

SRI LANKA STANDARD 1022-1:2015
IEC 61009-1:2010+A1:2012+A2:2013
UDC 621.316.92

**SPECIFICATION FOR
RESIDUAL CURRENT OPERATED
CIRCUIT-BREAKERS WITH INTEGRAL
OVERCURRENT PROTECTION FOR
HOUSEHOLD AND SIMILAR USES (RCBOs)-
PART 1 GENERAL REQUIREMENTS
(*THIRD REVISION*)**

SRI LANKA STANDARDS INSTITUTION

Sri Lanka Standard
SPECIFICATION FOR RESIDUAL CURRENT OPERATED CIRCUIT-BREAKERS
WITH INTEGRAL OVERCURRENT PROTECTION FOR HOUSEHOLD
AND SIMILAR USES (RCBOs) –
PART 1 GENERAL REQUIREMENTS
(THIRD REVISION)

SLS 1022-1:2015
IEC 61009-1:2010+A1:2012+A2:2013

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Sri Lanka Standard
SPECIFICATION FOR RESIDUAL CURRENT OPERATED CIRCUIT-
BREAKERS WITHOUT INTEGRAL OVERCURRENT PROTECTION
FOR HOUSEHOLD AND SIMILAR USES (RCBOs)-
PART 1 GENERAL REQUIREMENTS
(Third Revision)

NATIONAL FOREWORD

This standard was approved by the Sectoral Committee on Electrical Appliances and Accessories and was authorized for adoption and publication as a Sri Lanka Standard by the Council of Sri Lanka Standards Institution on 2015- 10-08

Part 1 of SLS 1022 is identical with **IEC 61009-1:2010+A1:2012+A2:2013**, Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) Part 1 General rules, Edition 3.2 2013-09, published by the International Electrotechnical Commission (IEC).

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the results of a test or an analysis shall be rounded off in accordance with **SLS 102**. The number of significant places to be retained in the rounded off value shall be the same as that of the specified value in the standard.

Terminology and conventions

The text of the International Standard has been accepted as suitable for publication as a Sri Lanka Standard with additional information indicated in the National Appendix. However, certain terminology and conventions are not identical with those used in Sri Lanka Standards; attention is therefore drawn to the following:

- a) Wherever the words “International Standard” appear referring to this standard they should be interpreted as “Sri Lanka Standard”.
- b) Wherever the page numbers are quoted they are page numbers of IEC standard.
- c) The comma has been used as a decimal marker. In the Sri Lanka Standards it is the current practices to use full point on the base line as a decimal marker.
- d) Whenever standard value of rated frequency appears it shall be taken as 50 Hz.

This part of the standard shall apply in conjunction with Part 2-1 Applicability of the general requirements to RCBOs functionally independent of line voltage.

Standard for RCBOs, functionally dependent on line voltage is not published as this type is not suitable to use for household and similar uses. (See National Appendix)

CROSS REFERENCES

International Standards

Corresponding Sri Lanka Standards

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

SLS 963 Degrees of protection provided by enclosures (IP Code)

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

SLS 1099 : Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General requirements

NOTE : *Corresponding Sri Lanka Standards for other international standards listed under references in IEC 61009-1 are not available.*

NATIONAL APPENDIX

1. Clause 4.1.2.2

Delete the existing “NOTE” and include the following “NOTE” immediately after the **b)** of **4.1.2.2**.

NOTE: The selection of the RCBOs in b) is subject to the following conditions of 532.2.2.2 of IEC 60364-5-53

The use of residual current protective devices with an auxiliary source not operating automatically in the case of failure of auxiliary source is permitted only if one of the following conditions is fulfilled:

- i) Protection against indirect contact according to clause **413.1** of IEC 60364-4-41 is ensured even in the case of failure of the auxiliary supply*
 - ii) The devices are installed in installations operated, tested and inspected by instructed persons or skilled persons*
-

FINAL VERSION

VERSION FINALE

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

**Interrupteurs automatiques à courant différentiel résiduel avec dispositif de
protection contre les surintensités incorporé pour usages domestiques et
analogues (DD) –
Partie 1: Règles générales**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 1: General rules

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This Consolidated version of IEC 61009-1 bears the edition number 3.2. It consists of the third edition (2010) [documents 23E/682/FDIS and 23E/686/RVD], its amendment 1 (2012) [documents 23E/741/FDIS and 23E/745/RVD] and its amendment 2 (2013) [documents 23E/796/FDIS and 23E/820/RVD]. The technical content is identical to the base edition and its amendments.

This Final version does not show where the technical content is modified by amendments 1 and 2. A separate Redline version with all changes highlighted is available in this publication.

This publication has been prepared for user convenience.

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

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

- complete revision of EMC sequences, including the new test T.2.6, already approved in IEC 61543;
- clarification of RCDs current/time characteristics reported in Tables 2 and 3;
- revision of test procedure for $I_{\Delta n}$ between 5 A and 200 A;
- tests for the use of RCBOs in IT systems;
- testing procedure regarding the 6mA d.c. current superimposed to the fault current;
- improvement highlighting RCDs with multiple sensitivity;
- some alignments with IEC 60898-1.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts in the IEC 61009 series, 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 the base publication and its amendments will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The contents of the corrigendum of January 2014 have been included in this copy.

INTRODUCTION

This part includes definitions, requirements and tests covering all types of RCBOs. For applicability to a specific type, this part applies in conjunction with the relevant part, as follows:

Part 2-1: Applicability of the general rules to RCBOs functionally independent of line voltage.

Part 2-2: Applicability of the general rules to RCBOs functionally dependent on line voltage.

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

Part 1: General rules

1 Scope

This International Standard applies to residual current operated circuit-breakers with integral overcurrent protection functionally independent of, or functionally dependent on, line voltage for household and similar uses (hereafter referred to as RCBOs), for rated voltages not exceeding 440 V a.c. 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 for operation at 50 Hz or 60 Hz.

These devices are intended to protect people against indirect contact, the exposed conductive parts of the installation being connected to an appropriate earth electrode and to protect against overcurrents the wiring installations of buildings and similar applications. They may be used to provide protection against fire hazards due to a persistent earth fault current, without the operation of the overcurrent protective device.

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

This standard applies to devices performing simultaneously the function 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, and also of performing the function of making, carrying and breaking overcurrents under specified conditions.

NOTE 1 The content of the present standard related to operation under residual current conditions is based on IEC 61008-1. The content of the present standard related to protection against overcurrents is based on IEC 60898-1.

NOTE 2 RCBOs are essentially intended to be operated by uninstructed persons and designed not to require maintenance. They may be submitted for certification purposes.

NOTE 3 Installation and application rules of RCBOs are given in the IEC 60364 series.

They are intended for use in an environment with pollution degree 2.

NOTE 4 For more severe overvoltage conditions, circuit-breakers complying with other standards (e.g. IEC 60947-2) should be used.

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

RCBOs of the general type are resistant to unwanted tripping, 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 proof against unwanted tripping even if the surge voltage causes a flashover and a follow-on current occurs.

NOTE 6 Surge arresters installed downstream of the general type of RCBOs and connected in common mode may cause unwanted tripping.

RCBOs are suitable for isolation.

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

Special precautions (e.g. lightning arresters) may 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).

NOTE 7 For RCBOs having a degree of protection higher than IP20 special constructions may be required.

This standard also applies to RCBOs obtained by the assembly of an adaptable residual current device with a circuit-breaker. The mechanical assembly shall be effected in the factory by the manufacturer, or on site, in which case the requirements of Annex G shall 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.

Supplementary requirements may be necessary for RCBOs of the plug-in type.

Particular requirements are necessary for RCBOs incorporated in or intended only for association with plugs and socket-outlets or with appliance couplers for household and similar general purposes and if intended to be used at frequencies other than 50 Hz or 60 Hz.

For RCBOs incorporated in, or intended only for association with socket-outlets, the requirements of this standard may 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-operated protective devices (RCDs) incorporated in, or intended only for association with socket-outlets, can either meet IEC 62640 or this standard.

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

NOTE 10 In the UK, the plug part associated with an RCBO shall comply with BS 1363-1 and the socket-outlet(s) associated with an RCBO shall comply 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 standard does not apply to:

- RCBOs intended to protect motors;
- RCBOs the current setting of which is adjustable by means accessible to the user in normal service.

The requirements of this standard apply for normal environmental conditions (see 7.1). Additional requirements may be necessary for RCBOs used in locations having severe environmental conditions.

RCBOs including batteries are not covered by this standard.

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

2 Normative references

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

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60060-2:1994, *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 + 12 h cycle)*

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

IEC 60112:2003, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60228:2004, *Conductors of insulated cables*

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

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

IEC 60364-5-52:2001, *Electrical installations of buildings – Part 5-52: Selection and erection of electrical equipment – Wiring systems¹*

IEC 60364-5-53:2001, *Low-voltage electrical installations – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*

IEC 60417, *Graphical symbols for use on equipment*

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

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

IEC 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 60695-2-11:2000, *Fire hazard testing – Part 2-11: Glowing /hot-wire based test methods – Glow-wire flammability test method for end-products*

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

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

Amendment 1:2004

Amendment 2:2005

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

¹ A third edition is currently in preparation.

3 Terms and definitions

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

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

NOTE 1 Reference to IEV definitions is also made when the terms "device" or "mechanical switching device" are replaced by the term "RCBO".

NOTE 2 For a glossary of symbols see Annex IB.

3.1 Definitions relating to currents flowing from live parts to earth

3.1.1

earth fault current

current flowing to earth due to an insulation fault

3.1.2

earth leakage current

current flowing from the live parts of the installation to earth in the absence of an insulation fault

3.1.3

pulsating direct current

current of pulsating wave form which assumes, in each period of the rated power frequency, the value 0 or a value not exceeding 0,006 A d.c. during one single interval of time, expressed in angular measure, of at least 150°

3.1.4

current delay angle α

time, expressed in angular measure, by which the starting instant of current conduction is delayed by phase control

3.2 Definitions relating to the energization of a residual current circuit-breaker

3.2.1

energizing quantity

electrical excitation quantity which, alone or in combination with other such quantities, shall be applied to an RCBO to enable it to accomplish its function under specified conditions

3.2.2

energizing input-quantity

energizing quantity by which the RCBO is activated when it is applied under specified conditions

NOTE These conditions may involve, for example, the energizing of certain auxiliary elements.

3.2.3

residual current

I_{Δ}

vector sum of the instantaneous values of the current flowing in the main circuit of the RCBO (expressed as r.m.s. value)

3.2.4

residual operating current

value of residual current which causes the RCBO to operate under specified conditions

3.2.5**residual non-operating current**

value of residual current at and below which the RCBO does not operate under specified conditions

3.2.6**residual current ($I_{\Delta t}$) of an RCBO**

value of residual current which is the lower limit of the overcurrent instantaneous tripping range according to type B, C or D (see footnote c of Table 2)

3.3 Definitions relating to the operation and functions of residual current circuit-breakers**3.3.1****switching device**

device designed to make or break the current in one or more electric circuits

[IEV 441-14-01:1984]

3.3.2**mechanical switching device**

switching device designed to close and open one or more electric circuits by means of separable contacts

[IEV 441-14-02: 1984, modified]

3.3.3**fuse**

switching device that, by the melting of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when it exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device

[IEV 441-18-01:1984, modified]

3.3.4**circuit-breaker**

mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and (automatically) breaking currents under specified abnormal conditions such as those of short-circuit

[IEV 441-14-20:1984, modified]

3.3.5**residual current operated circuit-breaker**

mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions

3.3.6**residual current operated circuit-breaker without integral overcurrent protection****RCCB**

residual current operated circuit-breaker not designed to perform the functions of protection against overloads and/or short-circuits

3.3.7**residual current operated circuit-breaker with integral overcurrent protection****RCBO**

residual current operated circuit-breaker designed to perform the functions of protection against overloads and/or short-circuits

3.3.8

RCBOs functionally independent of line voltage

RCBOs for which the functions of detection, evaluation and interruption do not depend on the line voltage

NOTE These devices are defined in 2.3.2 of IEC/TR 60755:1983 as residual current devices without auxiliary source.

3.3.9

RCBOs functionally dependent on line voltage

RCBOs for which the functions of detection, evaluation or interruption depend on the line voltage

NOTE 1 This definition covers partially the definition of residual current devices with auxiliary source of 2.3.3 of IEC 60755:1983.

NOTE 2 It is understood that the line voltage is applied to the RCBO, for detection, evaluation or interruption.

3.3.10

break time of an RCBO

time which elapses between the instant when the residual operating current is suddenly attained and the instant of arc extinction in all poles

3.3.11

limiting non-actuating time

maximum delay during which a value of residual current higher than the residual non-operating current can be applied to the RCBO without causing it to operate

3.3.12

time-delay RCBO

RCBO specially designed to attain a pre-determined value of limiting non-actuating time, corresponding to a given value of residual current

3.3.13

closed position

position in which the predetermined continuity of the main circuit of the RCBO is secured

[IEV 441-16-22]

3.3.14

open position

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

[IEV 441-16-23]

3.3.15

pole

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

3.3.15.1

overcurrent protected pole

pole provided with an overcurrent release, hereafter referred to as protected pole

3.3.15.2**overcurrent unprotected pole**

pole without an overcurrent release, but otherwise generally capable of the same performance as a protected pole of the same RCBO, hereafter referred to as unprotected pole

NOTE 1 To ensure this requirement, the unprotected pole may be of the same construction as the protected pole(s), or of a particular construction.

NOTE 2 If the short-circuit capacity of the unprotected pole is different from that of the protected pole(s), this should be indicated by the manufacturer.

3.3.15.3**switched neutral pole**

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

3.3.16**uninterrupted neutral**

current path, not interrupted and not protected against overcurrents, intended to be connected to the neutral conductor of the installation

3.3.17**main circuit (of an RCBO)**

all the conductive parts of an RCBO included in the current paths (see 4.3)

3.3.18**control circuit (of an RCBO)**

circuit (other than a path of the main circuit) intended for the closing operation or the opening operation, or both, of the RCBO

NOTE The circuits intended for the test device are included in this definition.

3.3.19**auxiliary circuit (of an RCBO)**

all the conductive parts of an RCBO which are intended to be included in a circuit other than the main circuit and the control circuit of the RCBO

[IEV 441-15-04]

3.3.20**RCBO type AC**

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

3.3.21**RCBO type A**

RCBO for which tripping is ensured for residual sinusoidal alternating currents and residual pulsating direct currents, whether suddenly applied or slowly rising

3.3.22**test device**

device incorporated in the RCBO simulating the residual current conditions for the operation of the RCBO under specified conditions

3.4 Definitions relating to values and ranges of energizing quantities**3.4.1****rated value**

quantity value assigned by the manufacturer, for a specific operating condition of an RCBO

3.4.2

overcurrent

any current exceeding the rated current

3.4.2.1

overload current

overcurrent occurring in an electrically undamaged circuit

NOTE An overload current may cause damage if sustained for a sufficient time.

3.4.2.2

short-circuit current

overcurrent resulting from a fault of negligible impedance between points intended to be at different potentials in normal service

NOTE A short-circuit current may result from a fault or from an incorrect connection.

3.4.3

prospective current

current that would flow in the circuit, if each main current path of the RCBO and of the overcurrent protective device (if any) were replaced by a conductor of negligible impedance

NOTE The prospective current may be qualified in the same manner as an actual current, for example: prospective breaking current, prospective peak current, prospective residual current, etc.

3.4.4

prospective peak current

peak value of a prospective current during the transient period following initiation

NOTE The definition assumes that the current is made by an ideal RCBO, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, for example polyphase circuits, it further assumes that the current is established simultaneously in all poles, even if the current only in one pole is considered.

3.4.5

maximum prospective peak current (of an a.c. circuit)

prospective peak current, when the initiation of the current takes place at the instant which leads to the highest possible value

NOTE For a multipole circuit-breaker in a polyphase circuit, the maximum prospective peak current refers to a single pole only.

3.4.6

short-circuit (making and breaking) capacity

alternating component of the prospective current, expressed by its r.m.s. value, which the RCBO is designed to make, to carry for its opening time and to break under specified conditions

3.4.6.1

ultimate short-circuit breaking capacity

breaking capacity for which the prescribed conditions according to a specified test sequence do not include the capability of the RCBO to carry 0,85 times its non-tripping current for the conventional time

3.4.6.2

service short-circuit breaking capacity

breaking capacity for which the prescribed conditions according to a specified test sequence include the capability of the RCBO to carry 0,85 times its non-tripping current for the conventional time

3.4.7

breaking current

current in a pole of an RCBO at the instant of initiation of the arc during a breaking process

[IEV 441-17-07:1984, modified]

NOTE For a.c., reference is made to the r.m.s. value.

3.4.8

applied voltage

voltage which exists across the terminals of a pole of an RCBO just before the making of the current

[IEV 441-17-24:1984]

NOTE This definition refers to a single-pole RCBO. For a multipole RCBO, the applied voltage is the voltage across the supply terminals of the RCBO.

3.4.9

recovery voltage

voltage which appears across the terminals of a pole of an RCBO after the breaking of the current

[IEV 441-17-25:1984]

NOTE 1 This voltage may be considered as comprising two successive intervals of time, one during which a transient voltage exists, followed by a second one during which power-frequency voltage alone exists.

NOTE 2 This definition refers to a single-pole RCBO. For a multipole RCBO, the recovery voltage is the voltage across the supply terminals of the RCBO.

3.4.9.1

transient recovery voltage

recovery voltage during the time in which it has a significant transient character

NOTE The transient voltage may be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit and of the RCBO. It includes the voltage shift of the neutral of a polyphase circuit.

[IEV 441-17-26:1984, modified]

3.4.9.2

power-frequency recovery voltage

recovery voltage after the transient voltage phenomena have subsided

[IEV 441-17-27;1984]

3.4.10

opening time

time measured from the instant at which, the RCBO being in the closed position, the current in the main circuit reaches the operating value of the overcurrent release to the instant when the arcing contacts have separated in all poles

NOTE The opening time is commonly referred to as tripping time, although, strictly speaking, tripping time applies to the time between the instant of initiation of the opening time and the instant at which the opening command becomes irreversible.

3.4.11

Definitions relating to arcing time

3.4.11.1

arcing time of a pole

interval of time between the instant of initiation of the arc in a pole and the instant of final arc extinction in that pole

[IEV 441-17-37, modified]

3.4.11.2**arcing time of a multipole RCBO**

interval of time between the instant of first initiation of the arc and the instant of final arc extinction in all poles

[IEV 441-17-38]

3.4.12**break time** (in case of overcurrent)

interval of time between the beginning of the opening time of an RCBO and the end of the arcing time, in case of overcurrent

[IEV 441-17-39:1984, modified]

3.4.13 **I^2t (Joule integral)**integral of the square of the current over a given time interval (t_0 , t_1):

$$I^2t = \int_{t_0}^{t_1} i^2 dt$$

[IEV 441-18-23:1984]

3.4.14 **I^2t characteristic of an RCBO**curve giving the maximum value of I^2t as a function of the prospective current under stated conditions of operation**3.4.15****Coordination between overcurrent protective devices in series****3.4.15.1****selectivity-limit current** I_s

current coordinate of the intersection between the maximum break-time current characteristic of the protective device on the load side and the pre-arcing (for fuses) or tripping (for circuit-breakers) time-current characteristic of the other protective device

NOTE 1 The selectivity-limit current is a limiting value of current:

- below which, in the presence of two overcurrent protective devices in series, the protective device on the load side completes its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is ensured);
- above which, in the presence of two overcurrent protective devices in series, the protective device on the load side may not complete its breaking operation in time to prevent the other protective device from starting its operation (i.e. selectivity is not ensured).

NOTE 2 I^2t characteristics may be used instead of time-current characteristics.**3.4.15.2****take-over current** I_B

current coordinate of the intersection between the maximum break time-current characteristics of two overcurrent protective devices

NOTE 1 The take-over current is a limiting value of current above which, in the presence of two overcurrent protective devices in series, the protective device generally, but not necessarily, on the supply side, provides back-up operation for the other protective device.

NOTE 2 I^2t characteristics may be used instead of time-current characteristics.

**3.4.16
conventional non-tripping current**

I_{nt}
specified value of current which the RCBO can carry for a specified time (conventional time) without operating

[IEV 441-17-22 :1984]

**3.4.17
conventional tripping current**

I_t
specified value of current which causes the RCBO to operate within a specified time (conventional time)

**3.4.18
instantaneous tripping current**

minimum value of current which causes the circuit-breaker to operate automatically without intentional time-delay

**3.4.19
non-operating overcurrents in the main circuit**

NOTE In the case of overcurrent in the main circuit, in the absence of residual current, operation of the detecting device may occur as a consequence of asymmetry existing in the detecting device itself.

3.4.19.1**limiting value of overcurrent in case of a load through an RCBO with two current paths**

maximum value of overcurrent of a load which, in the absence of any fault to frame or to earth, and in the absence of an earth leakage current, can flow through an RCBO with two current paths without causing it to operate

3.4.19.2**limiting value of overcurrent in case of a single phase load through a three-pole or four-pole RCBO**

maximum value of a single phase overcurrent which, in the absence of any fault to frame or to earth, and in the absence of an earth leakage current, can flow through a three-pole or a four-pole RCBO without causing it to operate

3.4.20**residual making and breaking capacity**

value of the a.c. component of a residual prospective current which an RCBO can make, carry for its opening time and break under specified conditions of use and behaviour

3.4.21**limiting values (U_x and U_y) of the line voltage for RCBOs functionally dependent on line voltage****3.4.21.1**

U_x

minimum value of the line voltage at which an RCBO functionally dependent on line voltage still operates under specified conditions in case of decreasing line voltage (see 9.17.1)

3.4.21.2

U_y

minimum value of the line voltage below which an RCBO functionally dependent on line voltage opens automatically in the absence of any residual current (see 9.17.2)

3.5 Definitions relating to values and ranges of influencing quantities

3.5.1

influencing quantity

any quantity likely to modify the specified operation of an RCBO

3.5.2

reference value of an influencing quantity

value of an influencing quantity to which the characteristics stated by the manufacturer are referred

3.5.3

reference conditions of influencing quantities

collectively, the reference values of all influencing quantities

3.5.4

range of an influencing quantity

range of values of an influencing quantity which permits the RCBO to operate under specified conditions, the other influencing quantities having their reference values

3.5.5

extreme range of an influencing quantity

range of values of an influencing quantity within which the RCBO suffers only spontaneously reversible changes, although not necessarily complying with any requirements

3.5.6

ambient air temperature

temperature, determined under prescribed conditions, of the air surrounding the RCBO

NOTE For RCBOs installed inside an enclosure, it is the temperature of the air outside the enclosure.

[IEV 441-11-13]

3.5.7

reference ambient air temperature

ambient air temperature on which the time-overcurrent characteristics are based

3.6 Definitions relating to terminals

3.6.1

terminal

conductive part of an RCBO, provided for re-usable electrical connection to external circuits

3.6.2

screw-type terminal

terminal for the connection and subsequent disconnection of one conductor or the interconnection of two or more conductors capable of being dismantled, the connections being made, directly or indirectly, by means of screws or nuts of any kind

3.6.3

pillar terminal

screw-type terminal in which the conductor is inserted into a hole or cavity, where it is clamped under the shank of the screw(s)

NOTE 1 The clamping pressure may be applied directly by the shank of the screw or by an intermediate clamping element to which pressure is applied by the shank of the screw.

NOTE 2 Examples of pillar terminals are shown in Figure IC.1 of Annex IC.

3.6.4**screw terminal**

screw-type terminal in which the conductor is clamped under the head of the screw. The clamping pressure may be applied directly by the head of the screw or through an intermediate part, such as a washer, a clamping plate or an anti-spread device

NOTE Examples of screw terminals are shown in Figure IC.2a of Annex IC.

3.6.5**stud terminal**

screw-type terminal in which the conductor is clamped under a nut

NOTE 1 The clamping pressure may be applied directly by a suitably shaped nut or through an intermediate part, such as a washer, a clamping plate or an anti-spread device.

NOTE 2 Examples of stud terminals are shown in Figure IC.2b.

3.6.6**saddle terminal**

screw-type terminal in which the conductor is clamped under a saddle by means of two or more screws or nuts

NOTE Examples of saddle terminals are shown in Figure IC.3.

3.6.7**lug terminal**

screw terminal or a stud terminal, designed for clamping a cable lug or a bar by means of a screw or nut

NOTE Examples of lug terminals are shown in Figure IC.4.

3.6.8**screwless terminal**

connecting terminal for the connection and subsequent disconnection of one conductor or the dismantlable interconnection of two or more conductors capable of being dismantled, the connection being made, directly or indirectly, by means of springs, wedges, eccentrics or cones, etc., without special preparation of the conductor other than removal of insulation

3.6.9**tapping screw**

screw manufactured from a material having high resistance to deformation, when applied by rotary insertion to a hole in a material having less resistance to deformation than the screw

NOTE The screw is made with a tapered thread, the taper being applied to the core diameter of the thread at the end section of the screw. The thread produced by application of the screw is formed securely only after sufficient revolutions have been made to exceed the number of threads on the tapered section.

3.6.10**thread forming tapping screw**

tapping screw having an uninterrupted thread

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

NOTE 2 An example of a thread forming tapping screw is shown in Figure 1.

3.6.11**thread cutting tapping screw**

tapping screw having an interrupted thread

NOTE 1 It is a function of this thread to remove material from the hole.

NOTE 2 An example of a thread cutting tapping screw is shown in Figure 2.

3.7 Definitions relating to conditions of operation

3.7.1 operation

transfer of the moving contact(s) from the open position to the closed position or vice versa

NOTE If distinction is necessary, an operation in the electrical sense (i.e. make or break) is referred to as a switching operation and an operation in the mechanical sense (i.e. close or open) is referred to as a mechanical operation.

3.7.2 closing operation

operation by which the RCBO is brought from the open position to the closed position

[IEV 441-16-08:1984]

3.7.3 opening operation

operation by which the RCBO is brought from the closed position to the open position

[IEV 441-16-09:1984]

3.7.4 dependent manual operation

operation solely by means of directly applied manual energy, such that the speed and force of the operation are dependent on the action of the operator

[IEV 441-16-13]

3.7.5 independent manual operation

stored energy operation where the energy originates from manual power, stored and released in one continuous operation, such that the speed and force of the operation are independent of the action of the operator

[IEV 441-16-16]

3.7.6 trip-free RCBO

an RCBO, the moving contacts of which return to and remain in the open position when the (automatic) opening operation is initiated after the initiation of the closing operation, even if the closing command is maintained

NOTE To ensure proper breaking of the current which may have been established, it may be necessary that the contacts momentarily reach the closed position.

[IEV 441-16-31]

3.7.7 operating cycle

succession of operations from one position to another and back to the first position through all other positions, if any

[IEV 441-16-02]

3.7.8 sequence of operations

succession of specified operations with specified time intervals

3.7.9

uninterrupted duty

duty in which the main contacts of an RCBO remain closed whilst carrying a steady current without interruption for long periods (which could be weeks, months, or even years)

3.8 Definitions relating to constructional elements

3.8.1

main contact

contact included in the main circuit of an RCBO, intended to carry, in the closed position, the current of the main circuit

[IEV 441-15-07:1984]

3.8.2

arcing contact

contact on which the arc is intended to be initiated

NOTE An arcing contact may serve as a main contact. It may also be a separate contact so designed that it opens after and closes before another contact which it is intended to protect from damage.

3.8.3

control contact

contact included in a control circuit of an RCBO and mechanically operated by the RCBO

[IEV 441-15-09]

3.8.4

auxiliary contact

contact included in an auxiliary circuit and mechanically operated by the RCBO (e.g. for indicating the position of the contacts)

[IEV 441-15-10:1984, modified]

3.8.5

release

device, mechanically connected to (or integrated into) an RCBO which releases the holding means and permits the automatic opening of the RCBO

[IEV 441-15-17, modified]

NOTE In the IEC definition, reference to closing is also made.

