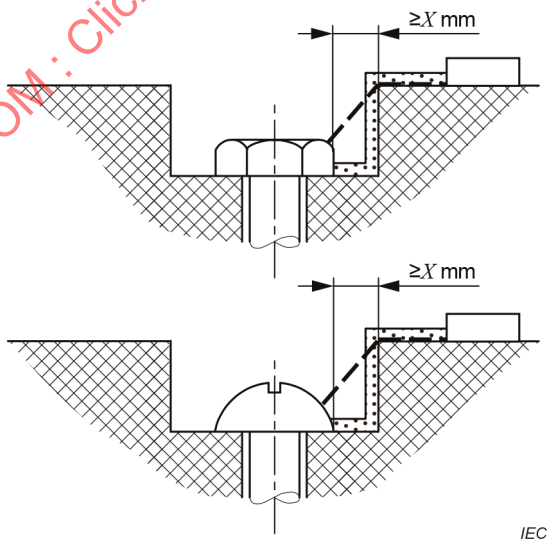
Figure B.7 – Measuring creepage distances and clearances: Example 7



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.

Figure B.8 – Measuring creepage distances and clearances: Example 8



Gap between head of screw and wall of recess wide enough to be taken into account.

Figure B.9 – Measuring creepage distances and clearances: Example 9

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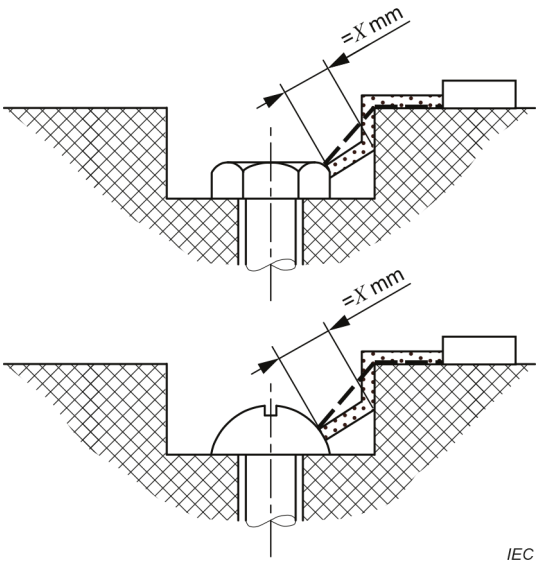
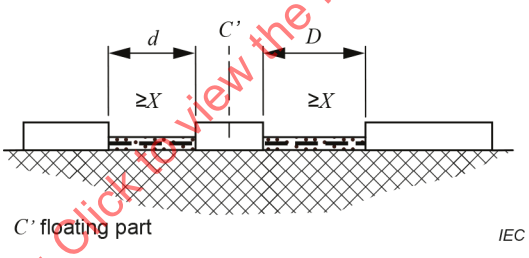


Gap between head of screw and wall of recess too narrow to be taken into account.

Measurement of creepage distance is from screw to wall when the distance is equal to X mm.

— — — Clearance ▨ Creepage distance

Figure B.10 – Measuring creepage distances and clearances: Example 10



Clearance is the distance = $d + D$

Creepage distance is also = $d + D$

— — — Clearance ▨ Creepage distance

Figure B.11 – Measuring creepage distances and clearances: Example 11

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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 can require adapting to the specific design of the device, and in accordance with the mounting 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 shall 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 B.11) shall be connected to the points B and C (see Figure 5 or Figure 6, as applicable).

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 9.11.9.2.

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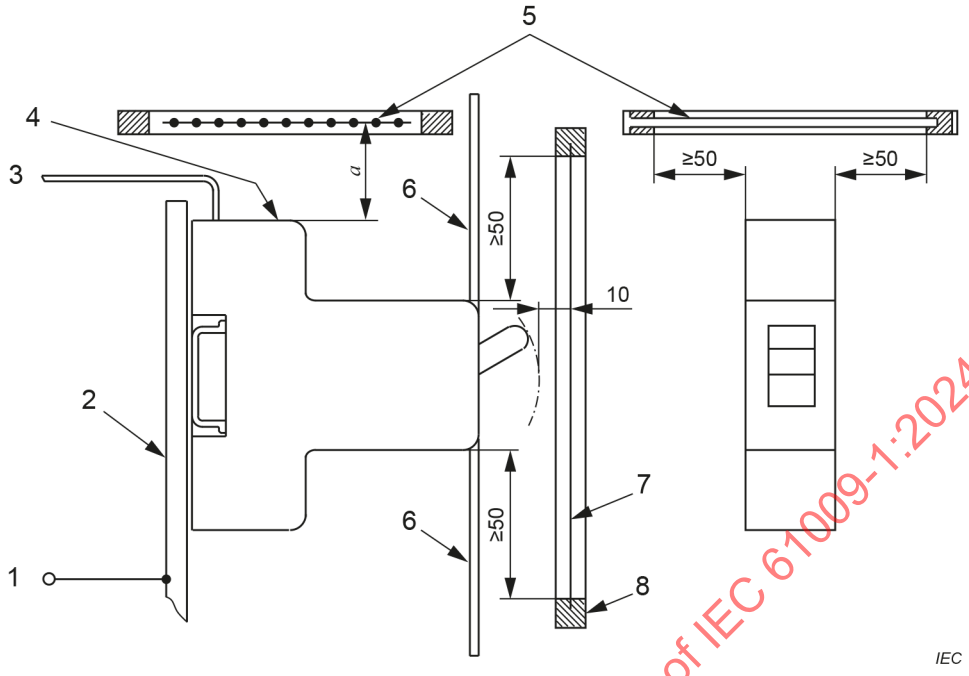
Dimensions in millimetres



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 – Example of test arrangement

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