3.8.6

overcurrent release

release which permits an RCBO to open with or without time-delay when the current in the release exceeds a predetermined value

NOTE In some cases, this value may depend upon the rate of rise of current.

[IEV 441-16-33:1984]

3.8.7

inverse time-delay overcurrent release

overcurrent release which operates after a time-delay inversely dependent upon the value of the overcurrent

NOTE Such a release may be designed so that the time-delay approaches a definite minimum for high values of overcurrent.

[IEV 441-16-35:1984]

3.8.8

direct overcurrent release

overcurrent release directly energized by the current in the main circuit of an RCBO

[IEV 441-16-36:1984]

3.8.9

overload release

overcurrent release intended for protection against overloads

[IEV 441-16-38:1984]

3.8.10

conductive part

part which is capable of conducting current, although it may not necessarily be used for carrying service current

[IEV 441-11-09:1984]

3.8.11

exposed conductive part

conductive part which can be readily touched and which normally is not live, but which may become live under fault conditions

[IEV 441-11-10:1984]

3.9 Definitions relating to tests

3.9.1

type test

test of one or more devices made to a certain design to show that the design meets certain requirements

3.9.2

routine test

test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

3.10 Definitions relating to insulation coordination

3.10.1

insulation coordination

mutual correlation of insulation characteristics of electrical equipment taking into account the expected micro-environment and other influencing stresses

[IEC 60664-1:2007, definition 3.1]

3.10.2

working voltage

highest r.m.s. value of the a.c. or d.c. voltage across any particular insulation which can occur when the equipment is supplied at rated voltage

NOTE 1 Transients are disregarded.

NOTE 2 Both open-circuit conditions and normal operating conditions are taken into account.

[IEC 60664-1:2007, definition 3.5]

3.10.3**overvoltage**

any voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions

[IEC 60664-1:2007, definition 3.7]

3.10.4**impulse withstand voltage**

highest peak value of impulse voltage of prescribed form and polarity, which does not cause breakdown of the insulation under specific conditions

[IEC 60664-1:2007, definition 3.8.1]

3.10.5**overvoltage category**

numeral defining a transient overvoltage condition

[IEC 60664-1:2007, definition 3.10]

3.10.6**macro-environment**

environment of the room or other location, in which the equipment is installed or used

[IEC 60664-1:2007, definition 3.12.1]

3.10.7**micro-environment**

immediate environment of the insulation which particularly influences the dimensioning of the creepage distances

[IEC 60664-1:2007, definition 3.12.2]

3.10.8**pollution**

any addition of foreign matter, solid, liquid or gaseous that can result in a reduction of electric strength or surface resistivity of the insulation

[IEC 60664-1:2007, definition 3.11]

3.10.9**pollution degree**

numeral characterizing the expected pollution of the micro-environment

[IEC 60664-1:2007, definition 3.13]

NOTE The pollution degree to which equipment is exposed may be different from that of the macro-environment where the equipment is located because of protection offered by means such as an enclosure or internal heating to prevent absorption or condensation of moisture.

3.10.10**isolation (isolating function)**

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

[IEC 60947-1:2007, definition 2.1.19, modified]

3.10.11**isolating distance**

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

[IEV 441-17-35:1984, modified]

3.10.12

clearance

shortest distance in air between two conductive parts along a string stretched the shortest way between these conductive parts

[IEV 441-17-31, modified]

NOTE 1 For the purpose of determining a clearance to accessible parts, the accessible surface of an insulating enclosure should be considered conductive as if it was covered by a metal foil wherever it can be touched by a hand or a standard test finger according to Figure 3.

NOTE 2 See also Annex B.

3.10.13

creepage distance

shortest distance along the surface of an insulating material between two conductive parts

[IEV 604-03-61:1987, modified]

NOTE 1 For the purpose of determining a creepage distance to accessible parts, the accessible surface of an insulating enclosure should be considered conductive as if it was covered by a metal foil wherever it can be touched by a hand or a standard test finger according to Figure 3.

NOTE 2 See also Annex B.

4 Classification

RCBOs are classified in the following 12 ways:

4.1 According to the method of operation

NOTE The selection of the various types is made according to the requirements of IEC 60364-5-53.

4.1.1 RCBO functionally independent of line voltage (see 3.3.8)

4.1.2 RCBO functionally dependent on line voltage (see 3.3.9)

4.1.2.1 Opening automatically in case of failure of the line voltage, without or with delay (see 8.12):

- a) reclosing automatically when the line voltage is restored;
- b) not reclosing automatically when the line voltage is restored.

4.1.2.2 Not opening automatically in case of failure of the line voltage:

- a) able to trip in case of a hazardous situation (e.g. due to an earth fault), arising on failure of the line voltage (requirements under consideration);
- b) not able to trip in case of a hazardous situation (e.g. due to an earth fault), arising on failure of line voltage.

NOTE The selection of the RCBOs in b) is subject to the conditions of 531.2.2.2 of IEC 60364-5-53:2001.

4.2 According to the type of installation

- RCBO for fixed installation and fixed wiring;
- RCBO for mobile installation and corded connection (of the device itself to the supply).

4.3 According to the number of poles and current paths

- single-pole RCBO with one overcurrent protected pole and uninterrupted neutral (see 3.3.16) (two current paths);
- two-pole RCBO with one overcurrent protected pole;
- two-pole RCBO with two overcurrent protected poles;
- three-pole RCBO with three overcurrent protected poles;
- three-pole RCBO with three overcurrent protected poles and uninterrupted neutral (four current paths);
- four-pole RCBO with three overcurrent protected poles;
- four-pole RCBO with four overcurrent protected poles.

NOTE The pole which is not an overcurrent protected pole (see 3.3.15.1) may be:

- "unprotected" (see 3.3.15.2), or
- "switched neutral" (see 3.3.15.3).

4.4 According to the possibility of adjusting the residual operating current

- RCBO with a single value of rated residual operating current;
- RCBO with multiple settings of residual operating current by fixed steps (see 5.2.3).

4.5 According to resistance to unwanted tripping due to voltage surges

- RCBOs with normal resistance to unwanted tripping (general type as in Table 2, and Table 3 if applicable);
- RCBOs with increased resistance to unwanted tripping (S type as in Table 2, and Table 3 if applicable).

4.6 According to behaviour in presence of d.c. components

- RCBOs of type AC;
- RCBOs of type A.

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

- RCBO without time-delay: type for general use;
- RCBO with time-delay: type S for selectivity.

4.8 According to the protection against external influences

- enclosed-type RCBO (not requiring an appropriate enclosure);
- unenclosed-type RCBO (for use with an appropriate enclosure).

4.9 According to the method of mounting

- surface-type RCBO;
- flush-type RCBO;
- panel board type RCBO, also referred to as distribution board type.

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

4.10 According to the method of connection

- RCBOs, the electrical connections which are not associated with the mechanical mounting;
- RCBOs, the electrical connections which are associated with the mechanical mounting.

NOTE Examples of this type are:

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

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

4.11 According to the instantaneous tripping current (see 3.4.18)

- B-type RCBO;
- C-type RCBO;
- D-type RCBO.

4.12 According to the I^2t characteristic

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.

4.13 According to the type of terminals

- RCBOs with screw-type terminals for external copper conductors;
- RCBOs with screwless type terminals for external copper conductors;

NOTE 1 The requirements for RCBOs equipped with these types of terminals are given in Annex J.

- RCBOs with flat quick-connect terminals for external copper conductors;

NOTE 2 The requirements for RCBOs equipped with these types of terminals are given in Annex K.

- RCBOs with screw-type terminals for external aluminium conductors.

NOTE 3 The requirements for RCBOs equipped with this type of terminal are given in Annex L.

5 Characteristics of RCBOs

5.1 Summary of characteristics

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

- type of installation (see 4.2);
- number of poles and current paths (see 4.3);
- rated current I_n (see 5.2.2);
- rated residual operating current $I_{\Delta n}$ (see 5.2.3);
- rated residual non-operating current $I_{\Delta no}$ (see 5.2.4);
- rated voltage U_n (see 5.2.1);
- rated frequency (see 5.2.5);
- rated short-circuit capacity I_{cn} (see 5.2.6);
- rated residual making and breaking capacity $I_{\Delta m}$ (see 5.2.7);
- time-delay, if applicable (see 5.2.8);
- operating characteristics in case of residual currents with d.c. components (see 5.2.9);
- method of mounting (see 4.9);
- method of connection (see 4.10);
- range of instantaneous tripping overcurrent (see 4.11);

- I^2t classification (see 4.12);
- degree of protection (see IEC 60529).

For RCBOs functionally dependent on line voltage:

- behaviour of the RCBO in case of failure of line voltage (see 4.1.2).

5.2 Rated quantities and other characteristics

5.2.1 Rated voltage

5.2.1.1 Rated operational voltage (U_e)

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

NOTE The same RCBO may be assigned a number of rated voltages and associated rated short-circuit capacities.

5.2.1.2 Rated insulation voltage (U_i)

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

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

5.2.1.3 Rated impulse withstand voltage (U_{imp})

The rated impulse withstand voltage of an RCBO shall be equal to or higher than the standard values of rated impulse withstand voltage given in Table 5.

5.2.2 Rated current (I_n)

A current assigned by the manufacturer as the current which the RCBO can carry in uninterrupted duty (see 3.7.9), at a specified reference ambient air temperature.

The standard reference ambient air temperature is 30 °C. If a different reference ambient air 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 a reference ambient air temperature of 30 °C, according to installation rules (see Clause 523 of IEC 60364-5-52:2001).

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

The value of residual operating current (see 3.2.4), assigned to the RCBO 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.

RCBOs with continuously adjustable settings are not allowed.

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

The value of residual non-operating current (3.2.5), assigned to the RCBO by the manufacturer, at which the RCBO does not operate under specified conditions.

5.2.5 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 The same RCBO may be assigned a number of rated frequencies.

5.2.6 Rated short-circuit capacity (I_{cN})

The rated short-circuit capacity of an RCBO is the value of the ultimate short-circuit breaking capacity (see 3.4.6.1) 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 22).

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

The r.m.s. value of the a.c. component of residual prospective current (3.2.3 and 3.4.3), assigned by the manufacturer, which an RCBO can make, carry and break under specified conditions.

The conditions are those specified in 9.12.13.

5.2.8 RCBO type S

A time-delay RCBO (see 3.3.12) which complies with the relevant part of Table 2 and Table 3 if applicable.

5.2.9 Operating characteristics in case of residual currents with d.c. components

5.2.9.1 RCBO type AC

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

5.2.9.2 RCBO type A

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

5.3 Standard and preferred values

5.3.1 Preferred values of rated voltage (U_n)

Preferred values of rated voltage are as follows:

RCBOs	Circuit supplying the RCBOs	Rated voltage of RCBOs for use in systems 230 V or 230/400 V or 400 V V	Rated 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, 3-wire)		120/240
	Three phase (4-wire) (230/400 V-system phase to neutral or 230 V-system phase to phase)	230	

Three-pole (with three or four current path)	Three phase (3-wire or 4-wire) (400 V or 230/400 V or 240 V-system)	400	240
Four-pole	Three phase (4-wire) (230/400 V-system)	400	

NOTE 1 In IEC 60038 the network voltage value of 230/400 V has been standardized. This value should progressively supersede the values of 220/380V and 240/415 V.

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

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

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

NOTE In Japan phase to neutral conductor and phase to earthed conductor (grounded conductor) is thought differently because single phase 2-wire system supplied from 2-wire system source do not have neutral point.

5.3.2 Preferred values of rated current (I_n)

Preferred values of rated current are:

6 – 8 – 10 – 13 – 16 – 20 – 25 – 32 – 40 – 50 – 63 – 80 – 100 – 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 – 0,01 – 0,03 – 0,1 – 0,3 – 0,5 A.

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

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 current delay angle α (see 3.1.4).

5.3.5 Standard values of rated frequency

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

5.3.6 Values of rated short-circuit capacity

5.3.6.1 Standard values up to and including 10 000 A

Standard values of rated short-circuit capacities up to and including 10 000 A are given in Table 1.

Table 1 – Standard values of rated short-circuit capacity

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

NOTE The values of 1 000 A, 2 000 A, 2 500 A, 7 500 A and 9 000 A are also considered as standard in some countries.

The corresponding ranges of power factor are given in 9.12.5.

5.3.6.2 Values above 10 000 A up to and including 25 000 A

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

The corresponding range of power factor is given in 9.12.5.

5.3.7 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.

The associated power factors are specified in Table 21.

5.3.8 Limiting values of break time and non-actuating time for RCBO of type AC and A**5.3.8.1 Limiting values of break time and non-actuating time for alternating residual currents (r.m.s. values) for type AC and A**

Table 2 – Limiting values of break time and non-actuating time for alternating residual currents (r.m.s. values) for type AC and A RCBO

Limiting values of break time and non-actuating time (s) for type AC and A RCBOs in event of alternating residual currents (r.m.s. values) equal to									
Type	I_n A	$I_{\Delta n}$ A	$I_{\Delta n}$	$2 I_{\Delta n}$	$5 I_{\Delta n}$	$5 I_{\Delta n}$ or $0,25 A^a$	$5 A - 200 A,$ $500 A^b$	$I_{\Delta t}^c$	
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	
		>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	Minimum non-actuating times
		>0,03	0,13	0,06	0,05		0,04	0,04	
<p>^a Value to be decided by the manufacturer for this test.</p> <p>^b The tests are only made during the verification of the correct operation as mentioned in 9.9.12 d) but in any case values exceeding the lower limit of the overcurrent instantaneous tripping range are not tested.</p> <p>^c The test is made 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 9.9.1.3 and 9.9.1.4 b), 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.</p>									

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

$$T = \left(\frac{20}{I} \right)^{1,43}$$

for high-resistance faults and

$$T = 125 \left(\frac{10}{V} \right)^{1,43}$$

for low resistance faults.

5.3.8.2 Maximum values of break time for half-wave residual currents (r.m.s. values) for type A

Table 3 – Maximum values of break time for half-wave residual currents (r.m.s. values) for type A RCBO

			Maximum values of break time and non-actuating time (s) for type A RCBOs in the event of half-wave pulsating residual currents (r.m.s. 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 This value shall be limited to the lower limit of the overcurrent instantaneous tripping ranges according to type B, C or D, as applicable.

5.3.9 Standard ranges of overcurrent instantaneous tripping

Standard ranges of overcurrent instantaneous tripping are given in Table 4.

Table 4 – 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 $50 I_n$ may also be used.

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

Table 5 gives the standard values of rated impulse withstand voltages as a function of the nominal voltage of the installation.

Table 5 – Rated impulse withstand voltage as a function of the nominal voltage of the installation

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

NOTE 1 For test voltages to check the insulation, see Table 19.

NOTE 2 For test voltages to check the isolation distance across open contacts, see Table 28.

^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 Tables 7 and 28).

^b For installation practice in Japan.

^c For installation practice in North American countries.

6 Marking and other product information

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

- a) manufacturer's name or trade mark;
- b) type designation, catalogue number or serial number;
- c) rated voltage(s);
- d) rated current without symbol "A", preceded by the symbol of overcurrent instantaneous tripping (B, C or D), for example B 16;
- e) rated frequency; RCBOs with more than one rated frequency (e.g. 50/60 Hz) shall be marked accordingly;
- f) rated residual operating current;
- g) settings of residual operating current for RCBOs with multiple residual operating currents;
- h) rated short-circuit capacity, in amperes;
- j) reference calibration temperature, if different from 30 °C;
- k) the degree of protection (only if different from IP 20);
- l) the position of use, if necessary;
- m) rated residual making and breaking capacity, if different from rated short-circuit capacity;
- n) the symbol S (S in a square) for type S devices;
- o) indication that the RCBO is functionally dependent on line voltage, if applicable (under consideration);
- p) operating means of the test device, by the letter T;
- q) wiring diagram;
- r) operating characteristic in presence of residual currents with d.c. components
 - RCBOs of type AC with the symbol  (IEC 60417-5032-2002-10)
 - RCBOs of type A with the symbol 
- s) for type D RCBOs: the maximum instantaneous tripping current, if higher than 20 I_n (see Table 4).

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

The suitability for isolation, which is provided by all RCBOs of this standard, may be indicated by the symbol  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 1 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 is marked on the device, it shall comply with it, whichever the method of installation. If the higher degree of protection is obtained only by a specific method of installation and/or with the use of specific accessories (e.g. terminal covers, enclosures, etc.), this shall be specified in the manufacturer's literature.

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

For RCBOs other than those operated by means of push-button, the open position shall be indicated by the symbol "O" and the closed position by the symbol "I" (a short straight line).

Additional national symbols are allowed for this indication. Provisionally, the use of national indications only is allowed. 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 red and/or be marked with the symbol "O".

RED 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.

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

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

Terminals intended for the protective conductor, if any, shall be indicated by the symbol



(IEC 60417-5019-2006-08).

NOTE 2 The symbol  (IEC 60417-5017-2006-08), previously recommended, shall be progressively superseded by the preferred symbol IEC 60417-5019, given above.

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.

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

- no marking.

For non-universal terminals:

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

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

7 Standard conditions for operation in service and for installation

7.1 Standard conditions

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

Table 6 – Standard conditions for operation in service

Influencing quantity	Standard range of application	Reference value	Test tolerances (see note 6)
Ambient temperature (see notes 1 and 7)	-5 °C to +40 °C (see note 2)	20 °C	± 5 °C
Altitude	Not exceeding 2 000 m		
Relative humidity maximum value at 40°C	50 % (see note 3)		
External magnetic field	Not exceeding 5 times the earth's magnetic field in any direction	Earth's magnetic field	(see note 4)
Position	As stated by the manufacturer with a tolerance of 2° in any direction (see note 5)	As stated by the manufacturer	2° in any direction
Frequency	Reference value ± 5 % (see note 6)	Rated value	± 2 %
Sinusoidal wave distortion	Not exceeding 5 %	Zero	5 %
<p>NOTE 1 The maximum value of the mean daily temperature is +35 °C.</p> <p>NOTE 2 Values outside the range are admissible where more severe climatic conditions prevail, subject to agreement between manufacturer and user.</p> <p>NOTE 3 Higher relative humidities are admitted at lower temperatures (for example 90 % at 20 °C).</p> <p>NOTE 4 When an RCBO is installed in proximity to a strong magnetic field, supplementary requirements may be necessary.</p> <p>NOTE 5 The device should be fixed in such a way that it does not cause deformation liable to impair its functions.</p> <p>NOTE 6 The tolerance given apply unless otherwise specified in the relevant test.</p> <p>NOTE 7 Extreme limits of –20 °C and +60 °C are admissible during storage and transportation, and should be taken into account in the design of the device.</p>			

7.2 Conditions of installation

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

7.3 Pollution degree

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

8 Requirements for construction and operation

8.1 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.

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

In case of an RCBO having multiple settings of residual operating current, the rating refers to the highest setting.

8.1.2 Mechanism

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

The switched neutral pole (see 3.3.15.3) 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 (see 3.7.5), 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 (see 3.3.13) or in the open position (see 3.3.14), even when the operating means is released in an intermediate position.

RCBOs shall provide in the open position (see 3.3.14) 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 1 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.

Compliance is checked by inspection and by the tests of 9.9.2.2.

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.

Compliance is checked by inspection and by the tests of 9.12.12.1 and 9.12.12.2.

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.

NOTE 2 Locking of the operating means in the closed position is permitted for particular applications.

Compliance is checked by inspection, taking into account the instructions of the manufacturer.

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.

In the case of RCBOs functionally dependent on line voltage reclosing automatically (see 4.1.2.1 a)) when the line voltage is restored after failure of line voltage, the operating means shall remain in the ON position following automatic opening of the contacts; when the line voltage is re-established, the contacts shall reclose automatically unless in the meantime the operating means has been placed in the OFF position.

NOTE 3 For this type of RCBO, the operating means cannot be used as a means for indicating the closed and open positions.

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.

NOTE 4 Provisionally in certain countries top to bottom closing movement is allowed.

Compliance with the above requirements is checked by inspection, by manual test and, for the trip-free mechanism, by the test of 9.11.

8.1.3 Clearances and creepage distances (see also Annex B)

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

Compliance for item 1 in Table 7 is checked by measurement and by the test of 9.7.7.4.1 and 9.7.7.4.2. The test is carried out with samples not submitted to the humidity treatment described in 9.7.1.

The clearances of items 2 and 4 (except accessible surface after installation, see Note 1) may be reduced provided that the measured clearances are not shorter than the minimum allowed in IEC 60664-1 for homogenous field conditions.

NOTE 1 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.

In this case, after the humidity treatment described in 9.7.1, compliance for item 2 and 4 and arrangements of 9.7.2 items b), c), d) and e) is checked in the following order:

- Tests according to 9.7.2 to 9.7.6 as applicable;
- Test according to 9.7.7.2 is applied with test voltages given in Table 19 with test arrangements of 9.7.2 items b), c), d), e).

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

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

NOTE 2 All measurements required in 8.1.3 are carried out in Test sequence A on one sample and the tests 9.7.7.2 are carried out before 9.7.1 on three samples of Test sequence B.

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

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

NOTE 3 Information on the requirements for design of solid insulation and appropriate testing is provided in IEC 60664-1:2007, 5.3 and 6.1.3.

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

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

Table 7 – Minimum clearances and creepage distances

	Minimum clearances mm			Minimum creepage distances ^{e, f} mm											
				Group IIIa ^h (175 V ≤ CTI < 400 V) ^d				Group II (400 V ≤ CTI < 600 V) ^d				Group I (600 V ≤ CTI) ^d			
	Rated voltage V			Working voltage ^e V											
	U_{imp}														
	2,5 kV	4 kV	4 kV	>25 ≤50 ⁱ	120	250	400	>25 ≤50 ⁱ	120	250	400	>25 ≤50 ⁱ	120	250	400
Description	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	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	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 voltage V											
				120 / 240	230 / 400	120 / 240	230 / 400	120 / 240	230 / 400	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	1,5	3,0	1,5	3,0	1,5	3,0

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

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

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

- a For auxiliary and control contacts the values are given in the relevant standard.
- b The values are doubled if clearances and creepage distances between live parts of the device and the metallic screen or the surface on which the RCBO is mounted are not dependent on the design of the RCBO only, so that they can be reduced when the RCBO is mounted in the most unfavourable condition.
- c Including a metal foil in contact with the surfaces of insulating material which are accessible after installation for normal use. The foil is pushed into corners, grooves, etc., by means of a straight unjointed test finger according to 9.6 (see Figure 3).
- d See IEC 60112.
- e Interpolation is allowed in determining creepage distances corresponding to voltage values intermediate to those listed as working voltage. When interpolating, linear interpolation shall be used and values shall be rounded to the same number of digits as the values picked up from the tables. For determination of creepage distances, see Annex B.
- f Creepage distances cannot be less than the associated clearances.
- g To cover all different voltages including ELV in an auxiliary contact.
- h For material group IIIb ($100 \text{ V} \leq \text{CTI} < 175 \text{ V}$) the values for material group IIIa multiplied by 1,6 apply.
- i For working voltages up to and including 25 V, reference may be made to IEC 60664-1.

8.1.4 Screws, current-carrying parts and connections

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

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

NOTE 1 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.

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

NOTE 2 Screwed connections are considered as checked by the tests of 9.8, 9.12, 9.13, 9.14 and 9.23.

8.1.4.2 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.

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

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

Compliance is checked by inspection.

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

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

Examples of suitable materials are given below:

- copper;
- an alloy containing at least 58 % copper for parts worked cold, or at least 50 % copper for other parts;

- other metal or suitably coated metal, no less resistant to corrosion than copper and having mechanical properties no less suitable.

In case of using ferrous alloys or suitably coated ferrous alloys, compliance to resistance to corrosion is checked by a test of resistance to rusting (see 9.25).

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

8.1.5 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.

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

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

Compliance is checked by inspection, by the tests of 9.5 for screw-type terminals, by specific tests for plug-in or bolt-on RCBOs included in the standard, or by the tests of Annexes J, K or L, as relevant for the type of connection.

8.1.5.2 RCBOs shall be provided with:

- either terminals which shall allow the connection of copper conductors having nominal cross-sectional areas as shown in Table 8;

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

- or terminals for external untreated aluminium conductors and with aluminium screw-type terminals for use with copper or with aluminium conductors according to Annex L.

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

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

Rated current ^{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 ID.

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 mm² up to 6 mm² be designed to clamp solid conductors only.

c) Rigid stranded conductors shall be used for conductors having cross-sections from 1,5 mm² up to 50 mm² and shall be in compliance with class 2 of IEC 60228, related to stranded conductors for single-core.

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 and by the tests of 9.5.

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.

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

Compliance is checked by inspection and by the tests of 9.4 and 9.5.1.

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 9.5.2.

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 9.5.1.

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 9.5.3.

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 standard.

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

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

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

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 IC 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 of the tapping screw type.

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.

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

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

For 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 conditions of use, shall either be of insulating material, or be lined throughout with insulating material, unless the live parts are within an internal enclosure of insulating material.

Linings shall be fixed in such a way that they are not likely to be lost during installation of 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.

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.

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 and shall ensure isolation.

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

Compliance is checked by the tests of 9.7.

8.4 Temperature-rise

8.4.1 Temperature-rise limits

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

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

Table 9 – Temperature-rise values

Parts ^{a, b}	Temperature-rise K
Terminals for external connections ^c	65
External parts liable to be touched during manual operation of the 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
<p>^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.</p> <p>The test of reliability (see 9.22) is considered to be sufficient for checking indirectly the behaviour of the contacts with respect to undue temperature-rises in service.</p> <p>^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.</p> <p>^c For plug-in type RCBOs, the terminals of the base on which they are installed.</p>	

8.4.2 Ambient air temperature

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

8.5 Operating characteristics

The operating characteristic of RCBOs, under residual current or overcurrent conditions, shall comply with the requirements of 9.9, if applicable.

8.5.1 Under residual current conditions

The operating characteristic of RCBOs shall comply with the requirements of 9.9.1.

8.5.2 Under overcurrent conditions

RCBOs shall comply with the requirements of 8.5.2.1 and 8.5.2.3.

8.5.2.1 Standard time-(over)current zone

The tripping characteristic of RCBOs shall ensure adequate 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 10.

This table 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 (see the note in Table 10).

Compliance is checked by the tests specified in 9.9.2.

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

Under no circumstances shall the variation of the test current of Table 10 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.

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

Table 10 – 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.

8.5.2.2 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 no-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.

8.5.2.3 Overcurrent tripping characteristic

The overcurrent tripping characteristic of RCBOs shall be contained within the zone defined in 8.5.2.1.

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.) may affect the tripping characteristic of RCBOs.

The manufacturer shall be prepared to give information on the variation of the tripping characteristic for ambient temperatures differing from the reference value, within the limits of 7.1.

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

Ambient temperatures other than the reference 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 9.12.

8.8 Resistance to mechanical shock and impact

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

Compliance is checked by the test of 9.13.

8.9 Resistance to heat

RCBOs shall be sufficiently resistant to heat.

Compliance is checked by the test of 9.14.

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 checked by the other tests of this standard.

Compliance is checked by inspection and by the test of 9.15.

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 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 4.4) the lowest setting for which the RCBOs have been designed shall be used.

The test device shall comply with the test of 9.16.

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.

8.12 Requirements for RCBOs functionally dependent on line voltage

RCBOs functionally dependent on line voltage shall operate correctly at any value of the line voltage between 0,85 and 1,1 times their rated voltage, for which purpose multipole RCBOs shall have all their current paths supplied from the phases and neutral, if any.

Compliance is checked by the test of 9.17 under the supplementary test conditions specified in 9.9.1.2.

According to their classification, RCBOs shall comply with the requirements given in Table 11.

Table 11 – Requirements for RCBOs functionally dependent on line voltage

Classification of the device according to 4.1		Behaviour in case of failure of the line voltage
RCBOs opening automatically in case of failure of the line voltage (4.1.2.1)	Without delay	Opening without delay, according to the conditions stated in 9.17.2 a)
	With delay	Opening with delay, according to 9.17.2 b). Correct operation during the delay shall be verified according to 9.17.3
RCBOs which do not open automatically in case of failure of the line voltage (4.1.2.2)		No opening

8.13 Void

8.14 Behaviour of RCBOs in case of current surges caused by impulse voltages

RCBOs shall adequately withstand the current surges to earth due to the loading of the capacitance of the installation and the current surges to earth due to flashover in the installation. S type RCBOs shall additionally show adequate resistance against unwanted tripping in case of current surges to earth due to flashover in the installation.

Compliance is checked by the tests of 9.19.

8.15 Behaviour of RCBOs in case of earth fault currents comprising a d.c. component

RCBOs shall adequately perform in presence of earth fault currents comprising a d.c. component in accordance with their classification.

Compliance is checked by the tests of 9.9.3.

8.16 Reliability

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

Compliance is checked by the tests of 9.22 and 9.23.

8.17 Electromagnetic compatibility (EMC)

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

Compliance is checked by the tests of 9.24.

9 Tests

9.1 General

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

Type tests required by this standard are listed in Table 12.

Table 12 – List of type tests

Test	Subclause
– Indelibility of marking	9.3
– Reliability of screws, current-carrying parts and connections	9.4
– Reliability of terminals for external conductors	9.5
– Protection against electric shock	9.6
– Dielectric properties	9.7
– Temperature-rise	9.8
– Operating characteristic	9.9
– Mechanical and electrical endurance	9.10
– Trip-free mechanism	9.11
– Short-circuit ^a	9.12
– Resistance to mechanical shock and impact	9.13
– Resistance to heat	9.14
– Resistance to abnormal heat and to fire	9.15
– Operation of the test device at the limits of rated voltage	9.16
– Behaviour of RCBOs in case of failure of the line voltage for RCBOs classified according to 4.1.2.1.	9.17
– Resistance against unwanted tripping due to current surges	9.19
– Reliability	9.22
– Ageing of electronic components	9.23
– Electromagnetic compatibility (EMC)	9.24
– Resistance to rusting	9.25
^a This comprises several tests.	

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

NOTE The term "certification" denotes:

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

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

Unless otherwise specified, each type test (or sequence of type tests) is made on RCBOs in a clean and new condition, the influencing quantities having their normal reference values (see Table 6).

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

9.2 Test conditions

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

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, the RCBO is wired with the appropriate cable of cross-section *S* specified in Table 13 and is fixed on a dull black painted plywood board 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.

Table 13 – 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

NOTE 2 For AWG copper conductors, see Annex ID.

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

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

For the tests of 9.8, 9.9, 9.10, 9.22.2 and 9.23, 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 mm²,
 - 2 m for cross-sections larger than 10 mm².

The tightening torques to be applied to the terminal screws are two-thirds of those specified in Table 14.

For RCBOs with dependent manual operation, an operating speed of 0,1 m/s $\pm 25\%$ shall be used during actuation for the tests of 9.10 and 9.12. 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 9.12

9.3 Test of indelibility of marking

The test is made by rubbing the marking by hand for 15 s with a piece of cotton soaked with water and again for 15 s with a piece of cotton soaked with aliphatic solvent hexane (with a content of aromatics of maximum 0,1 % volume, a kauributanol value of 29, initial boiling point approximately 65 °C, dry point approximately 69 °C and specific gravity of 0,68 g/cm³).

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

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

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

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

Compliance with the requirements of 8.1.4 is checked by inspection and, for screws and nuts which are operated when mounting and 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 made by means of a suitable test screwdriver or spanner applying a torque as shown in Table 14.

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

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

Table 14 – Screw thread diameters and applied torques

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

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

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

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

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.

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

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 8 is placed in the terminal (for nominal cross-sections exceeding 6 mm², a rigid stranded conductor is used; for other nominal cross-sections, a solid conductor is used), and by the tests of 9.5.1, 9.5.2 and 9.5.3.

These last tests are made using a suitable test screwdriver or spanner, and applying the torque specified in Table 14.

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

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

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

- Tests for solid conductors shall use conductors having cross-sections from 1 mm² up to 6 mm², as applicable.
- Tests for stranded conductors shall use conductors having cross-sections from 1,5 mm² up to 50 mm², as applicable.
- Tests for flexible conductors shall use conductors having cross-sections from 1 mm² up to 35 mm², as applicable.

NOTE Information on AWG is given in Annex ID.

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

The clamping screws are then tightened with a torque equal to two-thirds of that shown in the appropriate column of Table 14.

Each conductor is then subjected to a pull of the value, in Newton, shown in Table 15, according to the relevant cross-section of the tested conductor.

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

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

Table 15 – Pulling forces

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

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

9.5.2 The terminals are fitted with copper conductors of the smallest and largest cross-sections specified in Table 8, solid or stranded, whichever is the more unfavourable, and the terminal screws are tightened with a torque equal to two-thirds of that shown in the appropriate column of Table 14.

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.

9.5.3 The terminals are fitted with the largest cross-section area specified in Table 8, 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 14.

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 made with the standard test finger shown in Figure 3 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 temperature of $35\text{ °C} \pm 2\text{ °C}$, 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 of the same dimensions as the standard test finger. This finger is applied to all places where yielding of insulating material could impair the safety of the RCBO, but is not applied to knock-outs.

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

Unenclosed 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 $\pm 1\text{ °C}$ 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 $T\text{ °C}$ and $T + 4\text{ °C}$.

9.7.1.3 Test procedure

The sample is kept in the cabinet for 48 h.

NOTE 1 A relative humidity between 91 % and 95 % may 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.

NOTE 2 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 standard 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 d.c. 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) between metal parts of the mechanism and the frame;
NOTE Access to the metal part of the mechanism may be specifically provided for this measurement.
- e) for 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 measurements a), b) and c) are carried out after having connected all auxiliary circuits to the frame.

The term "frame" includes:

- all accessible metal parts and a metal foil in contact with the surfaces of insulating material which are accessible after installation as for normal use;
- the surface on which the base of the 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 b), c), d) and e), the metal foil is applied in such a way that the sealing compound, if any, is effectively tested.

The insulation resistance shall not be less than:

- 2 M Ω for the measurements according to a) and b);
- 5 M Ω 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 wave-form, and a frequency between 45 Hz and 65 Hz.

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

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

The values of the test voltage shall be as follows:

- 2 000 V for a) to d) of 9.7.2;
- 2 500 V for e) of 9.7.2.

Initially, not more than half the prescribed voltage is applied, then it is raised to the full value within 5 s.

No flashover or breakdown shall occur during the test.

Glow discharges without drop in voltage are neglected.

9.7.4 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 b) and c) below.

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

- b) The measurements of the insulation resistance are carried out:

- between the auxiliary circuits connected to each other and to the frame;
- between each of the parts of the auxiliary circuits which might be isolated from the other parts in normal service and the whole of the other parts connected together, at a voltage of approximately 500 V d.c., after this voltage has been applied for 1 min.

The insulation resistance shall be not less than 2 M Ω .

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

The voltage values to be applied are specified in Table 17.

Table 17 – Test voltage of auxiliary circuits

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

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

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

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

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

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

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

9.7.5 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 withstanding high d.c. 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 d.c. voltage source is used with the following characteristics:

- open voltage: $600 \text{ V } \begin{matrix} +25 \\ 0 \end{matrix} \text{ V}$

NOTE This value is provisional.

- maximum ripple : 5 %

where

$$\text{ripple (\%)} = \frac{\text{max. value} - \text{mean value}}{\text{mean value}} \times 100$$

- short-circuit current: $12 \text{ mA } \begin{matrix} +2 \\ 0 \end{matrix} \text{ mA}$

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

After this treatment, the RCBO shall be capable of performing satisfactorily the tests specified in 9.9.1.2 c).

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

9.7.7.1 General testing procedure for the impulse withstand voltage tests

The impulses are given by a generator producing positive and negative impulses having a front time of $1,2 \mu\text{s}$, and a time to half-value of $50 \mu\text{s}$, 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 being at least 1 s for impulses of the same polarity and being at least 10 s for impulses of the opposite polarity.

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

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

NOTE 1 In 9.7.7.2, for the verification of clearances within the basic insulation, on complete RCBO, a very low impedance of the generator is needed for the test. For this purpose, a hybrid generator with a virtual impedance of 2 Ω is appropriate if internal components are not disconnected before testing. However, in any case, a measurement of the correct test voltage directly at the clearance is needed.

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. It is recommended to disconnect surge protective components before testing.

NOTE 2 For RCBOs with incorporated surge arresters that cannot be disconnected, the shape of the impulses is adjusted without connection of the RCBO to the impulse generator.

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

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

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

NOTE 3 It is recommended that an oscilloscope be used to observe the impulse voltage in order to detect disruptive discharge.

9.7.7.2 Verification of clearances with the impulse withstand voltage

If the measurement of clearances of items 2 and 4 in Table 7 and arrangements given in 9.7.2 b), c) d) and e) shows a reduction of the required length, this test applies. This test is carried out immediately after the measurement of the insulation resistance in 9.7.4.

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

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

The test impulse voltage values shall be chosen in Table 19 in accordance with the rated impulse voltage of the RCBO as given in Table 5. These values are corrected for barometric pressure and/or altitude at which the tests are carried out, according to Table 19.

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

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

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

- the phase pole(s), connected together,
- and the neutral pole (or path) of the RCBO, as applicable.

A third series of tests is made applying the impulse voltage between arrangements given in 9.7.2 b), c), d) and e) and not tested during the two first sequences described here above.

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

No further disruptive discharge shall occur.

Table 19 – Test voltage for verification of impulse withstand voltage

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

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

Each pole of a RCBO having been submitted to one of the applicable tests of 9.12.11.2.1, 9.12.11.2.2, 9.12.11.3, 9.12.11.4 b), 9.12.11.4 c) is supplied at a voltage 1,1 times its rated operational voltage, the RCBO being in the open position.

The leakage current flowing across the open contacts is measured and shall not exceed 2 mA.

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

9.7.7.4.1 General

These tests are not preceded by the humidity treatment described in 9.7.1.

NOTE The tests in 9.7.7.4, as stated in requirements of 8.1.3, will be carried out before 9.7.1 on three samples of Test sequence B.

The test impulse voltage values shall be chosen from Table 28, in accordance with the rated voltage of the installation for which the RCBO is intended to be used as given in Table 5. These values are corrected for barometric pressure and/or altitude at which the tests are carried out, according to Table 28.

Table 28 – Test voltage for verifying the suitability for isolation, referred 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				
	$U_{1,2/50}$ a.c. 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.

9.7.7.4.2 RCBO in opened position

The series of tests is carried out on a RCBO fixed on a metal support as in normal use.

The impulses are applied between:

- the line terminals connected together;

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

There shall be no disruptive discharges during the test.

9.7.7.4.3 RCBO in closed position

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

All components bridging the basic insulation have to be disconnected.

NOTE If necessary, separate samples can be prepared by the manufacturer.

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

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

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

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

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

No further disruptive discharge shall occur.

Afterwards, a new sample is tested according to 9.7.7.5.

9.7.7.5 Verification of the behaviour of components bridging the basic insulation

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

NOTE 1 Afterwards it is necessary to ensure that components, bridging the basic insulation and having been disconnected during the impulse voltage test for testing the basic insulation, would not impair the behaviour or the safety of the basic insulation of the equipment during normal use.

The test voltage has a frequency of 50/60 Hz. In accordance with IEC 60364-4-44:2007, Table 44.A2, and to IEC 60664-1, the r.m.s. value of the test voltage for the basic insulation is $1\,200\text{ V} + U_0$, U_0 being the nominal voltage value between line and neutral.

NOTE 2 This test is performed only on RCBOs, where components bridging the basic insulation have been disconnected during the impulse voltage test of 9.7.7.4.3.

NOTE 3 As an example, for an RCBO having a rated voltage of $U_0 = 250\text{ V}$, the value of the a.c. test voltage for basic insulation is $1\,200\text{ V} + 250\text{ V}$, thus the r.m.s. test voltage is $1\,450\text{ V}$.

The voltage is applied during 5 s between:

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

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

NOTE 4 It is accepted to replace a fuse before connecting the equipment to the mains. If a fuse protecting a surge arrester has blown, it is accepted to replace the surge arrester too.

Then, the equipment is connected to the mains in accordance with the manufacturer's instruction. Under the condition of 9.9.1.2 c) the RCBO shall trip with a test current of $1,25 I_{\Delta n}$. One test only is made on one pole, taken at random, without measurement of break time.

This test is not applied to devices with solid neutral.

9.8 Test of temperature-rise

9.8.1 Ambient air temperature

The ambient air temperature shall be measured during the last quarter of the test period by means of at least two thermometers or thermocouples symmetrically distributed around the 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.

NOTE 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 made 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.

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

9.8.3 Measurement of the temperature of parts

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

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

9.8.4 Temperature-rise of a part

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

9.9 Verification of the operating characteristic

9.9.1 Verification of the operating characteristics under residual current conditions

9.9.1.1 Test circuit and test procedure

The RCBO is installed as for normal use.

The test circuit shall be of negligible inductance. For tests according to 9.9.1.2, the test circuit shall correspond to Figure 4. For tests according to 9.9.1.3, the test circuit shall correspond to Figure 5 or Figure 6, as applicable.

The instruments for the measurement of the residual current shall display (or allow to determine) the true r.m.s. value.

NOTE The information for instrument measurement is available at the following CTL webserver:

http://www.iecee.org/ctl/sheet/pdf/CTL%20DSH%20251B%20Beijing%202009_05_15.pdf

Unless otherwise specified, the tests are performed with no load at the reference temperature of $20\text{ °C} \pm 5\text{ °C}$.

The RCBO shall perform the tests of 9.9.1.2, 9.9.1.3 and 9.9.1.4, as applicable. Each test is made on one pole only, taken at random, with five measurements, unless otherwise specified.

For RCBOs having more than one rated frequency, the tests shall be carried out at the lowest and highest frequency, except for test in 9.9.1.2 e), where verification is performed at only one frequency.

For RCBOs having multiple settings of residual operating current, the tests shall be made for each setting.

9.9.1.2 Tests for all RCBOs

The test conditions according to 9.9.1.1 apply to all RCBOs.

a) Verification of correct operation in case of a steady increase of the residual current

The test switches S_1 and S_2 and the RCBO being in the closed position, the residual current is steadily increased, starting from a value not higher than $0,2 I_{\Delta n}$, trying to attain the value of $I_{\Delta n}$ within 30 s, the tripping current being measured each time.

All five measured values shall be situated between $I_{\Delta n0}$ and $I_{\Delta n}$.

b) Verification of correct operation on closing on a residual current

The test circuit being calibrated at the value of the rated residual operating current $I_{\Delta n}$ and the test switches S_1 and S_2 being closed, the RCBO is closed so as to simulate service conditions as closely as possible. The break time is measured five times. No measurement shall exceed the limiting value specified for $I_{\Delta n}$ in Table 2, according to the type of RCBO.

c) Verification of correct operation in case of sudden appearance of residual current

1) All types

The test circuit being successively calibrated at each of the values of residual current specified in Table 2, the test switch S_2 and the RCBO being in the closed position, the test voltage is suddenly established by closing the test switch S_1 .

The RCBO shall trip during each test.

Five measurements of the break time are made at each value of residual current.

No value shall exceed the relevant specified limiting value given in Table 2.

2) Additional test for type S

The test circuit being successively calibrated at each of the values of residual current specified in Table 2, the test switch S_1 and the RCBO being in the closed position, the residual current is suddenly established by closing the test switch S_2 for periods corresponding to the relevant minimum non-actuating times, with a tolerance of $\pm 5\%$.

Each application of residual current shall be separated from the previous one by an interval of at least 1 min.

The RCBO shall not trip during any of the tests.

d) Verification of correct operation in case of sudden appearance of residual currents between $5 I_{\Delta n}$ and 500 A

The test circuit is calibrated at any two values of the residual current chosen at random within the range 5 A to 200 A, among the following list 5 A, 10 A, 20 A, 50 A, 100 A, 200 A.

NOTE In Australia the measurement of the break time is made at 5 A, 10 A, 20 A, 50 A, 100 A, 200 A.

The test switch S_1 and the RCBO being in the closed position, the residual current is suddenly established by closing the test switch S_2 .

The RCBO shall trip during each test. The break time shall not exceed the times given in Table 2.

The test is made once for each value of residual current on one pole only, taken at random.

e) Verification of correct operation with load

The tests of 9.9.1.2 b) and 9.9.1.2 c) are repeated, the pole under test and one other pole of the RCCB being loaded with rated current, this current being established shortly before the test.

For the test of 9.9.1.2 c), the switch S_1 and the RCBO are in closed position. The residual current is established by closing S_2 .

f) Tests at the temperature limits

The RCBO shall perform the tests specified in 9.9.1.2 c) under the following conditions, successively:

- 1) ambient temperature: $-5\text{ }^\circ\text{C}$, off-load;
- 2) ambient temperature: $+40\text{ }^\circ\text{C}$, the RCBO having been previously loaded with the rated current, at any convenient voltage, until it attains thermal steady-state conditions.

In practice these conditions are reached when the variation of temperature-rise does not exceed 1 K per hour.

For the tripping tests in 2), the flow of rated current may be interrupted, provided that the total interruption period does not exceed 30 s. As soon as the sum of interruption periods exceed 30 s, the RCBO shall be loaded again with rated current for 5 min before next tripping time measurement.

NOTE Preheating may be carried out at any convenient voltage at either 50 Hz or 60 Hz but auxiliary circuits shall be connected to their normal operating voltage (particularly for components depending on line voltage).

9.9.1.3 Verification of correct operation at residual currents with d.c. components

This subclause applies to type A RCBOs, under test conditions of 9.9.1.1.

a) Verification of correct operation in case of a continuous rise of residual pulsating direct current

The test shall be performed according to Figure 5.

The auxiliary switches S_1 and S_2 and the RCBO shall be closed. The relevant thyristor shall be controlled in such a manner that current delay angles α of 0° , 90° and 135° are

obtained. Each pole of the RCBO shall be tested twice at each of the current delay angles, in position I as well as in position II of the auxiliary switch S_3 .

For each test, the current shall be steadily increased at an approximate rate of $1,4 I_{\Delta n} / 30$ amperes per second for RCBOs with $I_{\Delta n} > 0,01$ A, and at an approximate rate of $2 I_{\Delta n} / 30$ amperes per second for RCBOs with $I_{\Delta n} \leq 0,01$ A, starting from zero. The tripping current shall be in accordance with Table 26.

- b) Verification of correct operation in case of suddenly appearing residual pulsating direct currents

The RCBO shall be tested according to Figure 5.

The circuit being successively calibrated at the values specified hereafter and the auxiliary switch S_1 and the RCBO being in the closed position, the residual current is suddenly established by closing the switch S_2 .

The test is carried out at each value of residual current specified in Table 3, according to the type of RCBO.

Two measurements of the break time are made at each value of residual current, at a current delay angle $\alpha = 0^\circ$ with the auxiliary switch S_3 in position I for the first measurement and in position II for the second measurement.

No value shall exceed the specified limiting values.

- c) Verification of correct operation with load

The tests of 9.9.1.3 a) are repeated, the pole under test and one other pole of the RCBO being loaded with the rated current, this current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure 5.

- d) Verification of correct operation in case of residual pulsating direct currents superimposed by a smooth direct current of 0,006 A

The RCBO shall be tested according to Figure 6 with a half-wave rectified residual current (current delay angle $\alpha = 0^\circ$) superimposed by a smooth direct current of 0,006 A.

Each pole of the RCBO is tested in turn, twice at each of positions I and II.

The half-wave current I_1 , starting from zero, being steadily increased at an approximate rate of $1,4 I_{\Delta n} / 30$ amperes per second for RCBOs with $I_{\Delta n} > 0,01$ A and $2 I_{\Delta n} / 30$ amperes per second for RCBOs with $I_{\Delta n} \leq 0,01$ A, the device shall trip before this half-wave current I_1 reaches a value not exceeding $1,4 I_{\Delta n}$ or $2 I_{\Delta n}$ respectively.

Table 26 – Tripping current ranges for type A RCBOs

Angle, α °	Tripping current A	
	Lower limit $I_{\Delta n}$	Upper limit $I_{\Delta n}$
0	0,35	} 1,4 or 2 (5.3.8)
90	0,25	
135	0,11	

9.9.1.4 Particular test conditions for RCBOs functionally dependent on line voltage

For RCBOs functionally dependent on line voltage, each test is made at each of the following values of the line voltage, applied to the relevant terminals: 1,1 and 0,85 times the rated line voltage.

9.9.2 Verification of the operating characteristic under overcurrent conditions

This test is made to verify that the RCBO complies with the requirements of 8.5.2.

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 (see 8.5.2.1 and 8.5.2.2 a)) through all poles, starting from cold (see Table 10).

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

- a) General test conditions

For the lower values of the test current of 9.9.2.2 b), 9.9.2.2 c) and 9.9.2.2 d) respectively the test is made once, 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 10.
- At rated voltage U_0 (phase to neutral) 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

the interval, t, being as defined in 9.12.11.1. The tripping time of the O operation is measured. After each operation the indicating means shall show the open position of the contacts.

- b) For B type RCBOs

A current equal to $3 I_n$ is passed through all poles, starting from cold.

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

A current equal to $5 I_n$ is then passed through all poles, again starting from cold.

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

- c) For C type RCBOs

A current equal to $5 I_n$ is passed through all poles, starting from cold.

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

A current equal to $10 I_n$ is then passed through all poles, again starting from cold.

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

- d) For D type RCBOs

A current equal to $10 I_n$ is passed through all poles, 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 Clause 6, item t) is then passed through all poles, 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 temperature on the tripping characteristic

Compliance is checked by the following tests.

- a) The RCBO is placed in an ambient temperature of (35 ± 2) K 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 temperature of (10 ± 2) K 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.

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 made 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 appreciably 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 13.

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 effected 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 $I_{\Delta n} \leq 0,010$ 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 $I_n \leq 25$ 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 $I_n \leq 25$ 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.

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

9.10.3 Condition of the RCBO after test

Following the test of 9.10.2 the RCBO shall not show

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

Under the test condition of 9.9.1.2 c) 1) the RCBO shall trip with a test current of $1,25 I_{\Delta n}$. One test only is made without measurement of 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 Verification of the trip-free mechanism

9.11.1 General test conditions

The RCBO is mounted and wired as in normal use.

It is tested in a substantially non-inductive circuit, the diagram of which is shown in Figure 4.

9.11.2 Test procedure

A residual current equal to $1,5 I_{\Delta n}$ is passed by closing the switch S_2 , the RCBO having been closed and the operating means being held in the closed position: the RCBO shall trip.

This test is then repeated by moving the operating means of the RCBO slowly over a period of approximately 1 s to a position where the current starts to flow. Tripping shall occur without further movement of the operating means.

Both tests are carried out three times, at least once on each pole intended to be connected to a phase.

NOTE 1 If the RCBO is fitted with more than one operating means, the trip-free operation is verified for all operating means.

NOTE 2 For RCBOs having multiple settings of residual operating current, the tests are made at each setting.

9.12 Short-circuit tests

9.12.1 General conditions for test

The conditions of 9.12.1 to 9.12.12 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 9.12.13.

NOTE For RCBOs having multiple settings of residual operating current, the tests are made 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 20.

All RCBOs are tested:

- at 500 A or $10 I_n$, whichever is the higher, according to 9.12.11.2 and 9.12.12.1;
- at 1 500 A, according to 9.12.11.3 and 9.12.12.1;
- at rated residual making and breaking capacity (see 5.2.7) according to 9.12.13.1 and 9.12.13.2.

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

- at service short-circuit breaking capacity (see 3.4.6.2) according to 9.12.11.4 b) and 9.12.12.1; 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 22;
- at rated short-circuit capacity (see 5.2.6) according to 9.12.11.4 c) and to 9.12.12.2, if the factor k is less than 1, in which case new samples shall be used.

Table 20 – List of short-circuit tests

Test type	RCBOs to be tested	Verification according to subclause
Test at reduced short-circuit currents (9.12.11.2)	All RCBOs	9.12.12.1
Test at 1 500 A (9.12.11.3)		
Test at rated residual making and breaking capacity (9.12.13.1)		9.12.13.2
Test at service short-circuit capacity (9.12.11.4 b))	RCBOs having $I_{cn} > 1\,500\text{ A}$	9.12.12.1
Test at rated short-circuit capacity (9.12.11.4 c))		9.12.12.2

9.12.2 Test circuit for short-circuit performance

Figures 7, 8 and 9 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 shall preferably be air-cored, they 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 9). 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 for testing the rated short-circuit capacity, the impedances Z are inserted between the supply source S and the circuit-breaker under test.

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

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 having a length of 0,75 m per pole and the maximum cross-section corresponding to the rated current according to Table 8.

NOTE It is recommended that 0,5 m be connected on the supply side and 0,25 m 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 9.12.13.

A resistor R_2 of about 0,5 Ω is connected in series with a copper wire, F , as shown in Figures 7 and 8.

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.

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.

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

RCBOs functionally dependent on line voltage are supplied on the line side with the rated voltage or, if relevant, with a voltage having the lower value of its range of rated voltages.

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

9.12.3 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 standard.

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 voltage of the RCBO under test.

NOTE The value of 105 % (± 5 %) of the rated 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.

9.12.4 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: $\begin{matrix} +5 \\ 0 \end{matrix}$ %
- Frequency: ± 5 %
- Power factor: $\begin{matrix} 0 \\ -0,05 \end{matrix}$
- Voltage: (including recovery voltage): ± 5 %

9.12.5 Power factor of the test circuit

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

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

The power factor ranges are given in Table 21.

Table 21 – Power factor ranges of the test circuit

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

9.12.6 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 9.12.11.2, 9.12.11.3 and 9.12.11.4.

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

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.

9.12.7 Calibration of the test circuit

9.12.7.1 To calibrate the test circuit, links G_1 and G_2 having negligible impedance compared with that of the test circuit are connected in the positions shown in Figures 7 and 8.

9.12.7.2 To obtain a prospective current equal to the rated short-circuit capacity of the RCBO at the corresponding power factor as stated in Table 21, impedances Z are inserted on the supply side of the links G_1 .

9.12.7.3 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 Figures 7 and 8.

9.12.7.4 To obtain a prospective current equal to the rated residual making and breaking capacity, at the corresponding power factor as Table 21, an impedance Z_2 is inserted as shown in Figure 7.

9.12.8 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 13.

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 a.c. component of the prospective current is taken as being equal to the r.m.s. value of the a.c. component of the calibration current (value corresponding to A_2 of Figure 13).

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

9.12.9 Condition of the RCBO for test

RCBOS shall be tested in free air according to 9.12.9.1, 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 9.12.9.2 or, with the agreement of the manufacturer, according to 9.12.9.1.

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.

9.12.9.1 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.

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

NOTE 1 If the position of the vents is not obvious, or if there are no vents, appropriate information should be provided by the manufacturer.

The grid circuit(s) (see Figure C.3) shall be connected to the points B and C as shown in the test circuit diagrams of Figures 7 and 8.

The resistor R' shall have a resistance of 1,5 Ω . The copper wire F' (see Figure C.3) shall have a length of 50 mm and a diameter of 0,12 mm for RCBOs having a rated voltage of 230 V and 0,16 mm for RCBOs having a rated voltage of 400 V.

NOTE 2 Data for other voltages are under consideration.

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

For higher short-circuit currents up to I_{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 – 45 – 50 – 55 – ... mm and stated by the manufacturer.

9.12.9.2 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.

NOTE 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 could be installed there. These RCBOs (or other devices) should be supplied as in normal use, but via F' and R' as defined in 9.12.9.1 and connected as shown in the appropriate Figures 7 and 8.

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.

9.12.10 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, of the fuse F'.

9.12.11 Test procedure

9.12.11.1 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 may 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 not less than 0,1 s.

Three samples shall be tested for each of the tests of 9.12.11.2, 9.12.11.3 and 9.12.11.4.

9.12.11.2 Test at reduced short-circuit currents

9.12.11.2.1 Tests on all RCBOs

The additional impedances Z_1 (see 9.12.7.3) 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 Figure 7, 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 – 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 $\pm 5^\circ$.

9.12.11.2.2 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 9.12.7.3) 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 4, 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 5.3.7, 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_0 for the pole marked N, if any.

For RCBOs having an instantaneous tripping value exceeding $20 I_n$, the impedances are adjusted 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 8.

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 (see Clause C.2) this point is shifted each time by 30° with respect to the point on wave of the previous test, with a tolerance of $\pm 5^\circ$.

RCBOs with uninterrupted neutral are not subjected to this test.

NOTE According to IEC 60364-4-43, devices with uninterrupted neutral cannot obviously be tested according to this clause.

9.12.11.3 Test at 1 500 A

For RCBOs having rated short-circuit capacity of 1 500 A, the test circuit is calibrated according to 9.12.7.1 and 9.12.7.2 to obtain a current of 1 500 A at a power factor corresponding to this current according to Table 21.

For RCBOs having a rated short-circuit capacity exceeding 1 500 A, the test circuit is calibrated according to 9.12.7.1 and 9.12.7.3 at a power factor corresponding to 1 500 A, according to Table 21.

The RCBOs are tested in a circuit according Figure 7.

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 $\pm 5^\circ$.

The sequence of operations shall be as specified in 9.12.11.2.1.

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

9.12.11.4 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 22.

Table 22 – Ratio between service short-circuit capacity (I_{cs}) and rated short-circuit capacity (I_{cn}) – (factor k)

I_{cn}	k
$\leq 6\ 000\ \text{A}$	1
$> 6\ 000\ \text{A}$ $\leq 10\ 000\ \text{A}$	0,75 ^a
$> 10\ 000\ \text{A}$	0,5 ^b
^a Minimum value of I_{cs} : 6 000 A.	
^b Minimum value of I_{cs} : 7 500 A.	

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

1) The test circuit is calibrated according to 9.12.7.1 and 9.12.7.3, with a power factor in accordance with Table 21.

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 $\pm 5^\circ$.

This test procedure is shown in Table 23.

Table 23 – 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

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 $\pm 5^\circ$. The same pole shall be used as reference for the purpose of synchronization for the different samples.

This test procedure is shown in Table 24.

Table 24 – Test procedure for I_{cs} in the case of three- and four-pole RCBOs

Operation	Sample		
	1	2	3
1	O (x°)	O ($x^\circ + 60^\circ$)	O ($x^\circ + 120^\circ$)
2	CO	CO	CO
3	CO	CO	CO

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

The test circuit is calibrated according to 9.12.7.1 and 9.12.7.2.

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 $\pm 5^\circ$.

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 25.

Table 25 – Test procedure for I_{cn}

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

9.12.12 Verification of the RCBO after short-circuit test

9.12.12.1 After each of the tests according to 9.12.11.2 or 9.12.11.3 or 9.12.11.4 b), the RCBOs shall show no damage impairing their further use and shall be capable, without maintenance, withstanding the following tests:

- a) leakage current across open contacts, according to 9.7.7.3;
- 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 prescribed 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 9.12.11.3 or 9.12.11.4 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.

9.12.12.2 After the tests according to 9.12.11.4.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, according to 9.7.7.3.
- 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 10 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.

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

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.

9.12.13.1 Test procedure

The RCBO shall be tested according to the general test conditions prescribed in 9.12.1, but connected in such a manner that the short-circuit current is a residual current.

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.

In the case of RCBOs according to 4.1.2.1, in order to permit the breaking operations to be made, it is necessary either to position the making switch T making the short-circuit on the load side of the RCBO or to insert an additional short-circuit making device in that position.

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 $45^\circ \pm 5^\circ$.

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

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

After the test carried out in accordance with 9.12.13.1, 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, but at a voltage equal to twice its rated voltage, for 1 min, without previous humidity treatment, and
- making and breaking its rated current at its rated voltage.

Under the condition of 9.9.1.2 c) the RCBO shall trip with a test current of $1,25 I_{\Delta n}$. One test only is made on one pole, taken at random, without measurement of break time.

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

In addition RCBOs functionally dependent on line voltage shall be capable to satisfy the test of 9.17, if applicable.

9.13 Verification of resistance to mechanical shock and impact

9.13.1 Mechanical shock

9.13.1.1 Test device

The RCBO is subjected to mechanical shocks using an apparatus as shown in Figure 14. A wooden base A is fixed to a concrete block and a wooden platform B is hinged to A. This platform carries a wooden board C, which can be fixed at various distances from the hinge and in two vertical positions. The end of B bears a metal stop-plate D which rests on a coiled spring having a flexion constant of 25 N/mm.

The 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 the figure.

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, in order to ensure that the moment of inertia of the complete system is substantially constant.

9.13.1.2 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.

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.

9.13.2 Mechanical impact

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 9.13.2.1, for all types of RCBO and, in addition, by the tests of

- 9.13.2.2 for RCBOs intended to be mounted on a rail;
- 9.13.2.3 for plug-in type RCBOs.

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

9.13.2.1 The samples are subjected to blows by means of an impact-test apparatus as shown in Figures 15 to 17.

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 $150 \text{ g} \pm 1 \text{ g}$ 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 $1\,000 \text{ mm} \pm 1 \text{ mm}$ 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: $12,7 \text{ mm} \pm 0,0025 \text{ mm}$;
- initial load: $100 \text{ N} \pm 2 \text{ N}$;
- overload: $500 \text{ N} \pm 2,5 \text{ N}$.

NOTE 1 Additional information concerning the determination of the Rockwell hardness of plastics is given in ASTM specification D 785-65 (1970).

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 17.

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 18, which is fixed to the mounting support.

Panel mounting-type RCBOs are mounted in a test device, as shown in Figure 19, 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 18 or 19, as applicable.

RCBOs for rail mounting are mounted on their appropriate rail which is rigidly fixed to the mounting support, as shown in Figure 20.

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 14.

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 should be 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.

If cable entries or knock-outs are provided, the sample is so mounted that the two lines of blows are as nearly as possible equidistant from these entries.

The two blows on the operating means shall be applied: one when the operating means is in the ON position and the other when the operating means is in the OFF position.

After the test, the samples shall show no damage within the meaning of this standard. In particular, covers which, when broken, make live parts accessible or impair the further use of the RCBO, operating means, linings or barriers of insulating material and the like, shall not show such a damage.

In case of doubt, it is verified that removal and replacement of external parts, such as enclosures and covers, is possible without these parts or their lining being damaged.

NOTE 3 Damage to the appearance, small dents which do not reduce the creepage distances or clearances below the values specified in 8.1.3 as well as small chips which do not adversely affect the protection against electric shock are neglected.

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

9.13.2.2 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 20).

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

9.13.2.3 Plug-in type RCBOs

NOTE Additional tests are under consideration.

9.14 Test of resistance to heat

9.14.1 The samples, without removable covers, if any, are kept for 1 h in a heating cabinet at a temperature of 100 °C ± 2 °C; removable covers, if any, are kept for 1 h in the heating cabinet at a temperature of 70 °C ± 2 °C.

During the test the samples shall not undergo any change impairing their further use, and sealing compound, if any, shall not flow to such an extent that live parts are exposed.

After the test and after the samples have been allowed to cool down to approximately room temperature, there shall be no access to live parts which are normally 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 test condition of 9.9.1.2 c) 1), the RCBO shall trip with a test current of $1,25 I_{\Delta n}$. Only one test is made, on one pole taken at random, without measurement of 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 standard.

9.14.2 External parts of RCBOs made of insulating material necessary to retain in position current-carrying parts, or parts, of the protective circuit, are subjected to a ball pressure test by means of the apparatus shown in Figure 21. Insulating parts necessary to retain in position terminals for protective conductors in a box, shall be tested as specified in 9.14.3.

The part to be tested is placed on a steel support with the appropriate surface in the horizontal position. A steel ball of 5 mm diameter is pressed against this surface with a force of 20 N.

The test is made in a heating cabinet at a temperature of $125\text{ °C} \pm 2\text{ °C}$.

After 1 h, the ball is removed from the sample which is then cooled down within 10 s to approximately room temperature by immersion in cold water.

The diameter of the impression caused by the ball is measured and shall not exceed 2 mm.

9.14.3 External parts of RCBOs made of insulating material not necessary to retain in position current-carrying parts and parts of the protective circuit, even though they are in contact with them, are subjected to a ball pressure test in accordance with 9.14.2, but the test is made at a temperature of $70\text{ °C} \pm 2\text{ °C}$ or at a temperature of $40\text{ °C} \pm 2\text{ °C}$ plus the highest temperature rise determined for the relevant part during the test of 9.8, whichever is the higher.

NOTE For the purpose of the tests of 9.14.2 and 9.14.3, bases of surface-type RCBOs are considered as external parts.

The tests of 9.14.2 and 9.14.3 are not made on parts of ceramic material.

If two or more of the insulating parts referred to in 9.14.2 and 9.14.3 are made of the same material, the test is carried out only on one of these parts, according to 9.14.2 or 9.14.3 as applicable.

9.15 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 of the protective circuit, by the test made at a temperature of $960\text{ °C} \pm 15\text{ °C}$;
- for all other external parts made of insulating material, by the test made at a temperature of $650\text{ °C} \pm 10\text{ °C}$.

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

If insulating parts within the above groups are made of the same material, the test is carried out only on one of these parts, according to the appropriate glow-wire test temperature.

The test is not made on parts of ceramic material.

The glow-wire test is applied to ensure that an electrically heated test wire under defined test conditions does not cause ignition of insulating parts or to ensure that a part of 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 made 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 terminals area or arc chamber or magnetic tripping device area, where the glow-wire cannot protrude far through the outer surface before touching either relatively big metal parts or even ceramics, which will cool down the glow-wire quickly and in addition limit the amount of insulating material ever getting in touch with the glow-wire. In this situation the parts ensure minimum severity of the test by cooling down the glow-wire and limiting access to the insulating material under test.

The sample shall be positioned during the test in the most unfavourable position of its intended use (with the surface tested in a vertical position).

If an internal part of insulation material influences the test with a negative result, it is allowed to remove the relevant identified internal part(s) of insulation material from a new sample. Then, the glow wire test shall be repeated at the same place on this new sample.

In accordance with the manufacturer, it is acceptable as an alternative method to remove the part under examination in its entirety and test it separately (see IEC 60695-2-11:2000, Clause 4).

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

- 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.

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

- a) The RCBO being supplied with a voltage equal to 0,85 times the rated 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 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 ampere-turns due to the actuation of the test device are less than 2,5 times the ampere-turns produced by a residual current equal to $I_{\Delta n}$ at the rated 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 verification, 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 covered by the tests of 9.10.

9.17 Verification of the behaviour of RCBOs functionally dependent on line voltage, classified under 4.1.2.1, in case of failure of the line voltage

NOTE Verification of the value of U_V (see 3.4.21.2) is not considered in this standard.

9.17.1 Determination of the limiting value of the line voltage (U_x)

A voltage equal to the rated voltage is applied to the line terminals of the RCBO and is then progressively lowered so as to attain zero within a period of about 30 s or within a period long enough with respect to the opening with delay, if any (see 8.12), whichever is the longer, until automatic opening occurs.

The corresponding voltage is measured.

Five measurements are made.

All the values measured shall be less than 0,85 times the rated voltage (or, if relevant, 0,85 times the minimum value of the range of rated voltages).

At the end of these measurements, it shall be verified that the RCBO operates in accordance with Table 2 when a residual current equal to $I_{\Delta n}$ is applied in the case of a drop in line voltage, under the conditions specified in this subclause, until automatic opening occurs, the applied voltage being just above the highest value measured.

Then it shall be checked that for any value of the line voltage less than the lowest value measured, it shall not be possible to close the apparatus by the manual operating means.

9.17.2 Verification of the automatic opening in case of failure of the line voltage

The RCBO is supplied on the line side with the rated voltage (or, if relevant, with a voltage having a value within its range of rated voltages) and is closed.

The line voltage is then switched off.

The time interval between the switching off and the opening of the main contacts is measured.

Five measurements are made:

- a) for RCBOs opening without delay: no value shall exceed 0,5 s;
- b) for RCBOs opening with delay: the maximum and the minimum values shall be situated within the range indicated by the manufacturer.

9.17.3 Verification of the correct operation, in presence of a residual current, for RCBOs opening with delay in case of failure of the line voltage

The RCBO is connected according to Figure 4 and is supplied on the line side with the rated voltage (or, if relevant, with any voltage having a value within its range of rated voltages).

All phases but one are then switched off by means of the switch S_3 .

During the delay (see Table 11) indicated by the manufacturer, the RCBO is submitted to the tests of 9.9.1.2, the closing and subsequent opening of switch S_3 being required before each measurement.

NOTE The test of 9.9.1.2 a) is only made if the delay is greater than 30 s.

9.17.4 Verification of correct operation of RCBOs with three or four current paths, in presence of a residual current, the neutral and one line terminal only being energized

In the case of RCBOs with three or four current paths (see 4.3) a test is made in accordance with 9.9.1.2 c), but with the neutral and one line terminal only being energized, connections being made in accordance with Figure 4.

The test is repeated with each of the other lines in turn.

9.17.5 Verification of the reclosing function of automatically reclosing RCBOs

Under consideration.

9.18 Void

9.19 Verification of behaviour of RCBOs in case 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 26. An example of a circuit diagram for the connection of the RCBO is shown in Figure 27.

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: $200 \text{ A } \begin{matrix} +10 \\ 0 \end{matrix} \%$
or $25 \text{ A } \begin{matrix} +10 \\ 0 \end{matrix} \%$ for RCBOs with $I_{\Delta n} \leq 10 \text{ mA}$
- virtual front time: $0,5 \text{ } \mu\text{s} \pm 30 \%$
- period of the following oscillatory wave: $10 \text{ } \mu\text{s} \pm 20 \%$
- each successive reverse peak: about 60 % of the preceding peak

During the tests, the RCBO shall not trip. After the ring wave test, the correct operation of the RCBO is verified by a test according to 9.9.1.2 c) at $I_{\Delta n}$ only with the measurement of the tripping time.

NOTE Test procedures and relevant test circuits for RCBOs with integral or incorporated overvoltage protection are under consideration.

9.19.2 Verification of 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 (IEC 60060-2) as shown in Figure 28. An example of a test circuit for the connection of the RCBO is shown in Figure 29.

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: $3\,000\text{ A} \begin{smallmatrix} +10 \\ 0 \end{smallmatrix} \%$
- virtual front time: $8\ \mu\text{s} \pm 20\ \%$
- virtual time to half value: $20\ \mu\text{s} \pm 20\ \%$
- 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 surge current tests, the correct operation of the RCBO is verified by a test according to 9.9.1.2 c), at $I_{\Delta n}$ only, with the measurement of the break time.

9.19.2.3 Test results for RCBOs of the general type

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

After the surge current tests, the correct operation of the RCBO is verified by a test according to 9.9.1.2 c), at $I_{\Delta n}$ only, with the measurement of the break time.

9.20 Void

9.21 Void

9.22 Verification of reliability

Compliance is checked by the tests of 9.22.1 and 9.22.2.

For RCBOs having multiple settings the tests shall be made at the lowest setting.

9.22.1 Climatic test

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

9.22.1.1 Testing chamber

The chamber shall be constructed as stated in Clause 4 of IEC 60068-2-30:2005. Condensed water shall be continuously drained from the chamber and not used again until it has been 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 $500\ \Omega\text{m}$ and a pH value of $7,0 \pm 0,2$. During and after the test, the resistivity should be not less than $100\ \Omega\text{m}$ and the pH value should remain within $7,0 \pm 1,0$.

9.22.1.2 Severity

The cycles are effected under the following conditions:

- upper temperature: $55\text{ °C} \pm 2\text{ °C}$;
- number of cycles : 28.

9.22.1.3 Test procedure

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

a) Initial verification

An initial verification is made by submitting the RCBO to the test according to 9.9.1.2 c), but only at $I_{\Delta n}$.

b) Conditioning

- 1) The RCBO mounted and wired as for normal use is introduced into the chamber.

It shall be in the closed position.

- 2) Stabilizing period (see Figure 23)

The temperature of the RCBO shall be stabilized at $25\text{ °C} \pm 3\text{ °C}$:

- 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 $25\text{ °C} \pm 3\text{ °C}$ 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 prescribed for standard atmospheric conditions for testing (see Table 6).

During the final hour, with the RCBO in the test chamber, the relative humidity shall be increased to not less than 95 % at an ambient temperature of $25\text{ °C} \pm 3\text{ °C}$.

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

- i) The temperature of the chamber shall be progressively raised to the appropriate upper temperature prescribed in 9.22.1.2.

The upper temperature shall be achieved in a period of $3\text{ h} \pm 30\text{ min}$ and at a rate within the limits defined by the shaded area in Figure 24.

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

NOTE The condition that condensation should occur implies that the surface temperature of the RCBO is below the dew point of the atmosphere. This means that the relative humidity has to be higher than 95 % if the thermal time-constant is low. Care should be taken so that no drops of condensed water can fall on the sample.

- ii) The temperature shall then be maintained at a substantially constant value within the prescribed limits of $\pm 2\text{ °C}$, for the upper temperature, for 12 h with a tolerance of $\pm 30\text{ min}$ from the beginning of the cycle.

During this period, the relative humidity shall be $93\% \pm 3\%$ 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 $25\text{ °C} \pm 3\text{ °C}$ 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 24, it would result in a temperature of $25\text{ °C} \pm 3\text{ °C}$ being attained in $3\text{ h} \pm 15\text{ min}$.

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 $25\text{ °C} \pm 3\text{ °C}$ with a relative humidity not less than 95 % until the 24 h cycle is completed.

9.22.1.4 Recovery

At the end of the cycles the RCBO shall not be removed from the test chamber.

The door of the test chamber shall be opened and the temperature 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 before making the final measurement.

During the 28 cycles the RCBO shall not trip.

9.22.1.5 Final verification

Under the test conditions specified in 9.9.1.2 c) 1), the RCBO shall trip with a test current of $1,25 I_{\Delta n}$. One test only is made on one pole taken at random, without measurement of break time.

9.22.2 Test with temperature of 40 °C

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

For each pole, a single-core cable, 1 m long and having a nominal cross-sectional area as specified in Table 13, is connected on each side of the RCBO, the terminal screws or nuts being tightened with a torque equal to two-thirds of that specified in Table 14. The assembly is placed in a heating cabinet.

The RCBO is loaded with a current equal to the rated current at any convenient voltage and is subjected, at a temperature of $40\text{ °C} \pm 2\text{ °C}$, 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 three overcurrent protected poles, only the three protected poles are loaded.

For four-pole RCBOs with four overcurrent protected poles, only any three of these 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 tests specified in 9.9.1.2 c) 1), the RCBO shall trip with a test current of $1,25 I_{\Delta n}$. One test only is made on one pole taken at random, without measurement of break time.

9.23 Verification of ageing of electronic components

The RCBO is placed for a period of 168 h in an ambient temperature of $40\text{ °C} \pm 2\text{ °C}$ and loaded with the rated current. The voltage on the electronic parts shall be 1,1 times the rated voltage.

After this test the 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 tests specified in 9.9.1.2 c), the RCBO shall trip with a test current of $1,25 I_{\Delta n}$. One test only is made on one pole taken at random without measurement of break time.

NOTE An example of the test circuit for this verification is given in Figure 25.

9.24 Electromagnetic compatibility (EMC)

9.24.1 Tests covered by the present standard

Tests listed in Table 27 are covered by the present standard and need not to be repeated.

Table 27 – Tests covered by this standard

Reference to Tables 4 and 5 of IEC 61543:1995 and Amendment 1:2004	Electromagnetic phenomena	Tests of IEC 61009-1
T 1.3	Voltage amplitude variations	9.9.1.4 and 9.17
T 1.4	Voltage unbalance	9.9.1.4 and 9.17
T 1.5	Power-frequency variations	9.2
T 1.8	Magnetic fields	9.12
T 2.4	Current oscillatory transients	9.19

9.24.2 Additional tests

Tests listed in Table 29 shall be carried out according to the test sequences H, I and J listed in Annex A of the present standard.

Table 29 – Test to be carried out according to IEC 61543

Reference to Tables 4, 5 and 6 of IEC 61543: 1995 and Amendment 1: 2004	Electromagnetic phenomena
T1.1	Harmonics, interharmonics
T1.2	Signalling voltage
T2.3	Surges
T2.1	Conducted sine-wave form voltages or currents
T2.5	Radiated electromagnetic field
T2.2	Fast transients (burst)
T2.6	Conducted common mode disturbances in the frequency range lower than 150 kHz
T3.1	Electrostatic discharges

For devices containing a continuously operating oscillator, the test of CISPR 14-1 shall be carried out on the samples prior to the tests of IEC 61543.

9.25 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 $(20 \pm 5) ^\circ\text{C}$.

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 $(20 \pm 5) ^\circ\text{C}$.

After the parts have been dried for 10 min in a heating cabinet at a temperature of $(100 \pm 5) ^\circ\text{C}$, their surfaces shall show no signs of rust.

NOTE 1 Traces of rust on sharp edges and any yellowish film removable by rubbing are ignored.

For small springs and the like and for inaccessible parts exposed to abrasion, a layer of grease may provide sufficient protection against rusting. Such parts are only subjected to the test if there is a doubt as to the effectiveness of the grease film, and in such a case the test is made without previous removal of the grease.

NOTE 2 When using the liquid specified for the test, adequate precautions should be taken to prevent inhalation of the vapour.

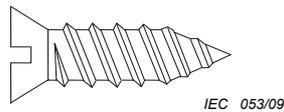


Figure 1 – Thread-forming tapping screw (3.6.10)

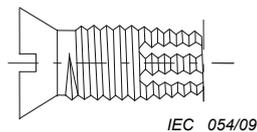
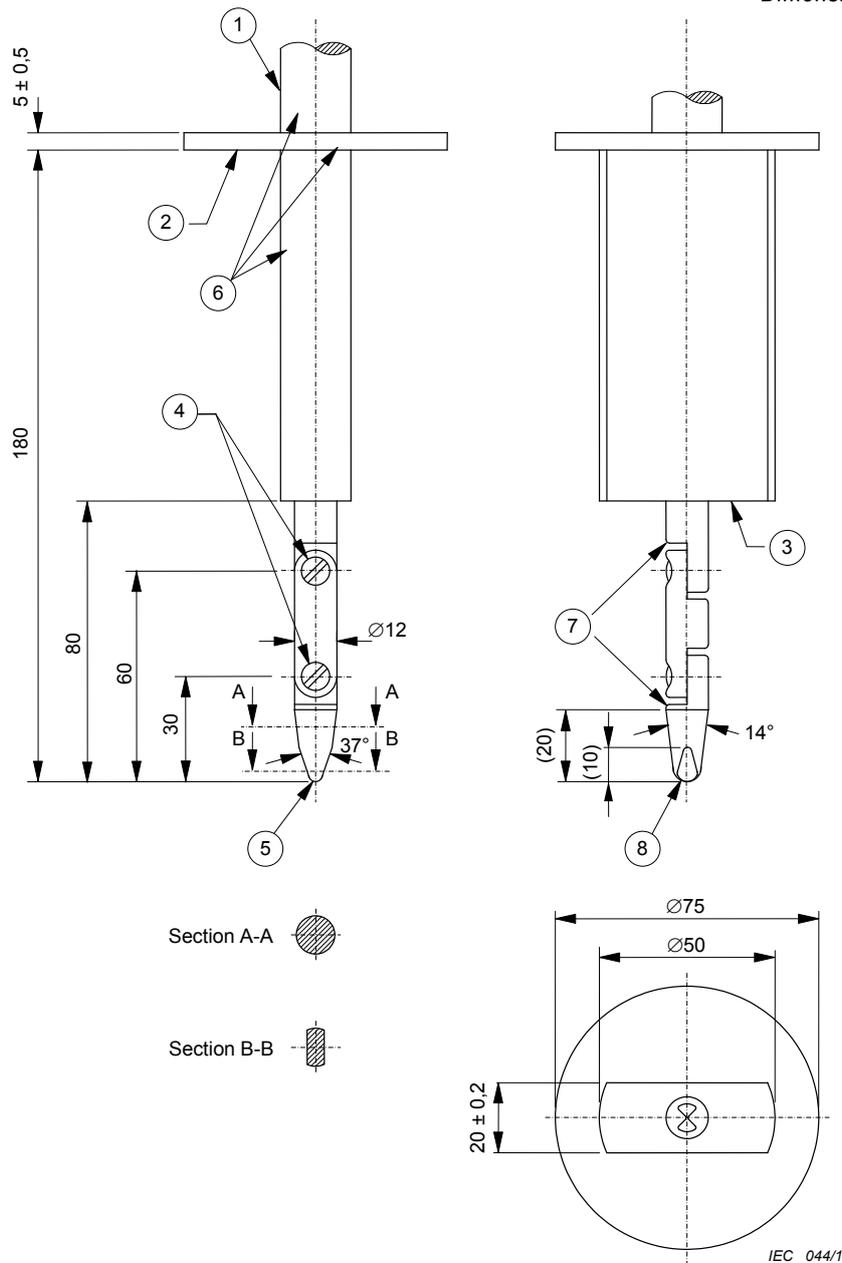


Figure 2 – Thread-cutting tapping screw (3.6.11)

Dimensions in millimetres



Key

- 1 Handle
- 2 Guard
- 3 Stop face
- 4 Joints

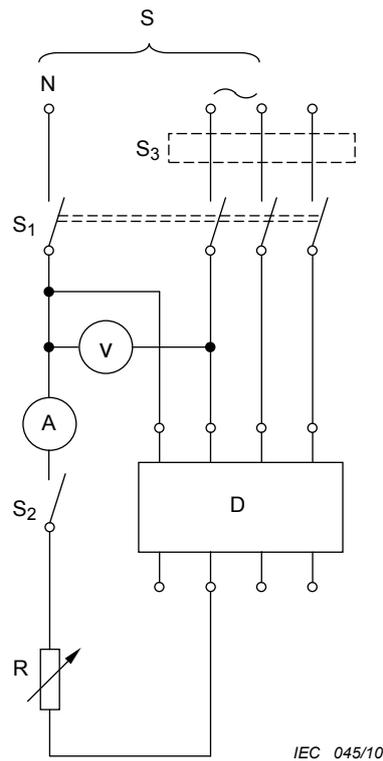
- 5 R2 ± 0,05 cylindrical
- 6 Insulating material
- 7 Chamfer all edges
- 8 R4 ± 0,05 spherical

Material : metal, except where otherwise specified
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 $\begin{matrix} +10^\circ \\ 0 \end{matrix}$.

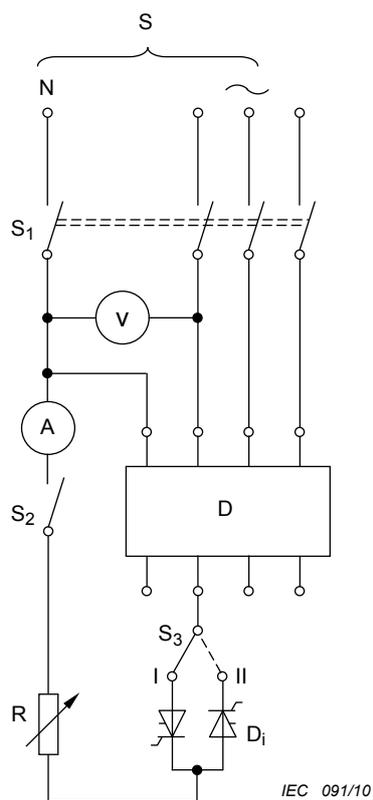
Figure 3 – Jointed test finger (9.6)

**Key**

S	Supply
V	Voltmeter
A	Ammeter
S ₁	All-pole switch
S ₂	Single-pole switch
S ₃	Switch operating all phases but one
D	RCBO under test
R	Variable resistor

NOTE S₃ remains closed except for the test of 9.17.3.

Figure 4 – Test circuit for the verification of
– operating characteristics (9.9.1)
– trip-free mechanism (9.11)
– behaviour in case of failure of line voltage (9.17.3 and 9.17.4)
for RCBOs functionally dependent on line voltage

**Key**

S	Supply
V	Voltmeter
A	Ammeter (measuring r.m.s. values)
D	RCBO under test
D _i	Thyristors
R	Variable resistor
S ₁	All-pole switch
S ₂	Single-pole switch
S ₃	Two-way switch

Figure 5 – Test circuit for the verification of the correct operation of RCBOs, in the case of residual pulsating direct currents

Explanation of letter symbols used in Figures 7, 8 and 9

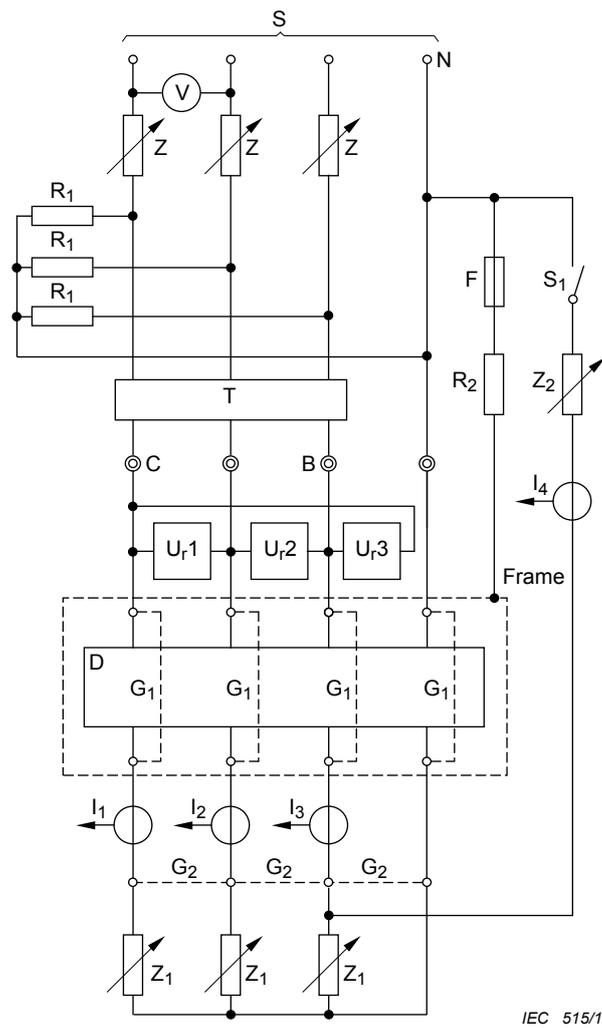
N	=	Neutral conductor
S	=	Supply
R	=	Adjustable resistor(s)
Z	=	Impedance in each phase for the calibration of the rated conditional short-circuit current. The reactors shall preferably be air-cored and connected in series with resistors in order to obtain the required power factor.
Z_1	=	Adjustable impedance to obtain current below the rated conditional short-circuit current
Z_2	=	Adjustable impedance for the calibration of I_{Δ}
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
U_{r1}, U_{r2}, U_{r3}	=	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 9.12.2)
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)

NOTE 1 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.

NOTE 2 The voltage sensors U_{r1}, U_{r2} and U_{r3} are connected between phase and neutral, as necessary.

NOTE 3 The adjustable load Z may be located at the high-voltage side of the supply circuit

NOTE 4 Resistances R_1 may be omitted with the agreement of the manufacturer.



IEC 515/12

Figure 7 – Typical diagram for all short-circuit tests except for 9.12.11.2.2

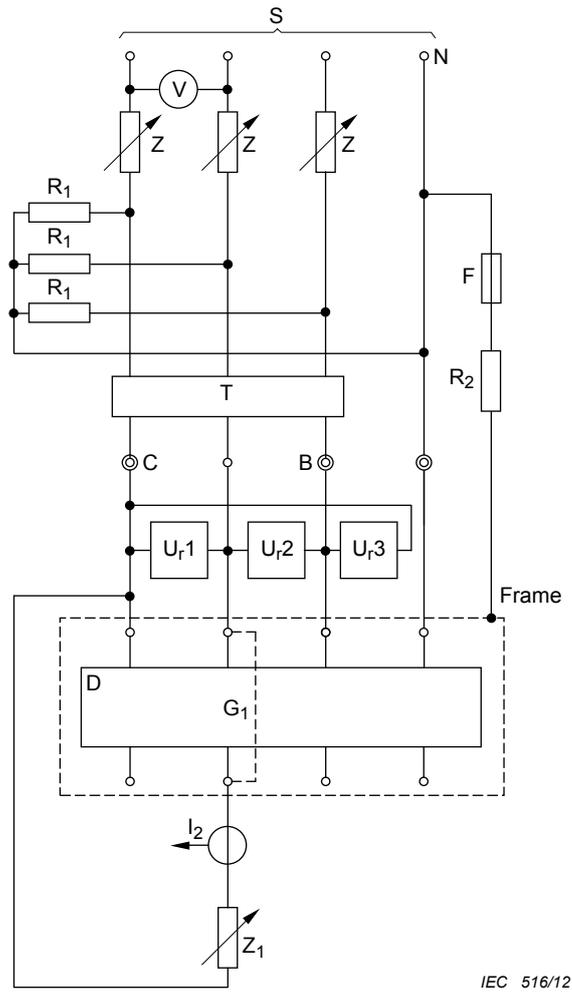


Figure 8 – Typical diagram for short-circuit tests according to 9.12.11.2.2

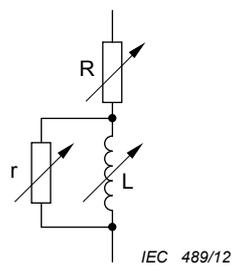
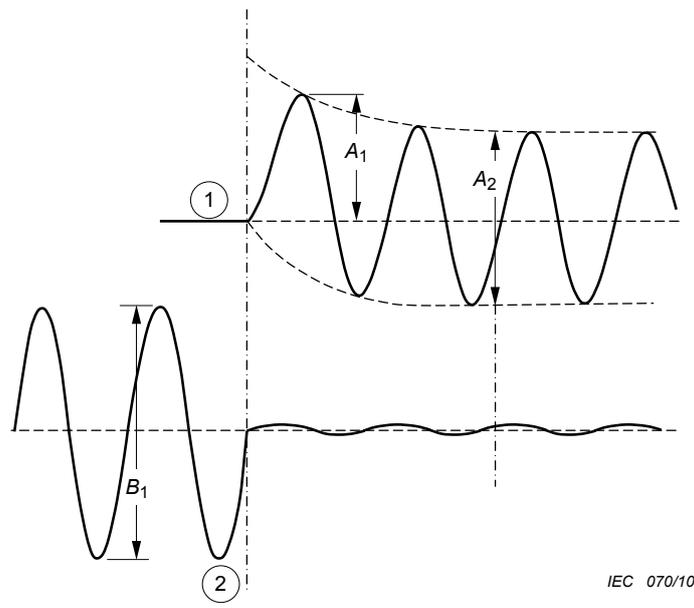


Figure 9 – Detail of impedances Z, Z₁ and Z₂

Figure 10 – Void

Figure 11 – Void

Figure 12 – Void

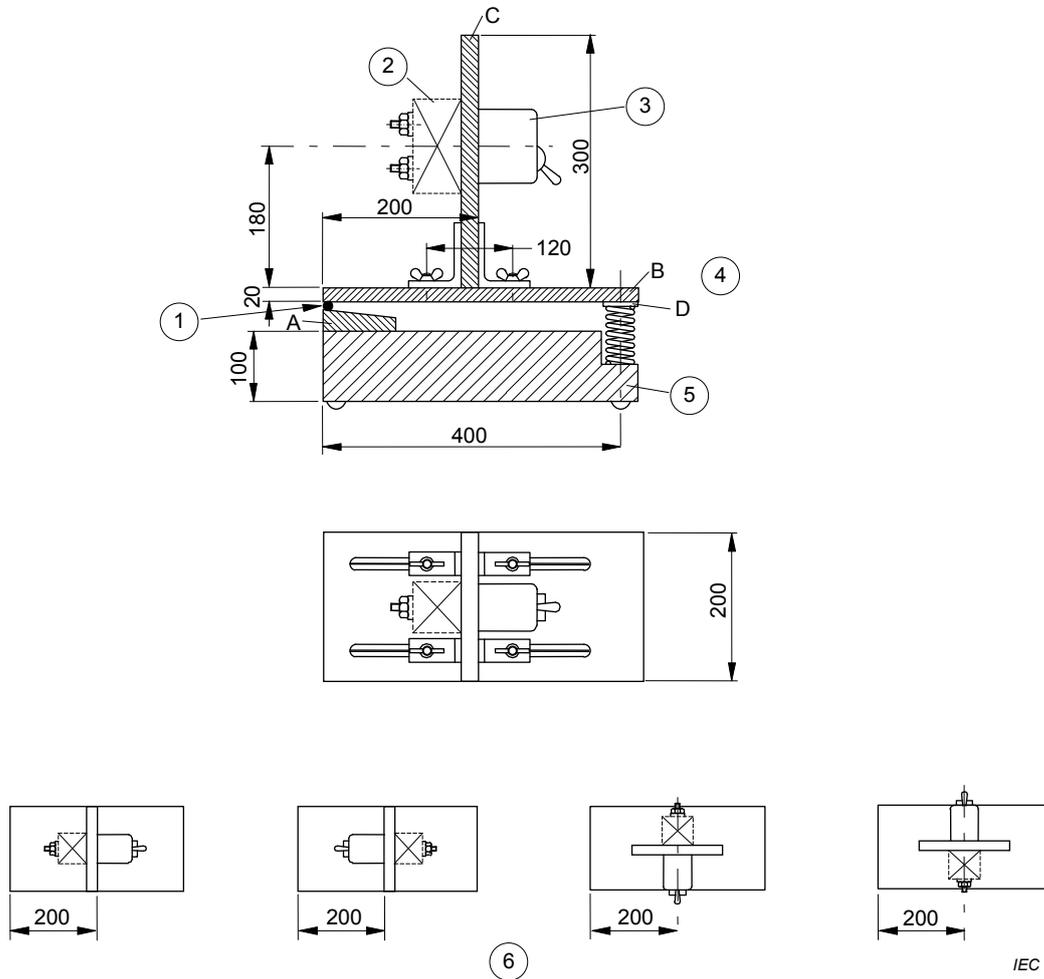


Key

- 1 Current
- 2 Voltage

Figure 13 – Example of calibration record for short-circuit test

Dimensions in millimetres



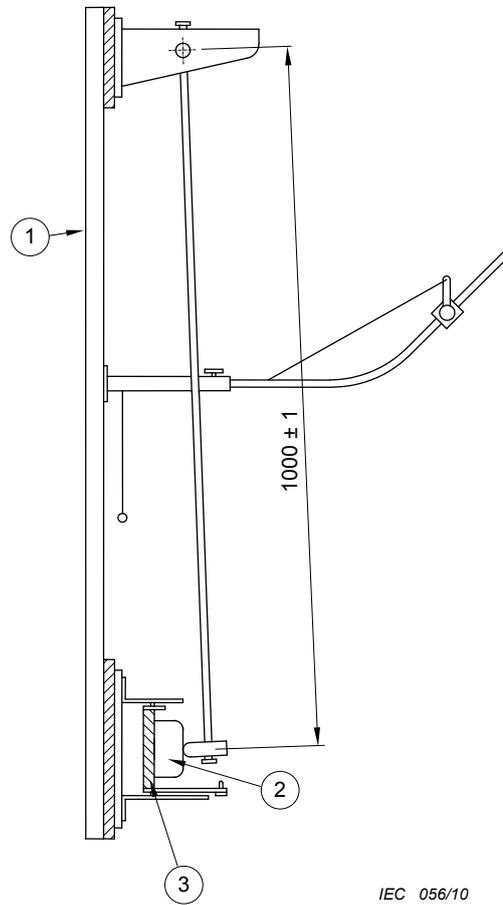
IEC 055/10

Key

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

Figure 14 – Mechanical shock test apparatus (9.13.1)

Dimensions in millimetres

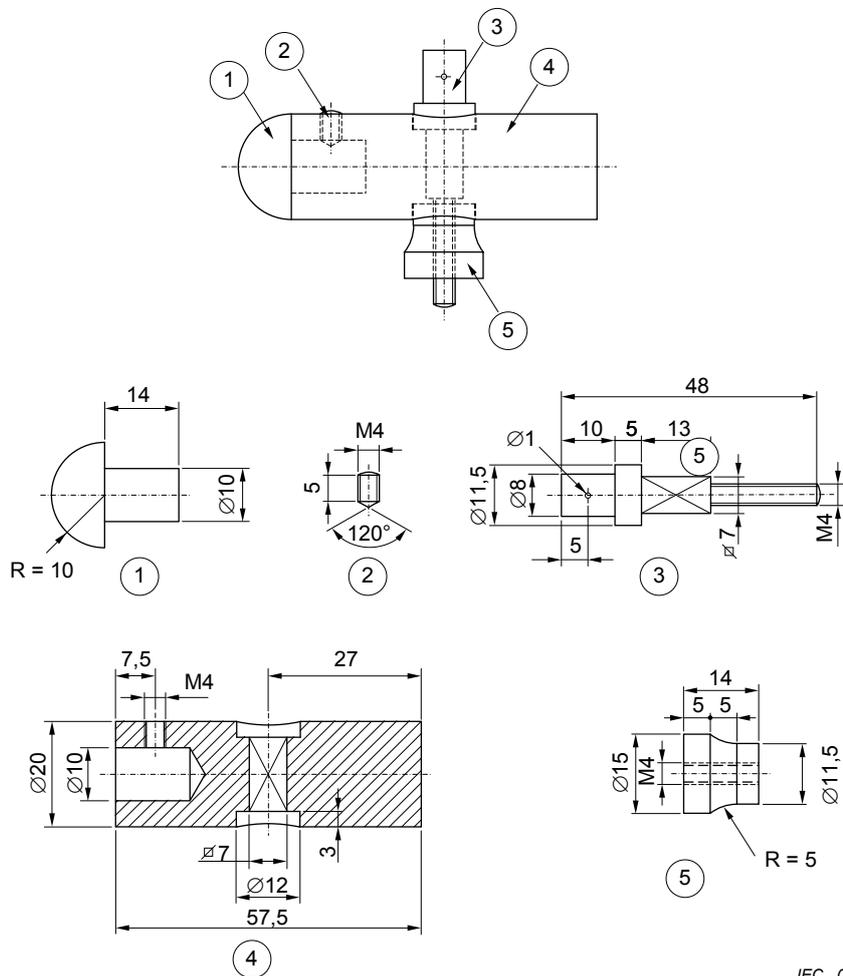


Key

- 1 Frame
- 2 Sample
- 3 Mounting support

Figure 15 – Mechanical impact test apparatus (9.13.2.1)

Dimensions in millimetres



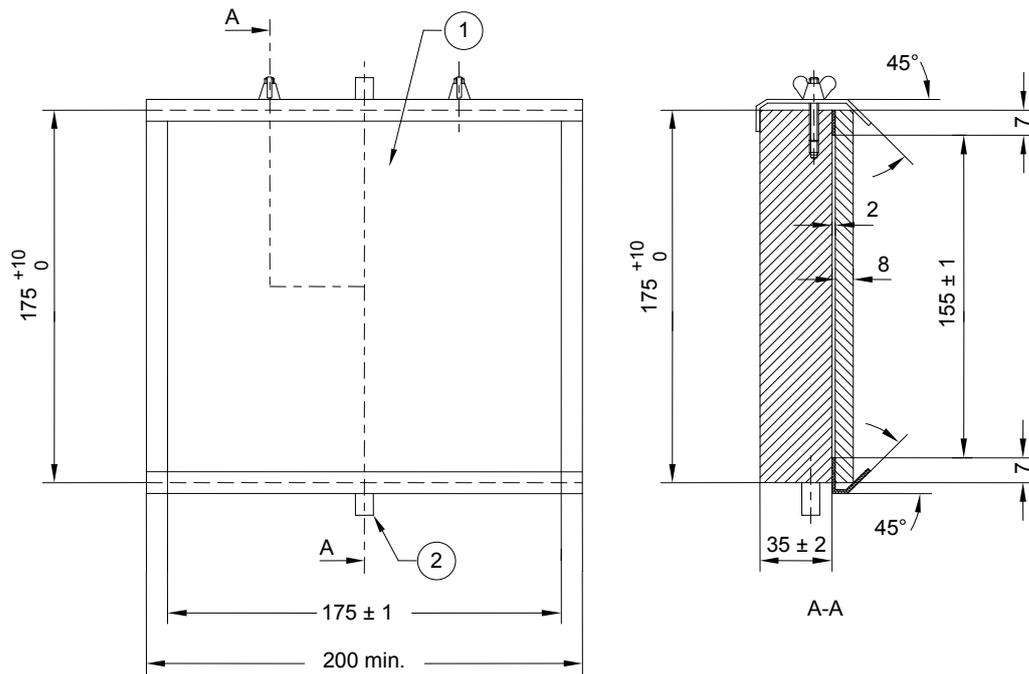
IEC 057/10

Key

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

Figure 16 – Striking element for pendulum impact test apparatus (9.13.2.1)

Dimensions in millimetres



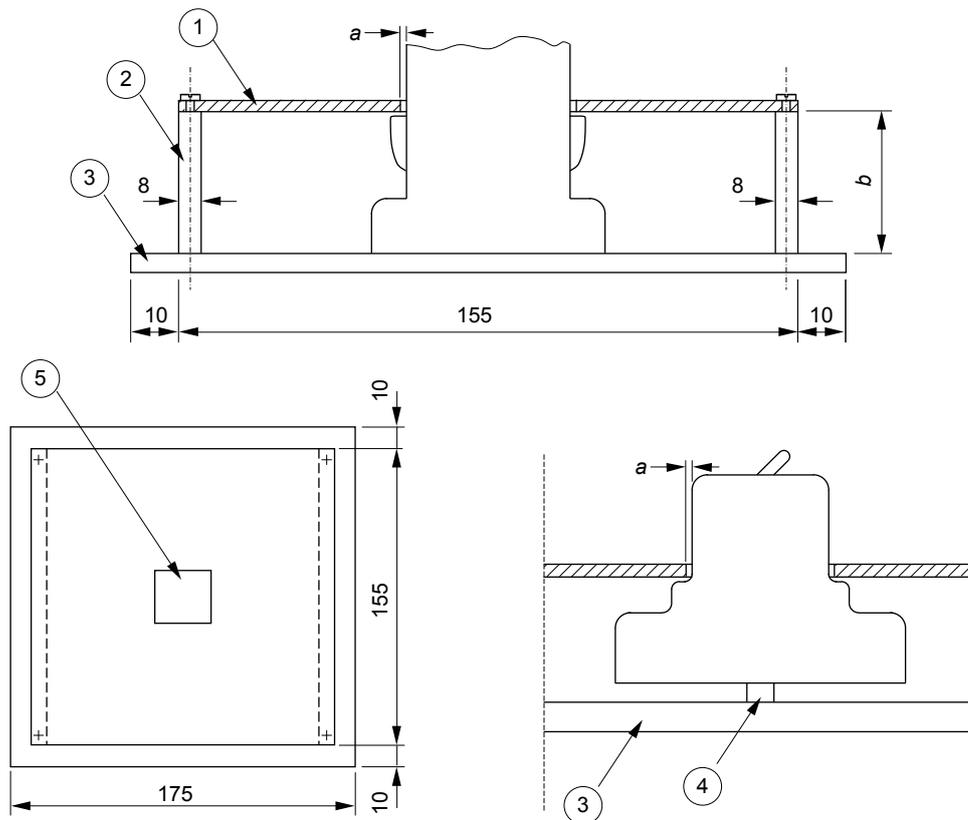
IEC 058/10

Key

- 1 Sheet of plywood
- 2 Pivot

Figure 17 – Mounting support for sample for mechanical impact test (9.13.2.1)

Dimensions in millimetres

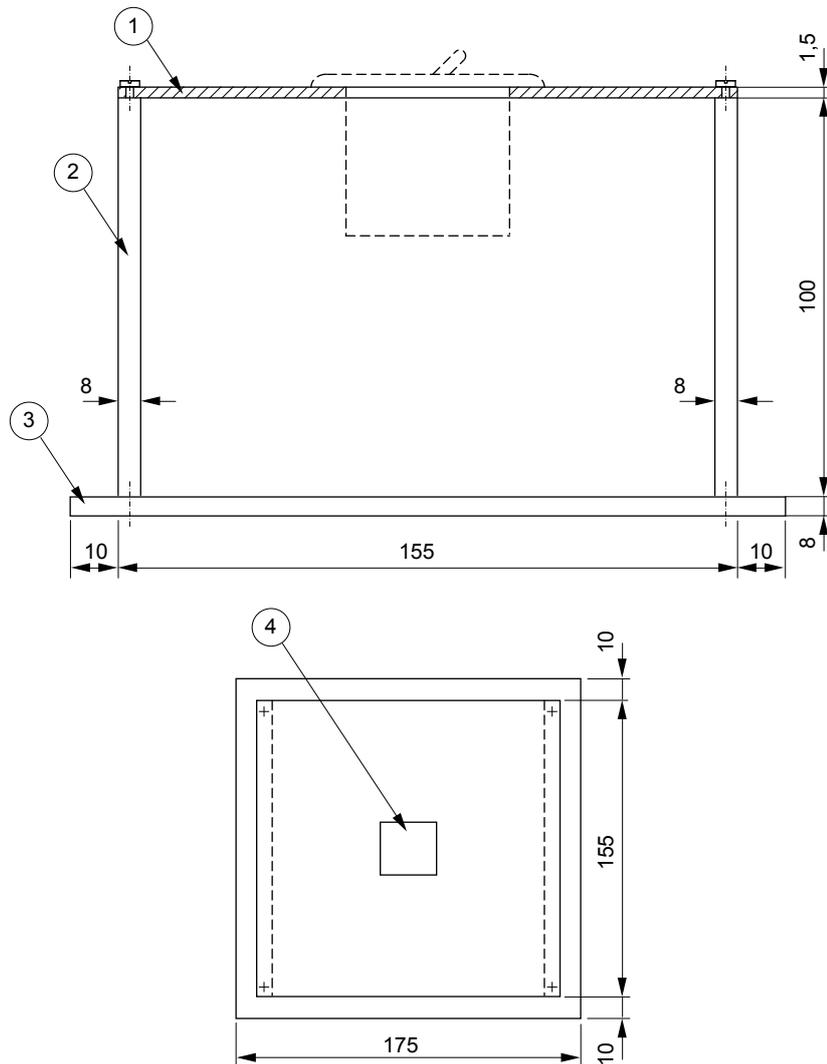


IEC 059/10

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 or, 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 18 – Example of mounting an unenclosed RCBO for mechanical impact test (9.13.2.1)



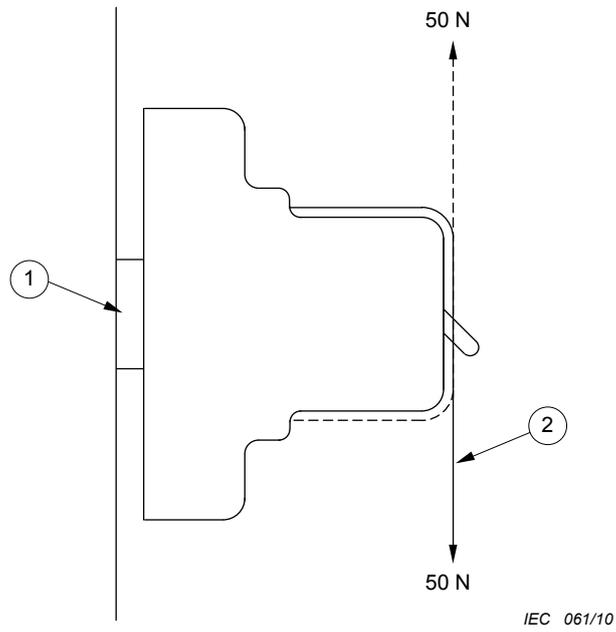
IEC 060/10

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

NOTE In particular cases the dimensions may be increased.

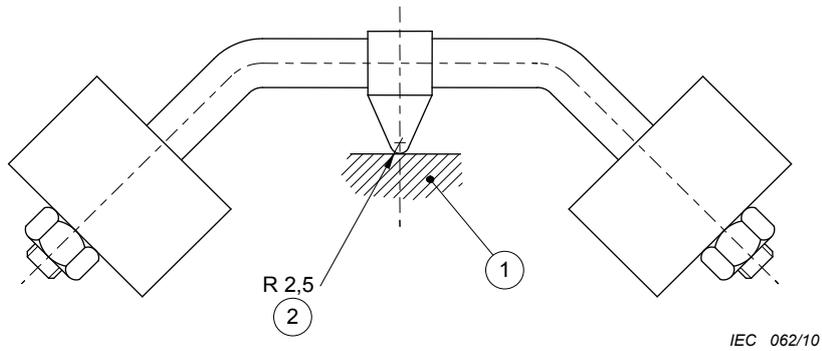
Figure 19 – Example of mounting of panel mounting type RCBO for the mechanical impact test (9.13.2.1)



Key

- 1 Rail
- 2 Cord

Figure 20 – Application of force for mechanical impact test of rail mounted RCBO (9.13.2.2)

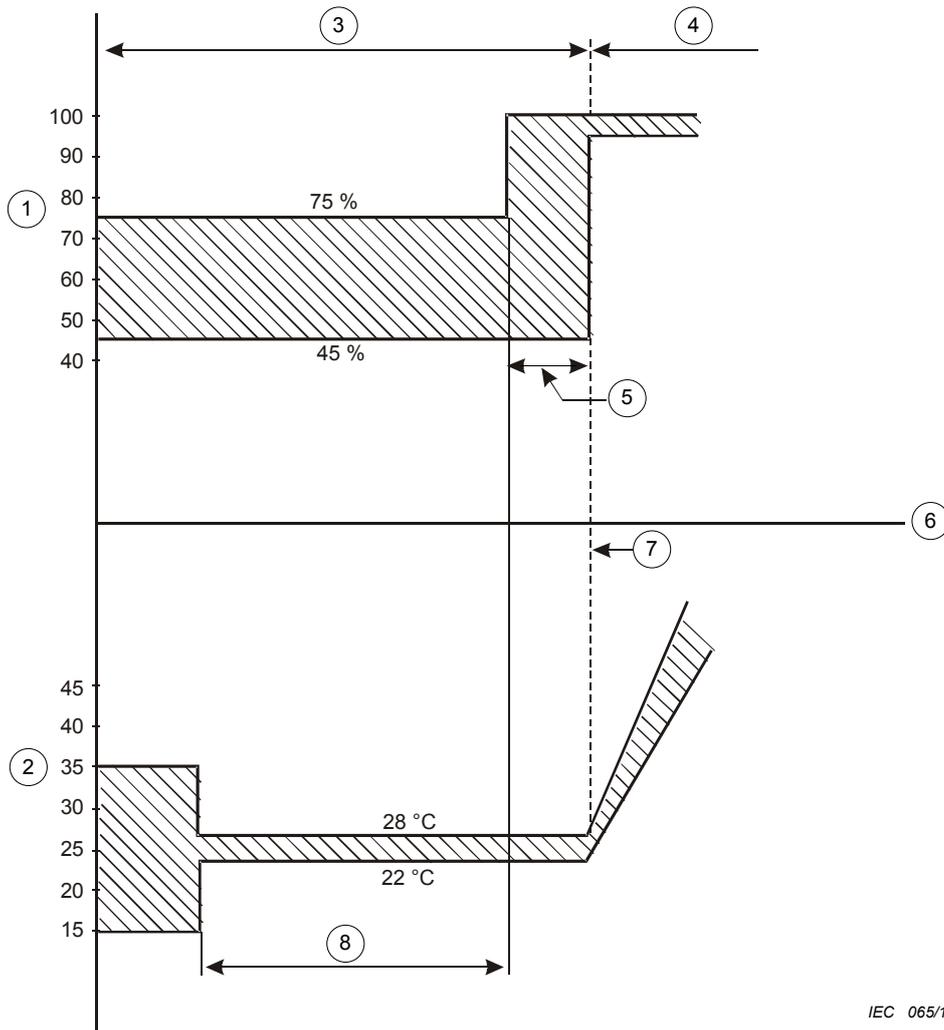


Key

- 1 Sample
- 2 Spherical

Figure 21 – Ball-pressure test apparatus (9.14.2)

Figure 22 – Void

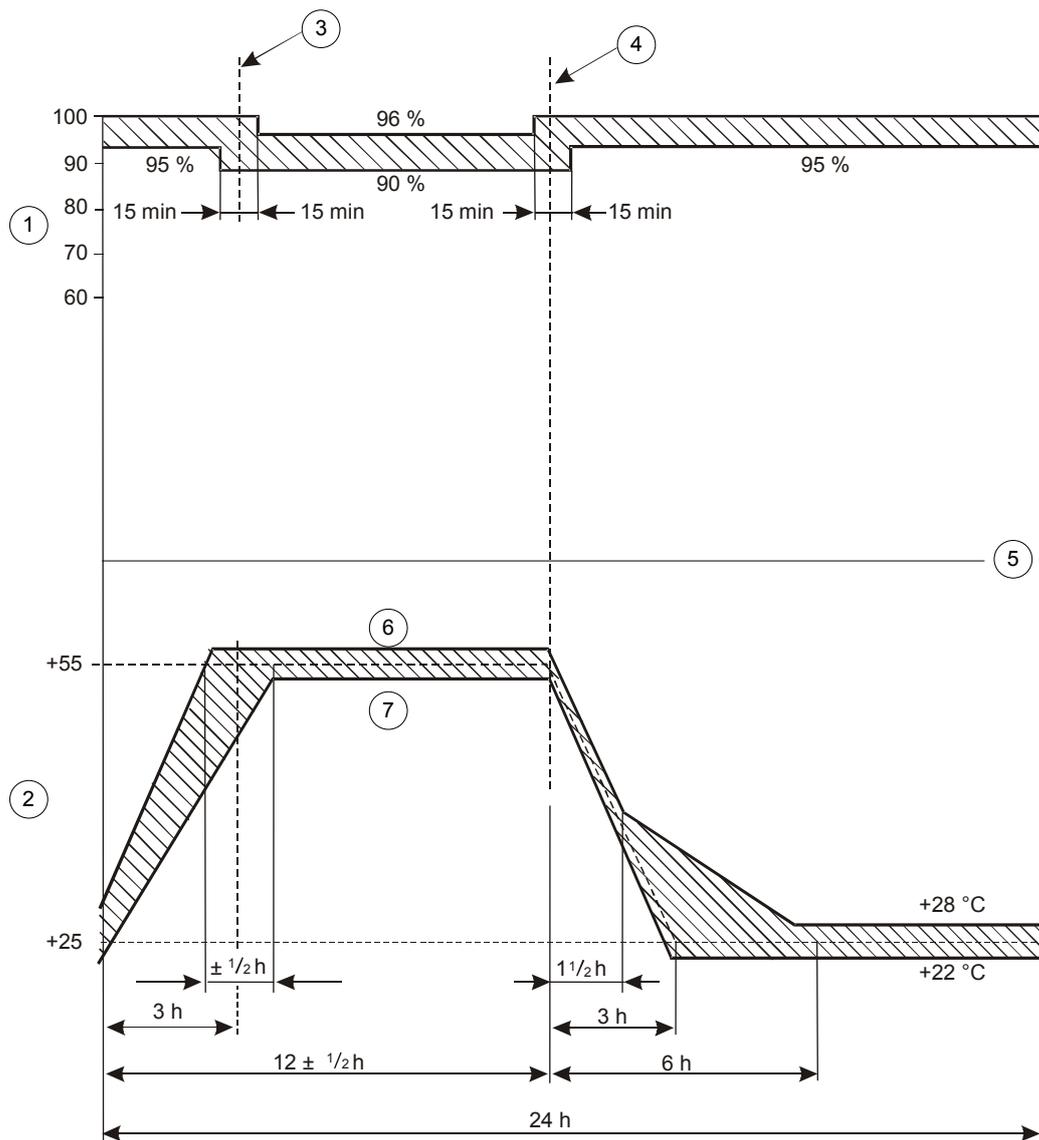


IEC 065/10

Key

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

Figure 23 – Stabilizing period for reliability test (9.22.1.3)

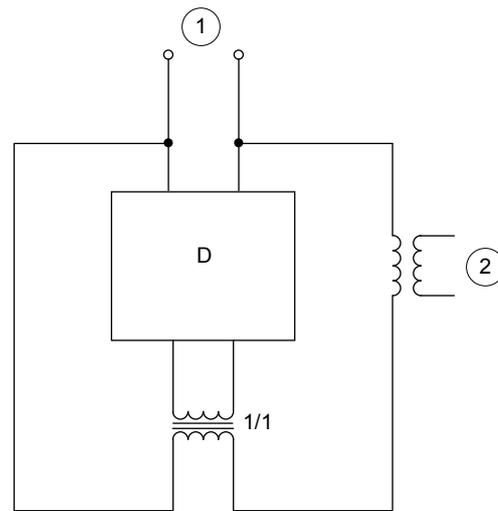


IEC 066/10

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 24 – Reliability test cycle (9.22.1.3)

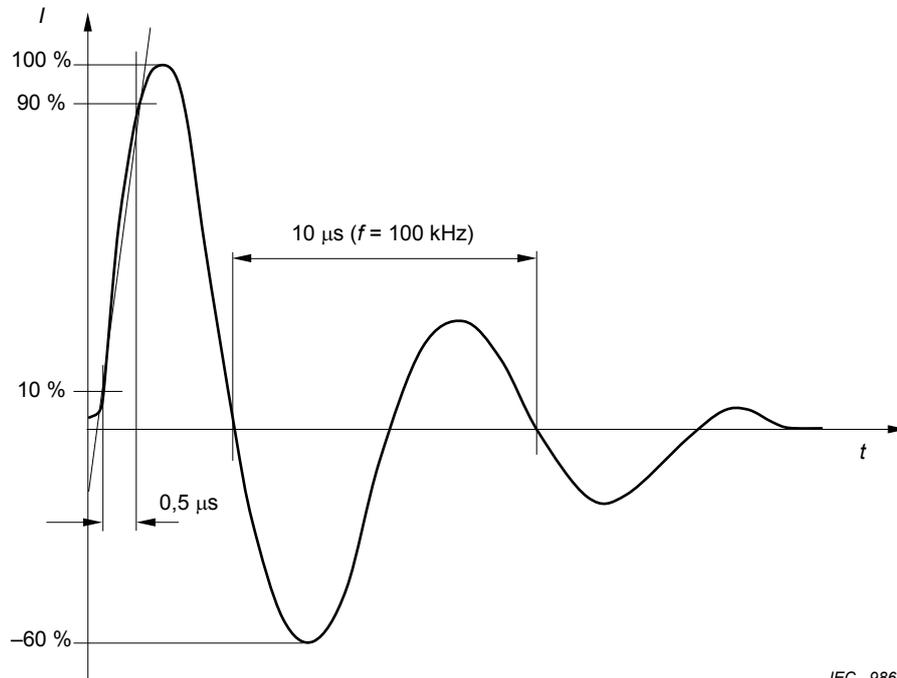


IEC 067/10

Key

- D RCBO under test
- 1 Supply at $1,1 U_n$
- 2 Current supply

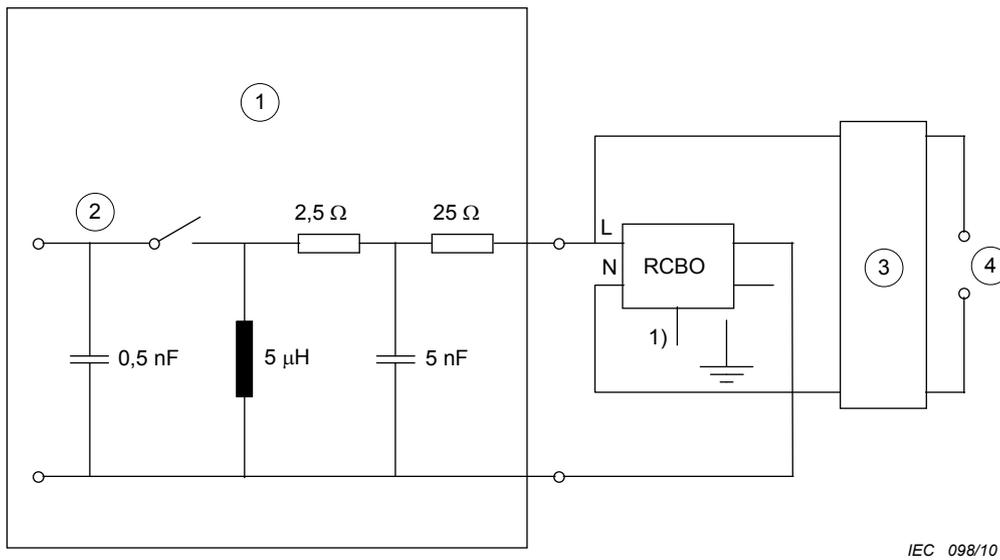
Figure 25 – Example of a test circuit for verification of ageing of electronic components (9.23)



IEC 986/08

NOTE Care should be taken that the oscillating wave is guaranteed at least up to the 5th full period (50 μs).

Figure 26 – Damped oscillator current wave, 0,5 μs/100 kHz



Key

- 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, and if so marked on the RCBO or, that failing, to any phase terminal.

Figure 27 – Test circuit for the ring wave test at RCBOs

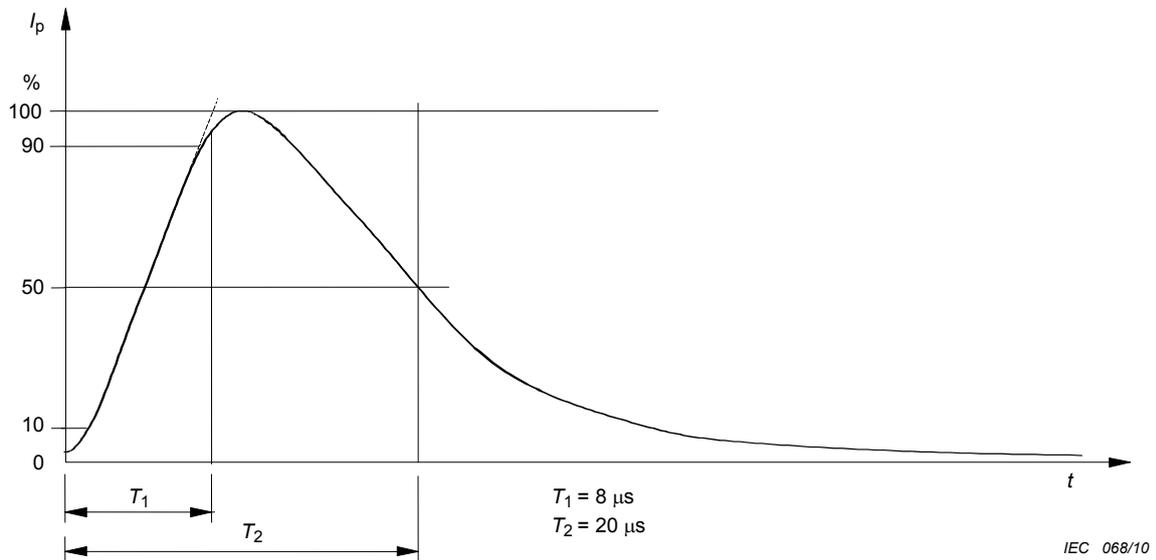


Figure 28 – Surge current impulse 8/20 μs

Annex A (normative)

Test sequence and number of samples to be submitted for certification² purposes

A.1 Test sequences

The tests are made according to Table A.1, the tests in each sequence being carried out in the order indicated.

Table A.1 – Test sequences

Test sequence	Clause or subclause	Test (or inspection)
A ₁	6	Marking
	8.1.1	General
	8.1.2	Mechanism
	9.3	Indelibility of marking
	8.1.3	Clearances and creepage distances (external parts only)
	8.1.6	Non-interchangeability
	9.11	Trip-free mechanism
	9.4	Reliability of screws, current-carrying parts and connections
	9.5	Reliability of terminals for external conductors
	9.6	Protection against electric shock
	9.14	Resistance to heat
	8.1.3	Clearance and creepage distances (internal parts)
	9.25	Resistance to rusting
A ₂	9.15	Resistance to abnormal heat and to fire
B	9.7.7.4	Resistance of the insulation of open contacts and basic insulation against an impulse voltage in normal conditions
	9.7.7.5 ^a	Verification of the behaviour of components bridging the basic insulation
	9.7.1	Resistance to humidity
	9.7.2	Insulation resistance of the main circuit
	9.7.3	Dielectric strength of the main circuit
	9.7.4	Insulation resistance and dielectric strength of auxiliary circuits
	9.7.7.2	Verification of clearances with the impulse withstand voltage
	9.7.5	Secondary circuit of detection transformers
	9.7.6	Capability of control circuits connected to the main circuits
	9.8	Temperature-rise
	9.22.2	Reliability at 40 °C
	9.23	Ageing of electronic components

² The term “certification” denotes either a Declaration of Conformity by the manufacturer, or a Third Party Certification, e.g. by an independent testing station.

Test sequence		Clause or subclause	Test (or inspection)
C	C ₁	9.10 9.12.11.2.1 (and 9.12.12)	Mechanical and electrical endurance Performance at reduced short-circuit currents (Verification of the RCBO after short-circuit tests)
	C ₂	9.12.11.2.2 (and 9.12.12)	Short-circuit test for verifying the suitability of RCBOs for use in IT systems (Verification of the RCBO after short-circuit tests)
D ₀		9.9.1	Operating characteristics under residual current conditions
D ₁		9.17 9.19 9.12.13 9.16	Behaviour in case of failure of the line voltage Behaviour in case of surge currents Performance at Δm Test device
E ₀		9.9.2	Overcurrent operating characteristics
E ₁		9.13 9.12.11.3 (and 9.12.12)	Resistance to mechanical shock and impact Short-circuit performance at 1 500 A
F ₀		9.12.11.4 b) (and 9.12.12)	Performance at service short-circuit capacity
F ₁		9.12.11.4 c) (and 9.12.12.2)	Performance at rated short-circuit capacity
G		9.22.1	Reliability (climatic tests)
H ^{ab}		IEC 61543 ³ Table 4 -T1.1 IEC 61543 Table 4 -T1.2 IEC 61543 Table 5 -T2.3	Harmonics, inter harmonics Signalling voltages Conducted unidirectional transients of the ms and μ s time scale
I		IEC 61543 Table 5 -T2.1 IEC 61543 Table 5 -T2.5 IEC 61543 Table 5 -T2.2	Conducted sine-wave form voltages or currents Radiated electromagnetic field Fast transients (bursts)
J		IEC 61543 Table 5 - T2.6 IEC 61543 Table 6 -3.1	Conducted common mode disturbances in the frequency range lower than 150 kHz Electrostatic discharges
<p>^a This test may be done on separate samples.</p> <p>^b For devices containing a continuously operating oscillator, the test of CISPR 14-1 shall be carried out on the samples prior to the tests of this sequence.</p>			

A.2 Number of samples to be submitted for full test procedure

If one current rating and one residual operating current rating of one type (number of poles, instantaneous tripping) of RCBO only is submitted for test, the number of samples to be submitted to the different test series are those indicated in Table A.2 where the minimum performance criteria are also indicated.

If all samples submitted according to the second column of Table A.2 pass the tests the compliance with the standard is met. If only the minimum number given in the third column pass the tests, additional samples as shown in the fourth column shall be tested and all shall then satisfactorily complete the test sequence.

³ Reference is made to IEC 61543:1995, Amendment 1:2004 and Amendment 2:2005.

For RCBOs having only one rated current but more than one residual operating current, two separate sets of samples shall be submitted to each test sequence, one adjusted to the highest residual operating current, the other adjusted to the lowest residual operating current.

Table A.2 – Number of samples for full test procedure

Test sequence	Number of samples	Minimum number of accepted samples ^{a, b}	Number of samples for repeated tests ^c
A ₁	1	1	–
A ₂	3	2	3
B	3	2	3
C ₁	3	2 ^d	3
C ₂	3	2 ^d	3
D	3	2 ^d	3
E	3	2 ^d	3
F ₀	3	2 ^d	3
F ₁	3	2 ^d	3
G	3	2	3
H ^e	3	2	3
I ^e	3	2	3
J ^e	3	2	3

^a In total a maximum of three test sequences may be repeated.

^b It is assumed that a sample which has not passed a test has not met the requirements due to workmanship or assembly defects which are not representative of the design.

^c In the case of repeated tests, all test results must be acceptable.

^d Except for tests of 9.12.10, 9.12.11.2, 9.12.11.3, 9.12.11.4 and 9.12.13, as appropriate, which all samples shall pass.

^e At the manufacturer's request, the same set of samples may be subjected to more than one of these test sequences.

A.3 Number of samples to be submitted for simplified test procedures in case of submitting simultaneously a range of RCBOs of the same fundamental design

A.3.1 If a range of RCBOs of the same fundamental design or additions to such a range of RCBOs are submitted for certification, the number of samples to be tested may be reduced according to Tables A.3, A.4 and A.5.

NOTE For the purposes of this annex, the term "same fundamental design" covers a range of RCBOs having a series of rated currents (I_N), a series of rated residual operating currents ($I_{\Delta N}$) and different numbers of poles.

RCBOs can be considered to be of the same fundamental design if all of the following conditions are met:

- 1) they have the same basic design; voltage dependent types and voltage independent types shall not occur together in the same range;
- 2) the residual current operating means have identical tripping mechanisms and identical relays or solenoids except for the variations permitted in c) and d) below;
- 3) the materials, finish and dimensions of the internal current-carrying parts are identical other than the variations detailed in a) below;
- 4) the terminals are of similar design (see b) below);
- 5) the contact size, material, configuration and method of attachment are identical;
- 6) the manual operating mechanism, materials and physical characteristics are identical;

- 7) the moulding and insulating materials are identical;
- 8) the method, materials and construction of the extinction device are identical;
- 9) the basic design of the residual current sensing device is identical, for a given type of characteristic, other than the variations permitted in c) below;
- 10) the basic design of the residual current tripping device is identical except for the variations permitted in d) below;
- 11) the basic design of the test device is identical except for the variations permitted in e) below.

The following variations are permitted provided that the RCBOs comply in all other respects with the requirements detailed above:

- a) cross-sectional area of the internal current-carrying connections and lengths of the toroid connections;
- b) size of terminals;
- c) number of turns and cross-sectional area of the windings and the size and material of the core of the differential transformer;
- d) the sensitivity of the relay and/or the associated electronic circuit, if any;
- e) the ohmic value of the means to produce the maximum ampere-turns necessary to conform to the tests of 9.16. The circuit may be connected across phases or phase to neutral.

A.3.2 For RCBOs of the same classification according to the method of operation (4.1), the behaviour in presence of d.c. components (4.6) and the same classification according to time-delay (4.7), having different current rating and rated residual operating current, the number of samples to be tested may be reduced, according to Table A.3.

Table A.3 – Number of samples for simplified test procedure

Test sequence	Number of samples according to number of poles ^{a, g}		
	2 poles ^{b, c}	3 poles ^{d, f, j}	4 poles ^e
A ₁	1 max. rating I_n min. rating $I_{\Delta n}$	1 max. rating I_n min. rating $I_{\Delta n}$	1 max. rating I_n min. rating $I_{\Delta n}$
A ₂	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$
B	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$
C	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$
D ₀ + D ₁	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$
D ₀	1 for all other ratings of $I_{\Delta n}$ with max. I_n		
E ₀ + E ₁	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$
E ₀	1 ⁱ for all other ratings of I_n with min. $I_{\Delta n}$		
F ₀	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$
	3 min. rating I_n max. rating $I_{\Delta n}$	3 min. rating I_n max. rating $I_{\Delta n}$	3 min. rating I_n max. rating $I_{\Delta n}$
F ₁	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$
	3 min. rating I_n max. rating $I_{\Delta n}$	3 min. rating I_n max. rating $I_{\Delta n}$	3 min. rating I_n max. rating $I_{\Delta n}$
G	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$
H ^k	3 ^h samples of the same rating I_n chosen at random min. rating $I_{\Delta n}$		
I	3 ^h samples of the same rating I_n chosen at random min. rating $I_{\Delta n}$		
J	3 ^h samples of the same rating I_n chosen at random min. rating $I_{\Delta n}$		

^a If a test is to be repeated according to the minimum performance criteria of Clause A.2, a new set of samples is used for the relevant test. In the repeated test all test results must be acceptable.

^b If only 3-pole or 4-pole RCBOs are submitted, this column shall also apply to a set of samples with the smallest number of poles.

^c Also applicable to 1-pole RCBOs with uninterrupted neutral and to 2-pole RCBOs with 1 protected pole.

^d Also applicable to 3-pole RCBOs with 2 protected poles.

^e Also applicable to 3-pole RCBOs with uninterrupted neutral and to 4-pole RCBOs with 3 protected poles.

^f This column is omitted when 4-pole RCBOs have been tested.

^g If only one value of $I_{\Delta n}$ is submitted, min. rating $I_{\Delta n}$ and max. rating $I_{\Delta n}$ are replaced by $I_{\Delta n}$.

^h Only the highest number of current paths.

ⁱ For this sequence only the test of 9.9.2 is required.

^j If a 3-pole RCBO with 4 current paths and a 4-pole RCBO are submitted, then only the 4-pole RCBO is tested, with exception of the test of 9.8 of test sequence B for which both types are submitted to the test.

^k If the requirement to test max. rating I_n and minimum rating $I_{\Delta n}$ does not cover all the possible range of RCBOs, the minimum $I_{\Delta n}$ shall in any case be chosen for the test.

A.3.3 For a sub-range of RCBOs of the same fundamental design as those described in A.3.1 and tested according to A.3.2, but of a different instantaneous tripping class according to 4.11, being subsequently submitted for tests, the additional sequences may be reduced according to Table A.4, the number of samples being taken from Table A.3.

Table A.4 – Test sequences for RCBOs having different instantaneous tripping currents

RCBO type tested first	Test sequences for other RCBO types		
	B-type	C-type	D-type
B-type	–	$(E_0 + E_1) + F$	$(E_0 + E_1) + F$
C-type	$E_0^a + B^a$	–	$(E_0 + E_1) + F$
D-type	$E_0^a + B^a$	$E_0^a + B^{a, b}$	–

^a For this sequence only the tests of 9.8 and 9.9.2.2 are required.

^b When certification is requested at the same time for B-type, C-type and D-type RCBOs having the same rated short-circuit capacity, only test sequence E_0 is required if B-type and D-type samples have been tested.

A.3.4 For a sub-range of RCBOs of the same fundamental design as those described in A.3.1, and tested according to A.3.2, but of a different time-delay classification according to 4.7, subsequently submitted for tests, the additional number of samples and sequences shall be as given in Table A.3, except that sequences A, B, and E_0 may be omitted.

A.3.5 For a sub-range of RCBOs of the same fundamental design as those described in A.3.1, and tested according to A.3.2, but of a different classification according to behaviour due to d.c. components (according to 4.6), subsequently submitted for tests, the additional number of samples and sequences may be reduced according to Table A.5.

Table A.5 – Test sequences for RCBOs of different classification according to 4.6

Test sequence	Number of samples according to the number of poles ^a		
	2-poles ^{b, c}	3-poles ^{d, f}	4-poles ^e
$D_0 + D_1$	1 max. rating I_n min. rating $I_{\Delta n}$	1 max. rating I_n min. rating $I_{\Delta n}$	1 max. rating I_n min. rating $I_{\Delta n}$
D_0	1 for all other ratings of $I_{\Delta n}$ with max. I_n		

^a If a test is to be repeated according to the minimum performance criteria of Clause A.2, a new set of samples is used for the relevant test. In the repeated test all test results must be acceptable.

^b If only 3-pole or 4-pole RCBOs are submitted, this column shall also apply to a set of samples with the smallest number of poles.

^c Also applicable to 1-pole RCBOs with uninterrupted neutral and to 2-pole RCBOs with 1 protected pole.

^d Also applicable to 3-pole RCBOs with 2 protected poles.

^e Also applicable to 3-pole RCBOs with uninterrupted neutral and to 4-pole RCBOs with 3 protected poles

^f This column is omitted when 4-pole RCBOs have been tested.

Annex B

(normative)

Determination of clearances and creepage distances

B.1 General

In determining clearances and creepage distances, it is recommended that the following points should be considered.

B.2 Orientation and location of a creepage distance

If necessary, the manufacturer shall indicate the intended orientation of the equipment or component in order that creepage distances be not adversely affected by the accumulation of pollution for which they were not designed.

B.3 Creepage distances where more than one material is used

A creepage distance may be split in several portions of different materials and/or have different pollution degrees if one of the creepage distances is dimensioned to withstand the total voltage or if the total distance is dimensioned according to the material having the lowest CTI.

B.4 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 60664-1:2007, 6.2 (see also Example 11 in Figure B.1).

B.5 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.

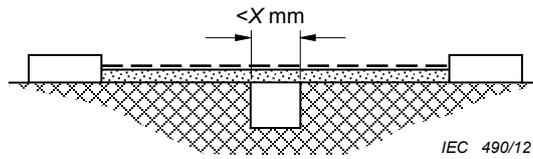
If the associated clearance is less than 3 mm, the minimum dimension X may be reduced to one third of this clearance.

The methods of measuring creepage distances and clearances are indicated in Figure B.1. These cases do not differentiate between gaps and grooves or between types of insulation.

The following assumptions are made:

- any recess is assumed to be bridged with an insulating link having a length equal to the specified width X and being placed in the most unfavourable position (see Example 3);
- where the distance across a groove is equal to or larger than the specified width X , the creepage distance is measured along the contours of the groove (see Example 2);
- creepage distances and clearances measured between parts which can assume different positions in relation to each other, are measured when these parts are in their most unfavourable position.

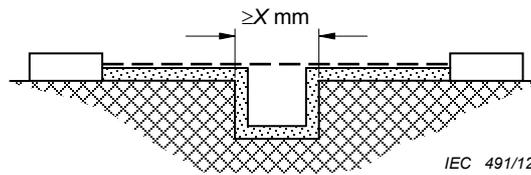
Example 1



Condition: Path under consideration includes a parallel- or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

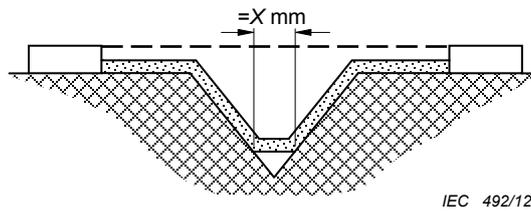
Example 2



Condition: Path under consideration includes a parallel-sided groove of any depth and 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.

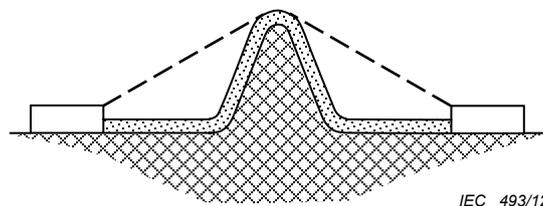
Example 3



Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

Example 4



Condition: Path under consideration includes a rib.

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

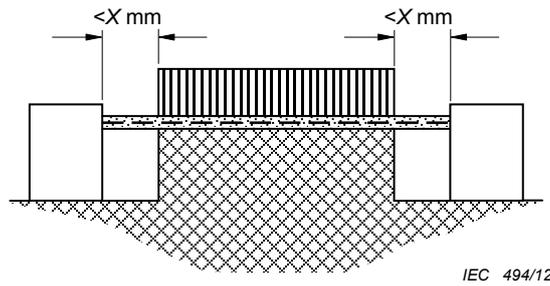


Clearance



Creepage distance

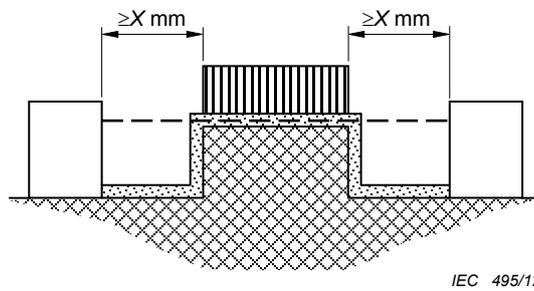
Example 5



Condition: Path under consideration includes an uncemented joint with grooves less than X mm wide on each side.

Rule: Creepage and clearance path is the "line of sight" distance shown.

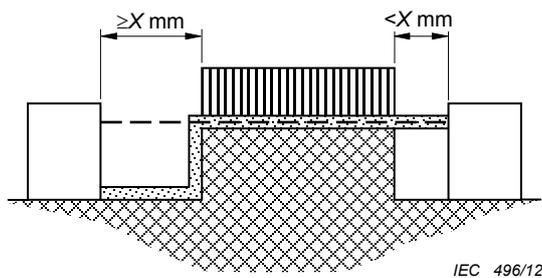
Example 6



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm wide on each side.

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

Example 7



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

Rule: Clearance and creepage paths area as shown.

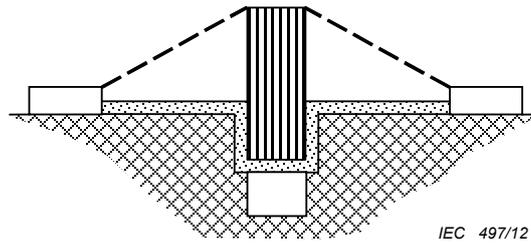


Clearance



Creepage distance

Example 8

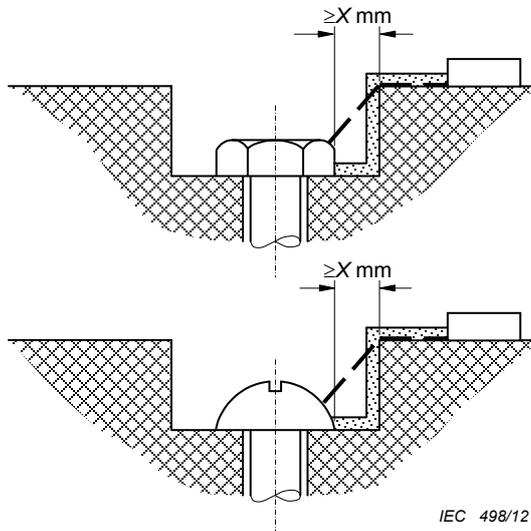


IEC 497/12

Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

Rule: Clearance is the shortest direct air path over the top of the barrier.

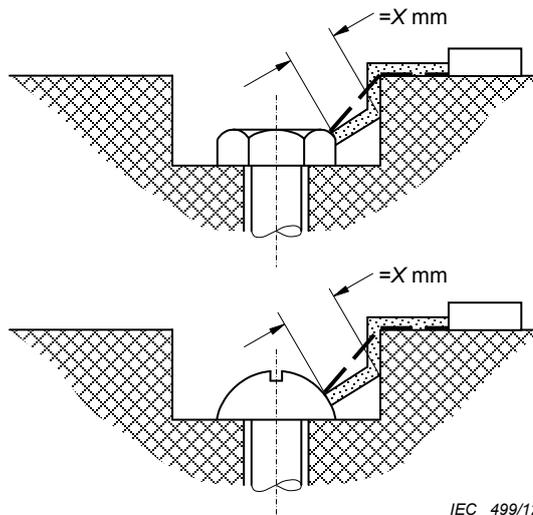
Example 9



IEC 498/12

Gap between head of screw and wall of recess wide enough to be taken into account.

Example 10



IEC 499/12

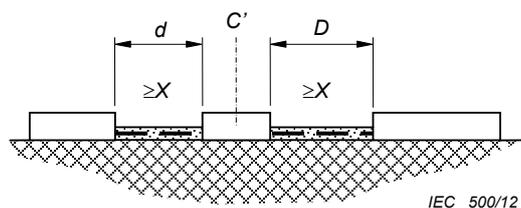
Gap between head of screw and wall of recess too narrow to be taken into account.

Measurement of creepage distance is from screw to wall when the distance is equal to X mm.

--- Clearance

▨ Creepage distance

Example 11



C' floating part

Clearance is the distance = $d + D$

Creepage distance is also = $d + D$

— — — Clearance

⋯⋯⋯ Creepage distance

Figure B.1 – Examples of methods of measuring creepage distances and clearances

Annex C (normative)

Arrangement for the detection of the emission of ionized gases during short-circuit tests

The device under test is mounted as shown in Figure C.1, which may require adapting to the specific design of the device, and in accordance with the manufacturer's instructions.

When required (i.e. during "O" operations), a clear polyethylene sheet ($0,05 \pm 0,01$) mm thick, 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 \times 200 mm, is fixed and reasonably stretched in a frame, placed at a distance of 10 mm from

- either the maximum projection of the operating means of a device without recess for the operating means,
- or the rim of a recess for the operating means of a device with recess for the operating means.

The sheet should have the following physical properties:

Density at 23 °C: $0,92 \text{ g/cm}^3 \pm 0,05 \text{ g/cm}^3$

Melting-point: 110 °C – 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 sheet to prevent damage of the sheet due to hot particles emitted from the arc vent.

When required, a grid (or grids) according to Figure C.2 is (are) placed at a distance of "a" mm from each arc vent side of the device.

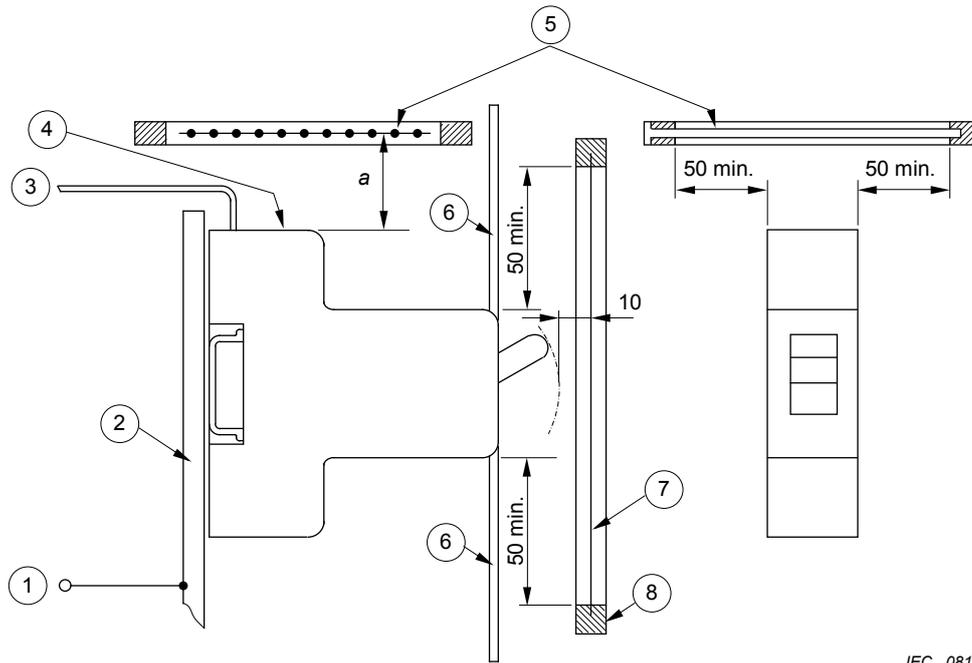
The grid circuit (see Figure C.3) shall be connected to the points B and C (see Figures 7 or 8, as applicable).

The parameters for the grid circuit are as follows:

Resistor R': 1,5 Ω

Copper wire F': length 50 mm, and diameter as required in 9.12.9.1.

Dimensions in millimetres



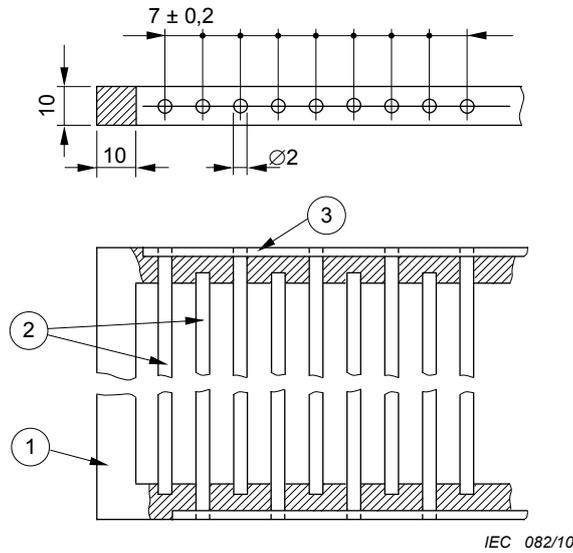
IEC 081/10

Key

- 1 To the fuse F
- 2 Metal plate
- 3 Cable
- 4 Arc vent
- 5 Grid
- 6 Barrier
- 7 Polyethylene sheet
- 8 Frame

Figure C.1 – Test arrangement

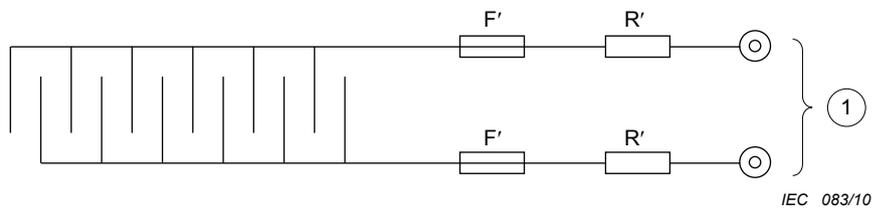
Dimensions in millimetres



Key

- 1 Frame of insulating material
- 2 Copper wires
- 3 Metal interconnection of copper wires

Figure C.2 – Grid



Key

- 1 Connected to points B and C (See Figure 7 or 8, as applicable)

Figure C.3 – Grid circuit

Annex D (normative)

Routine tests

D.1 General

The tests specified in this standard are intended to reveal, as far as safety is concerned, unacceptable variations in material or manufacture.

In general, further tests have to be made to ensure that every RCBO conforms with the samples that withstood the tests of this standard, according to the experience gained by the manufacturer.

D.2 Tripping test

A residual current is passed through each pole of the RCBO in turn. The RCBO shall not trip at a current less than or equal to $0,5 I_{\Delta n}$, but it shall trip at $I_{\Delta n}$ within a specified time (see Table 2).

The test current shall be applied at least five times to each RCBO and shall be applied at least twice to each pole.

D.3 Electric strength test

A voltage of substantially sine-wave form of 1 500 V having a frequency of 50 Hz/60 Hz is applied for 1 s as follows:

- a) with the RCBO in the open position, between the terminals which are electrically connected together, when the RCBO is in the closed position;
- b) for RCBOs not incorporating electronic components, with the RCBO in the closed position, between each pole in turn and the others connected together;
- c) for RCBOs incorporating electronic components, with the RCBO in the open position, either between all incoming terminals of poles in turn or between all outgoing terminals of poles in turn, depending on the position of the electronic components.

No flashover or breakdown shall occur.

D.4 Performance of the test device

With the RCBO in the closed position, and connected to a supply at the appropriate voltage, the test device, when operated, shall open the RCBO.

Where the test device is intended to operate at more than one value of rated voltage, the test shall be made at the lowest value of rated voltage.

Annex E
(normative)**Special requirements for auxiliary circuits for safety extra-low voltage**

Subclause 8.1.3 – Clearance and creepage distances

The following note applies to Table 7:

NOTE 1 Live parts of auxiliary circuits intended to be connected to safety extra-low voltages shall be separated from circuits of higher voltages in accordance with the requirements of 414.4.3 of IEC 60364-4-41:2005.

Subclause 9.7.4 – Insulation resistance and dielectric strength of auxiliary circuits

Add the following under item b):

NOTE A test for circuits intended for connection to safety extra-low voltage is under consideration.

Add the following to the notes that follow item c):

NOTE 5 The values of the test voltages for circuits intended for connection to safety extra-low voltage are under consideration.

Annex F
(normative)

**Coordination between RCBOs and separate fuses
associated in the same circuit**

The information given in Annex D of IEC 60898-1:2002 to ensure coordination between circuit-breakers and separate fuses associated in the same circuit may also be applicable to ensure coordination between RCBOs and separate fuses associated in the same circuit.

Annex G

(normative)

Additional requirements and tests for RCBOs consisting of a circuit-breaker and a residual current unit designed for assembly on site

G.1 General

The main body of this standard applies in all respects to devices covered by this annex, unless otherwise specified.

G.2 Scope

This annex applies to RCBOs consisting of a circuit-breaker complying with the requirements of IEC 60898-1 and a residual current unit complying with the appropriate requirements of this standard where applicable, designed for assembly on site, in accordance with the manufacturer's instructions.

G.3 Definitions

Add the following definition to Clause 3 of this standard:

3.3.23

residual current 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

G.4 Marking and other product information

G.4.1 Manufacturer's name or trade mark

With reference to Clause 6 item a) of this standard, the circuit-breaker and the r.c. unit with which it is to be assembled shall bear the same manufacturer's name or trade mark.

G.4.2 Marking

G.4.2.1 Marking of the circuit-breaker

Marking of the circuit-breaker shall be in accordance with IEC 60898-1.

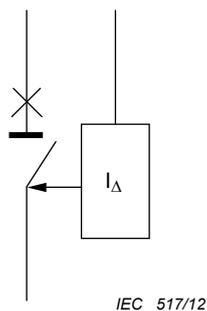
G.4.2.2 Marking of the r.c. unit

The r.c. unit shall be marked with the following items, with reference to Clause 6 of this standard:

a), b), c), e), f), g), k), m), n), q) and, if necessary, l).

In addition the r.c. unit shall be marked with

- the maximum rated current of the circuit-breaker with which it may be assembled (e.g. 63 A max.)
- the symbol



G.4.2.3 Marking of the assembled circuit-breaker and r.c. unit (RCBO)

The following marking on the r.c. unit specified in G.4.2.2 shall not be visible after assembly:

- c)
- maximum rated current of the circuit-breaker with which the r.c. unit may be assembled;

Marking l) of the r.c. unit, if applicable, shall remain visible after assembly.

G.4.3 Instructions for assembly and operation

The manufacturer shall provide adequate instructions with the r.c. unit.

These instructions shall cover at least the following:

- reference to the type(s) and catalogue number(s), covering current and voltage ratings, number of poles, etc. of the circuit-breakers with which the r.c. unit is designed to be assembled;

NOTE The number of paths of the RCBO corresponds to the number of paths of the r.c. unit. A neutral terminal or link may take the place of the neutral pole of a circuit-breaker.

- derating factor(s), if any;
- need for checking operation after assembly to verify the mechanical operation;
- verification of the tripping operation by use of test button.

G.5 Constructional requirements

G.5.1 General

The design shall be such that it shall be possible to assemble the RCBO on site.

Design may be such that the device may be disassembled on site in accordance with the manufacturer's instructions.

For devices declared not suitable for disassembling, the disassembly shall leave permanent visible damage.

Compliance is checked according to G.6.4.

G.5.2 Degree of protection

The degree of protection of the r.c. unit shall be no less than that of the circuit-breaker with which it is to be assembled.

G.5.3 Mechanical requirements

The circuit-breaker and the r.c. unit shall fit together readily in the correct manner, and the design shall be such as to prevent an incorrect assembly.

There shall be no loose parts for coupling the tripping mechanisms.

Fixing means for assembly shall be captive.

NOTE Terminal covers, if any, are not covered by this requirement.

G.5.4 Electrical compatibility

It shall not be possible to assemble a circuit-breaker of a given rated voltage with an r.c. unit of a lower rated voltage.

It shall not be possible to assemble a circuit-breaker of a given rated current with an r.c. unit of a lower maximum current marking (see G.4.2.2).

The terminals of the r.c. unit shall be able to clamp the range of nominal cross-sections of conductors specified in Table 5 of IEC 60898-1:2002 for the rated currents of the circuit-breakers with which it is designed to be assembled.

The electrical interconnections between the r.c. unit and the circuit-breaker with which it is to be assembled shall form part of the r.c. unit.

It shall not be possible to assemble a circuit-breaker of a given rated short-circuit capacity with an r.c. unit so as to result in a lower short-circuit performance.

Compliance is checked by inspection and manual test.

G.6 Type tests and verifications

G.6.1 Tests on circuit-breakers

The circuit-breakers shall comply with the type tests of IEC 60898-1.

G.6.2 Tests on r.c. units

The r.c. units shall comply with the following type tests specified in Table 12 of this standard: tests of 9.3, 9.4, 9.5, 9.11 (if applicable), 9.14 and 9.15.

G.6.3 Tests on assembled circuit-breaker and r.c. unit (RCBO)

The type tests specified in Table 12 of this standard apply to RCBOs covered by this annex except as follows:

- 9.3, 9.5, 9.9.2.3, 9.14 and 9.15 do not apply;
- 9.4: tests shall be made on the interconnections between the circuit-breaker and the r.c. unit;
- 9.12 applies with the exception of 9.12.11.3 unless $I_{cn} = 1\,500\text{ A}$, and of 9.12.11.4 b).
- Conventional non tripping current 1,13 I_n shall be replaced everywhere by I_n .

G.6.4 Verification of marking and constructional requirements of RCBOs

Compliance with the requirements of G.4.1, G.4.2, G.4.3, G.5.1, G.5.2, G.5.3 and G.5.4 shall be checked by inspection and manual test, as applicable.

For devices declared suitable to be disassembled, compliance with the requirements of G.5.1 is checked by the following test to be performed at the beginning of test sequence D_0 in Table A.1.

The number of samples shall be in accordance with test sequence D_0+D_1 in Table A.3.

The r.c. unit and compatible circuit-breakers as declared by the manufacturer have to be assembled and disassembled five times. The r.c. unit and the compatible circuit breaker are then reassembled and used for the test of test sequence D_0 . After each assembly the correct operation of the combination shall be verified by using the test button. The RCBO shall trip each time.

G.7 Routine tests on the r.c. unit

Annex D applies, but the tests shall be made on the r.c. units in association with a test circuit-breaker adjusted to the most onerous conditions.

Annex H
(informative)

Void

Annex IA (informative)

Methods for determination of short-circuit power-factor

There is no uniform method by which the short-circuit power-factor can be determined with precision. Two examples of acceptable methods are given in this annex.

Method I – Determination from d.c. components

The angle φ may be determined from the curve of the d.c. component of the asymmetrical current wave between the instant of the short-circuit and the instant of contact separation as follows:

The formula for the d.c. component is:

$$i_d = i_{do} \cdot e^{-Rt/L}$$

where

- i_d is the value of d.c. components at the instant t ;
- i_{do} is the value of the d.c. component at the instant taken as time origin;
- L/R is the time-constant of the circuit, in seconds;
- t is the time, in seconds, taken from the initial instant;
- e is the base of the Neperian logarithms.

The time-constant L/R can be ascertained from the above formula as follows:

- a) measure the value of i_{do} at the instant of short-circuit and the value of i_d at another instant t before the contact separation;
- b) determine the value of $e^{-Rt/L}$ by dividing i_d by i_{do} ;
- c) from a table of values of e^{-x} determine the value of $-x$ corresponding to the ratio of i_d/i_{do} ;
- d) the value x represents Rt/L from which L/R is obtained.

Determine the angle φ from:

$$\varphi = \arctan \omega L/R$$

where ω is 2π times the actual frequency.

This method should not be used when the currents are measured by current transformers.

Method II – Determination with pilot generator

When a pilot generator is used on the same shaft as the test generator, the voltage of the pilot generator on the oscillogram may be compared in phase first with the voltage of the test generator and then with the current of the test generator.

The difference between the phase angles between pilot generator voltage and main generator voltage on the one hand and pilot generator voltage and test generator current on the other hand gives the phase-angle between the voltage and current of the test generator, from which the power-factor can be determined.

Annex IB
(informative)

Glossary of symbols

Rated current	I_n
Residual current	I_{Δ}
Rated residual operating current	$I_{\Delta n}$
Rated residual non-operating current	$I_{\Delta no}$
Rated voltage	U_n
Rated operational voltage	U_e
Rated insulation voltage	U_i
Rated making and breaking capacity	I_m
Rated short-circuit capacity	$I_{\Delta m}$
Rated conditional short-circuit current	I_{nc}
Rated conditional residual short-circuit current	$I_{\Delta c}$
Limiting value of the line voltage at which an RCBO functionally dependent on line voltage still operates	U_{χ}
Limiting value of the line voltage below which an RCBO functionally dependent on line voltage opens automatically	U_y

Annex IC (informative)

Examples of terminals

In this annex some examples of designs of terminals are given. The conductor location shall have a diameter suitable for accepting solid rigid conductors and a cross-sectional area suitable for accepting rigid stranded conductors (see 8.1.5).

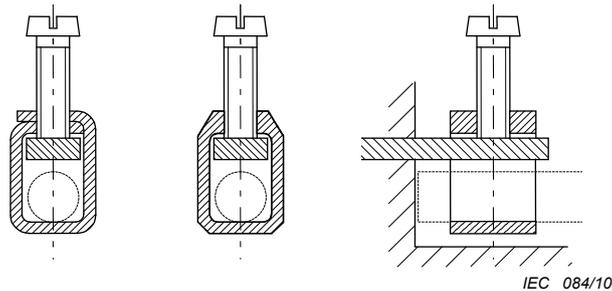


Figure IC.1a – Terminals with stirrup

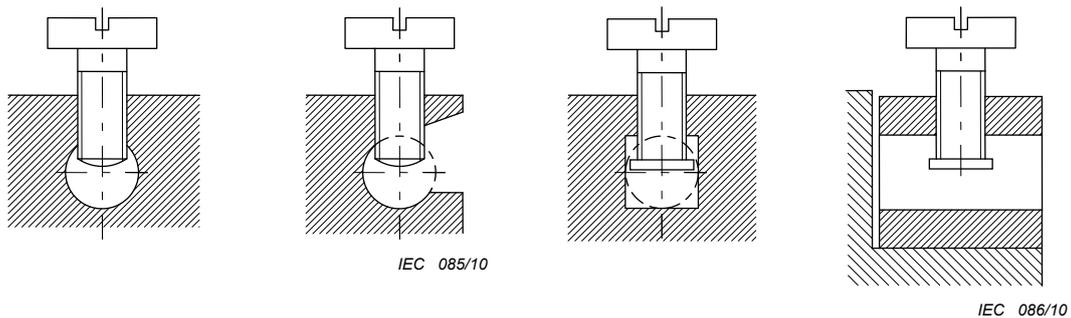


Figure IC.1b – Terminals without pressure plate

Figure IC.1c – Terminals with pressure plate

NOTE The part of the terminal containing the threaded hole and the part of the terminal against which the conductor is clamped by the screw may be two separate parts, as in the case of a terminal provided with a stirrup.

Figure IC.1 – Examples of pillar terminals

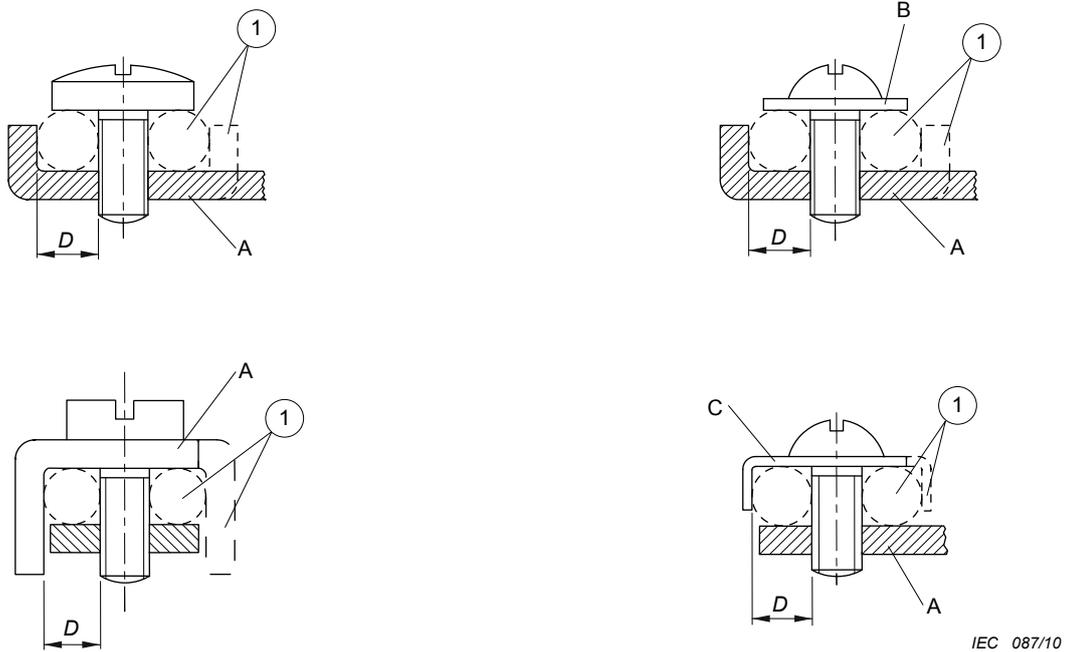


Figure IC.2a – Screw terminals

Screw not requiring washer or clamping plate

Screw requiring washer, clamping plate
or anti-spread device



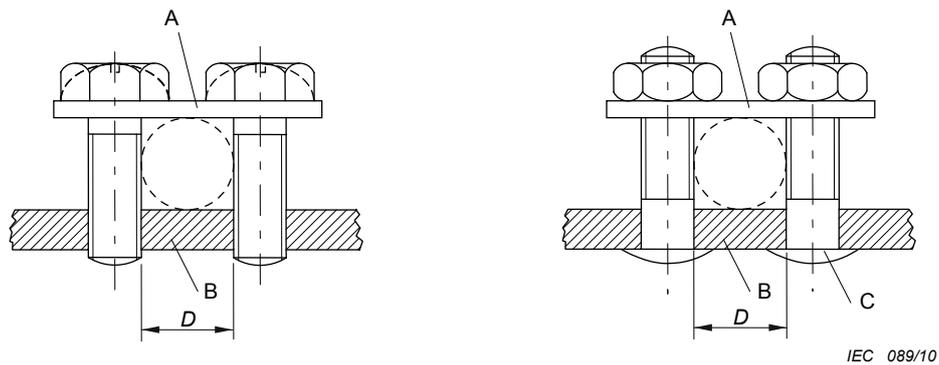
Figure IC2b – Stud terminals

Key

- 1 Optional
- A Fixed part
- B Washer or clamping plate
- C Anti-spread device
- D Conductor space
- E Stud

The part which retains the conductor in position may be of insulating material, provided the pressure necessary to clamp the conductor is not transmitted through the insulating material.

Figure IC.2 – Example of screw terminals and stud terminals

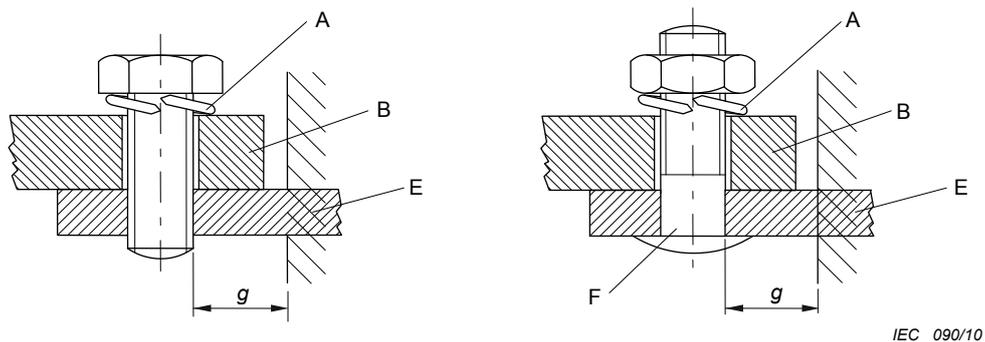


Key

- A Saddle
- B Fixed part
- C Stud
- D Conductor space

The two faces of the saddle may be of different shapes to accommodate conductors of either small or large cross-sectional area, by inverting the saddle. The terminals may have more than two clamping screws or studs.

Figure IC.3 – Example of saddle terminals



Key

- A Locking means
- B Cable lug or bar
- E Fixed part
- F Stud

For this type of terminal a spring washer or equally effective locking means shall be provided and the surface within the clamping area shall be smooth. For certain types of equipment the use of lug terminals of sizes smaller than that required is allowed.

Figure IC.4 – Examples of lug terminals

Annex ID
(informative)

Correspondence between ISO and AWG copper conductors

ISO sizes mm ²	AWG	
	Size	Cross-sectional area mm ²
1,0	18	0,82
1,5	16	1,3
2,5	14	2,1
4,0	12	3,3
6,0	10	5,3
10,0	8	8,4
16,0	6	13,3
25,0	3	26,7
35,0	2	33,6
50,0	0	53,5

In general, ISO sizes apply.

Upon request of the manufacturer, AWG sizes may be used.

Annex IE (informative)

Follow-up testing programme for RCBOs

IE.1 General

In order to guarantee the maintenance of the quality level of products, follow-up inspection procedures on the manufacturing process have to be set by the manufacturers.

This annex gives an example of follow-up procedure to be applied when manufacturing RCBOs.

It may be used as a guide by manufacturers for adapting their specific procedures and organization aimed at keeping the required quality level of the product output.

In particular any provision of the supplying follow-up as well as the manufacturing follow-up may be taken to guarantee the quality of the manufactured products on which the safe operation of the residual current device depends.

IE.2 Follow-up testing programme

The follow-up testing programme includes two series of tests.

IE.2.1 Quarterly follow-up testing programme

See Table IE.1, test sequence Q.

IE.2.2 Annual follow-up testing programme

See Table IE.1, test sequences Y1 to Y3.

NOTE The annual follow-up testing may be combined with the quarterly follow-up testing.

Table IE.1 – Test sequences during follow-up inspections

Test sequence	Clause or subclause	Test	Comments
Q	9.16	Test device	Items b) and c) only, except for the verification of the test circuit ampere turns
	9.9.1.2 a)	Residual operating characteristics	
	9.9.1.2 c)	Residual operating characteristics	
Y1	9.9.1.2 f)	Residual operating characteristics	
	9.7	Test of dielectric properties	
	9.10	Mechanical and electrical endurance	
Y2	9.22.1	Reliability (climatic test)	
Y3	9.23	Resistance to ageing	

IE.2.3 Sampling procedure

IE.2.3.1 Quarterly testing programme

For the purpose of the quarterly testing programme the following inspection levels are applied:

- normal inspection;
- tightened inspection.

Normal inspection will be used for the first follow-up inspection.

For successive inspections, normal or tightened inspection or stopping of the production is considered depending on the results of the on-going tests.

The following criteria for switching over from one level of inspection to another shall be applied:

- Stay at normal level

When normal inspection is applied, normal level is maintained if all six samples pass the test sequence (see Table IE.2, sequence Q). If five samples pass the test sequence, the subsequent inspection is made one month only after the preceding one with the same number of samples and the same test sequence.

- Normal to tightened

When normal inspection is applied, tightened inspection shall be applied when four samples only pass the test sequence.

- Normal to production stop

When normal inspection is applied and less than four samples pass the test sequence, the production shall be discontinued pending action to improve the quality.

- Tightened to normal

When tightened inspection is applied, normal inspection shall be applied when at least 12 samples pass the test sequence (see Table IE.2).

- Stay at tightened level

When, being at tightened level, 10 or 11 samples only pass the test sequence, the tightened level is maintained and the subsequent inspection is made one month after the preceding one with the same number of samples and the same test sequence.

- Tightened to production stop

In the event that four consecutive inspections remain on the tightened level or when less than 10 samples pass the test sequence, the production shall be discontinued pending action to improve the quality.

- Restart production

The production can restart after appropriate and confirmed corrective action. The restart shall be under tightened inspection conditions.

IE.2.3.2 Annual testing programme

For the purpose of the annual testing programme the following inspection levels are applied:

- normal inspection;
- tightened inspection.

Normal inspection will be used for the first follow-up inspection.

For successive inspections, normal or tightened inspections are considered, depending on the results of the on-going tests.

The following criteria for switching over from one level of inspection to another shall be applied.

– Stay at the normal level

When normal inspection is applied, normal level is maintained if all samples pass the test sequence. If two samples pass the test sequence Y1 and no failure occurs during the test sequences Y2 and Y3, the subsequent inspection is made three months after the preceding one with the same number of samples and the same test sequences.

– Normal to tightened

When normal inspection is applied, tightened inspection shall be applied when either:

- only one sample passes the sequence Y1;
- or one failure occurs during any one of test sequences Y2 or Y3.

The subsequent inspection shall be effected within three months of the preceding one, at tightened level for any test sequence in which the failure occurred and at normal level for the other test sequences.

– Normal to production stop

When normal inspection is applied and no sample passes the test sequence Y1, or more than one failure occurs during test sequences Y2 or Y3, the production shall be discontinued pending action to improve the quality.

– Tightened to normal

When tightened inspection is applied, normal inspection shall be applied when:

- at least five samples pass the test sequence Y1; and
- no failure occurs during the test sequence Y2 or Y3.

– Stay at tightened level

When, being at tightened level, four samples only pass the test sequence Y1 and no failure occurs during test sequences Y2 or Y3, the tightened level is maintained and the following inspection is made three months after the preceding one, with the same number of samples and the same test sequences.

– Tightened to production stop

In the event that four consecutive inspections remain on the tightened level or when during one annual inspection one of the following failures occurs:

- less than four samples pass the test sequence Y1;
- more than one failure occurs during test sequences Y2 or Y3;

the production shall be discontinued pending action to improve the quality.

– Restart production

The production can restart after appropriate and confirmed corrective action. The restart shall be under tightened inspection conditions.

IE.2.4 Number of samples to be tested

The numbers of samples for the various inspection levels are given in Table IE.2.

Table IE.2 – Number of samples to be tested

Inspection sequence	Number of samples for normal inspection	Number of samples for tightened inspection
Q	6	13
Y1, Y2, Y3	3 each	6 each

Out of each series of RCBOs of the same fundamental design only one set of samples need be tested, irrespective of the ratings.

For the purpose of this follow-up testing programme, RCBOs are considered to be of the same fundamental design, if they belong to the same classification according to 4.1, and

- the residual current operating means have identical tripping mechanism and identical relay or solenoid, except for:
 - the number of turns and cross-sectional area of the windings;
 - the sizes and material of the core of the differential transformer;
 - the rated residual current; and
- the electronic part, if any, is of the same design and uses the same components except for variations as to achieve different $I_{\Delta n}$.

Annex J

(normative)

Particular requirements for RCBOs with screwless type terminals for external copper conductors

J.1 Scope

This annex applies to RCBOs within the scope of Clause 1, equipped with screwless terminals, for current not exceeding 20 A primarily suitable for connecting unprepared (see J.3.6) copper conductors of cross-section up to 4 mm².

NOTE 1 In AT, CZ, DE, DK, NL, NO and CH the upper limit of current for use of screwless terminals is 16 A.

In this annex, screwless terminals are referred to as terminals and copper conductors are referred to as conductors.

NOTE 2 The numbering in this annex follows that of the main body of the text. Hence, the numbering is not necessarily continuous. Any content which is not explicitly mentioned, applies, without modification.

J.2 Normative references

Clause 2 applies.

J.3 Definitions

As a complement to Clause 3, the following definitions apply:

J.3.1

clamping units

parts of the terminal necessary for mechanical clamping and the electrical connection of the conductors including the parts which are necessary to ensure correct contact pressure

J.3.2

screwless-type terminal

terminal for the connection and subsequent disconnection obtained directly or indirectly by means of springs, wedges or the like

Note 1 to entry: Examples are given in Figure J.2

J.3.3

universal terminal

terminal for the connection and disconnection of all types of conductors (rigid and flexible)

Note 1 to entry: In the following countries only universal screwless type terminals are accepted: AT, BE, CN, DK, DE, ES, FR, IT, PT, SE and CH.

J.3.4

non-universal terminal

terminal for the connection and disconnection of a certain kind of conductor only (e.g. rigid-solid conductors only or rigid-[solid or stranded] conductors only)

J.3.5

push-wire terminal

non-universal terminal in which the connection is made by pushing-in rigid (solid or stranded) conductors

J.3.6**unprepared conductor**

conductor which has been cut and the insulation of which has been removed over a certain length for insertion into a terminal

Note 1 to entry: A conductor the shape of which is arranged for introduction into a terminal or of which the strands may be twisted to consolidate the end, is considered to be an unprepared conductor.

Note 2 to entry: The term "unprepared conductor" means conductor not prepared by soldering of the wire, use of cable lugs, formation of eyelets, etc., but includes its reshaping before introduction into the terminal or, in the case of flexible conductor, by twisting it to consolidate the end.

J.4 Classification

Clause 4 applies.

J.5 Characteristics of RCBOs

Clause 5 applies.

J.6 Marking and other product information

In addition to Clause 6, the following requirements apply:

Universal terminals:

- no marking.

Non-universal terminals:

- terminals declared for rigid-solid conductors shall be marked by the letters "sol";
- terminals declared for rigid (solid and stranded) conductors shall be marked by the letter "r";
- terminals declared for flexible conductors shall be marked by the letter "f".

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

An appropriate marking indicating the length of insulation to be removed before insertion of the conductor into the terminal shall be shown on the RCBO.

The manufacturer shall also provide information, in his literature, on the maximum number of conductors which may be clamped.

J.7 Standard conditions for operation in service and for installation

Clause 7 applies.

J.8 Requirements for construction and operation

Clause 8 applies, with the following modifications.

In 8.1.5, only 8.1.5.1, 8.1.5.2, 8.1.5.3, 8.1.5.6 and 8.1.5.7 apply.

Compliance is checked by inspection and by the tests of J.9.1 and J.9.2 of this annex, instead of 9.4 and 9.5.

In addition the following requirements apply.

J.8.1 Connection or disconnection of conductors

The connection or disconnection of conductors shall be made

- by the use of a general purpose tool or by a convenient device integral with the terminal to open it and to assist the insertion or the withdrawal of the conductors (e.g. for universal terminals);

or, for rigid conductors

- by simple insertion. For the disconnection of the conductors an operation other than a pull on the conductor shall be necessary (e.g. for push-wire terminals).

Universal terminals shall accept rigid (solid or stranded) and flexible unprepared conductors.

Non-universal terminals shall accept the types of conductors declared by the manufacturer.

Compliance is checked by inspection and by the tests of J.9.1 and J.9.2.

J.8.2 Dimensions of connectable conductors

The dimensions of connectable conductors are given in Table J.1.

The ability to connect these conductors shall be checked by inspection and by the tests of J.9.1 and J.9.2.

Table J.1 – Connectable conductors

Connectable conductors and their theoretical diameter									
Metric					AWG				
Rigid			Flexible		Rigid			Flexible	
	Solid	Stranded				Solid ^{a)}	Class B stranded ^{a)}		Classes I, K, M, stranded ^{b)}
mm ²	∅ mm	∅ mm	mm ²	∅ mm	gauge	∅ mm	∅ mm	gauge	∅ mm
1,0	1,2	1,4	1,0	1,5	18	1,02	1,16	18	1,28
1,5	1,5	1,7	1,5	1,8	16	1,29	1,46	16	1,60
2,5	1,9	2,2	2,5	2,3	14	1,63	1,84	14	2,08
4,0	2,4	2,7	4,0	2,9	12	2,05	2,32	12	2,70

NOTE Diameters of the largest rigid and flexible conductors are based on IEC 60228, and, for AWG conductors, on ASTM B 172-71, and ICEA publications S-19-81, S-66-524 and S-68-516.

^{a)} Nominal diameter + 5 %.

^{b)} Largest diameter + 5 % for any of the three classes I, K and M.

J.8.3 Connectable cross-sectional areas

The nominal cross-sections to be clamped are defined in Table J.2.

**Table J.2 – Cross-sections of copper conductors
connectable to screwless-type terminals**

Rated current A	Nominal cross-sections to be clamped mm ²
Up to and including 13	1 up to and including 2,5
Above 13 up to and including 20	1,5 up to and including 4

Compliance is checked by inspection and by the tests of J.9.1 and J.9.2.

J.8.4 Insertion and disconnection of conductors

The insertion and disconnection of the conductors shall be made in accordance with the manufacturer's instructions.

Compliance is checked by inspection.

J.8.5 Design and construction of terminals

Terminals shall be so designed and constructed that:

- each conductor is clamped individually;
- during the operation of connection or disconnection the conductors can be connected or disconnected either at the same time or separately;
- inadequate insertion of the conductor is avoided.

It shall be possible to clamp securely any number of conductors up to the maximum provided for.

Compliance is checked by inspection and by the tests of J.9.1 and J.9.2.

J.8.6 Resistance to ageing

The terminals shall be resistant to ageing.

Compliance is checked by the test of J.9.3.

J.9 Tests

Clause 9 applies, by replacing 9.4 and 9.5 by the following tests:

J.9.1 Test of reliability of screwless terminals

J.9.1.1 Reliability of screwless system

The test is carried out on three terminals of poles of new samples, with copper conductors of the rated cross sectional area in accordance with Table J.2. The types of conductors shall be in accordance with J.8.1.

The connection and subsequent disconnection shall be made five times with the smallest diameter conductor and successively five times with the largest diameter conductor.

New conductors shall be used each time, except for the fifth time, when the conductor used for the fourth insertion is clamped at the same place. Before insertion into the terminal, wires of stranded rigid conductors shall be re-shaped and wires of flexible conductors shall be twisted to consolidate the ends.

For each insertion, the conductors are either pushed as far as possible into the terminal or shall be inserted so that adequate connection is obvious.

After each insertion, the conductor being inserted is rotated 90 ° along its axis at the level of the clamped section and subsequently disconnected.

After these tests, the terminal shall not be damaged in such a way as to impair its further use.

J.9.1.2 Test of reliability of connection

Three terminals of poles of new samples are fitted with new copper conductors of the type and of the rated cross sectional area according to Table J.2.

The types of conductors shall be in accordance with J.8.1.

Before insertion into the terminal, wires of stranded rigid conductors and flexible conductors shall be reshaped and wires of flexible conductors shall be twisted to consolidate the ends.

It shall be possible to fit the conductor into the terminal without undue force in the case of universal terminals and with the force necessary by hand in the case of push-wire terminals.

The conductor is either pushed as far as possible into the terminal or shall be inserted so that adequate connection is obvious.

After the test, no wire of the conductor shall have escaped outside the terminal.

J.9.2 Tests of reliability of terminals for external conductors: mechanical strength

For the pull-out test three terminals of poles of new samples are fitted with new conductors of the type and of the minimum and maximum cross-sectional areas according to Table J.2.

Before insertion into the terminal, wires of stranded rigid conductors and flexible conductors shall be reshaped and wires of flexible conductors shall be twisted to consolidate the ends.

Each conductor is then subjected to a pull force of the value shown in Table J.3. The pull is applied without jerks for 1 min in the direction of the axis of the conductor.

Table J.3 – Pull forces

Cross-sectional area mm ²	Pull force N
1,0	35
1,5	40
2,5	50
4,0	60

During the test the conductor shall not slip out of the terminal.

J.9.3 Cycling test

The test is made with new copper conductors having cross section according to Table 13.

The test is carried out on new samples (a sample is one pole), the number of which is defined below, according to the type of terminals:

- universal terminals for rigid (solid and stranded) and flexible conductors: 3 samples each (6 samples in total);
- non-universal terminals for solid conductors only: 3 samples;
- non-universal for rigid (solid and stranded) conductors: 3 samples each (6 samples);

NOTE In case of rigid conductors, solid conductors should be used (if solid conductors are not available in a given country, stranded conductors may be used).

- non-universal for flexible conductors only: 3 samples.

A conductor having the cross section defined in Table 13 is connected in series as in normal use to each of the three samples as defined on Figure J.1.

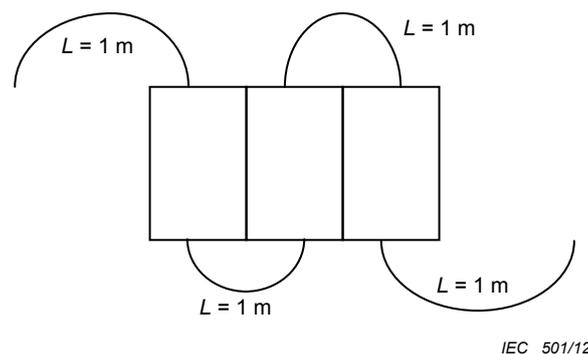


Figure J.1 – Connecting samples

The sample is provided with a hole (or equivalent) in order to measure the voltage drop on the terminal.

The whole test arrangement, including the conductors, is placed in a heating cabinet which is initially kept at a temperature of $(20 \pm 2) ^\circ\text{C}$.

To avoid any movement of the test arrangement until all the following voltage drop tests have been completed it is recommended that the poles are fixed on a common support.

Except during the cooling period, a test current corresponding to the rated current of the circuit breaker is applied to the circuit.

The samples shall be then subjected to 192 temperature cycles, each cycle having a duration of approximately 1 h, as follows:

The air temperature in the cabinet is raised to $40 ^\circ\text{C}$ in approximately 20 min. It is maintained within $\pm 5 ^\circ\text{C}$ of this value for approximately 10 min.

The samples are then allowed to cool down in approximately 20 min to a temperature of approximately $30 ^\circ\text{C}$, forced cooling being allowed. They are kept at this temperature for approximately 10 min and, if necessary for measuring the voltage drop, allowed to cool down further, to a temperature of $(20 \pm 2) ^\circ\text{C}$.

The maximum voltage drop, measured at each terminal, at the end of the 192nd cycle, with the nominal current shall not exceed the smaller of the two following values:

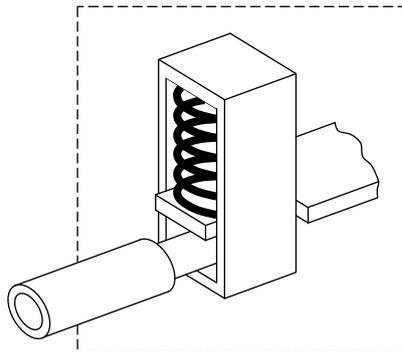
- either 22,5 mV;
- or 1,5 times the value measured after the 24th cycle.

The measurement shall be made as near as possible to the area of contact on the terminal.

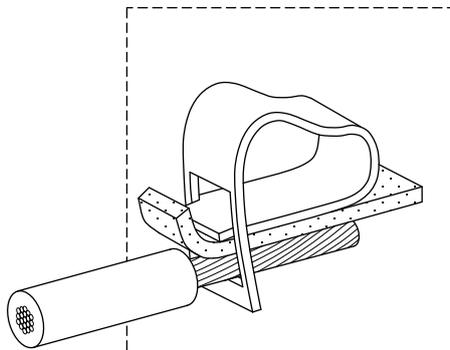
If the measuring points cannot be positioned closely to the point of contact, the voltage drop within the part of the conductor between the ideal and the actual measuring points shall be deducted from the voltage drop measured.

The temperature in the heating cabinet shall be measured at a distance of at least 50 mm from the samples.

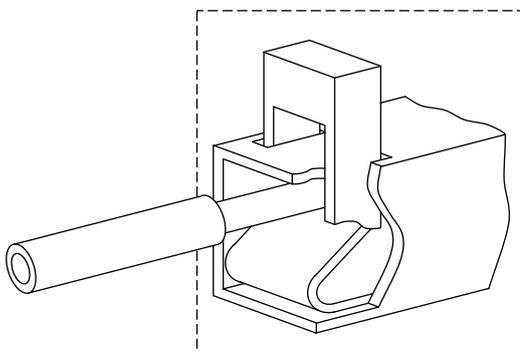
After this test an inspection with the naked eye, by normal or corrected vision, without additional magnification, shall show no changes evidently impairing further use, such as cracks, deformations or the like.



Screwless-type terminal with indirect pressure



Screwless-type terminal with direct pressure



Screwless-type terminal with actuating element

Figure J.2 – Examples of screwless-type terminals

J.10 Reference documents

IEC 60228, *Conductors of insulated cables*

IEC 60998-1, *Connecting devices for low-voltage circuits for household and similar purposes – Part 1: General requirements*

IEC 60998-2-2, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units*

IEC 60999 (all parts), *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units*

ASTM B172-01a, *Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors*

ICEA S-19-81 / NEMA WC3, *Rubber-Insulated Wire and Cable* ⁴

ICEA S-66-524 / NEMA WC7, *Cross-Linked-Thermosetting-Polyethylene Insulated Wire and Cable* ¹

ICEA S-68-516 / NEMA WC8, *Ethylene-Propylene-Rubber Insulated Wire and Cable* ⁵

⁴ Withdrawn.

⁵ Withdrawn.

Annex K (normative)

Particular requirements for RCBOs with flat quick-connect terminations

K.1 Scope

This annex applies to RCBOs within the scope of Clause 1, equipped with flat quick-connect terminations consisting of a male tab (see K.3.2) with nominal width 6,3 mm and thickness 0,8 mm, to be used with a mating female connector for connecting electrical copper conductors according to the manufacturer's instructions, for rated currents up to and including 16 A.

NOTE 1 The use of RCBOs with flat quick-connect terminations for rated currents up to and including 20 A is accepted in BE, FR, IT, ES, PT and US.

The connectable electrical copper conductors are flexible, having a cross-sectional area up to and including 4 mm², or rigid stranded, having a cross-sectional area up to and including 2,5 mm² (AWG equal to or greater than 12).

This annex applies exclusively to RCBOs having male tabs as an integral part of the device.

NOTE 2 The numbering in this annex follows that of the main body of the text. Hence, the numbering is not necessarily continuous. Any content which is not explicitly mentioned applies without modification.

K.2 Normative references

As a complement to Clause 2, the following normative reference applies:

IEC 61210, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

K.3 Definitions

As a complement to Clause 3, the following definitions apply:

K.3.1

flat quick-connect termination

electrical connection consisting of a male tab and a female connector which can be pushed into and withdrawn with or without the use of a tool

K.3.2

male tab

portion of a quick-connect termination which receives the female connector

K.3.3

female connector

portion of a quick-connect termination which is pushed onto the male tab

K.3.4

detent

dimple (depression) or hole in the male tab which engages a raised portion on the female connector to provide a latch for the mating parts.

K.4 Classification

Clause 4 applies.

K.5 Characteristics of RCBOs

Clause 5 applies.

K.6 Marking and other product information

The whole of Clause 6 applies, with the following addition after the lettered item k).

The following information regarding the female connector according to IEC 61210 and the type of conductor to be used shall be given in the manufacturers' instructions:

- l) manufacturer's name or trade mark;
- m) type reference;
- n) information on cross-sections of conductors and colour code of insulated female connectors (see Table K.1 below);
- o) the use of only silver or tin-plated copper alloys.

Table K.1 – Informative table on colour code of female connectors in relationship with the cross section of the conductor

Cross-section of the conductor mm ²	Colour code of the female connector
1	Red
1,5	Red or blue
2,5	Blue or yellow
4	Yellow

K.7 Standard conditions for operation in service and for installation

Clause 7 applies.

K.8 Requirements for construction and operation

Clause 8 applies, with the following exceptions:

Replace the contents of 8.1.3 by the following text:

K.8.1 Clearances and creepage distances (see also Annex B)

Subclause 8.1.3 applies, the female connectors being fitted to the male tabs of the RCBO.

Replace the contents of 8.1.5 by the following text:

K.8.2 Terminals for external conductors

K.8.2.1 Male tabs and female connectors shall be of a metal having mechanical strength, electrical conductivity and resistance to corrosion adequate for their intended use.

NOTE Silver or tin plated copper alloys are examples of suitable solutions.

K.8.2.2 The nominal width of the male tab is 6,3 mm and the thickness 0,8 mm, applicable to rated currents up to and including 16 A.

NOTE 1 The use for rated currents up to and including 20 A is accepted in BE, FR, IT, PT, ES and US.

The dimensions of the male tab shall comply with those specified in Table K.3 and in figures K.2, K.3, K.4 and K.5, where the dimensions A, B, C, D, E, F, J, M, N and Q are mandatory.

The dimensions of the female connector which may be fitted-on are given in Figure K.6 and in Table K.4.

NOTE 2 The shapes of the various parts may deviate from those given in the figures, provided that the specified dimensions are not influenced and the test requirements are complied with, for example: corrugated tabs, folded tabs, etc.

Compliance is checked by inspection and by measurement.

K.8.2.3 Male tabs shall be securely retained.

Compliance is checked by the mechanical overload test of K.9.1.

K 9 Tests

Clause 9 applies, with the following modifications:

Replace the contents of 9.5 by the following text:

K.9.1 Mechanical overload-force

This test is done on 10 terminals of RCBOs, mounted as in normal use when wiring takes place.

The axial push force, and successively the axial pull force specified in the following Table K.2, are gradually applied to the male tab integrated in the RCBO, once only with a suitable test apparatus.

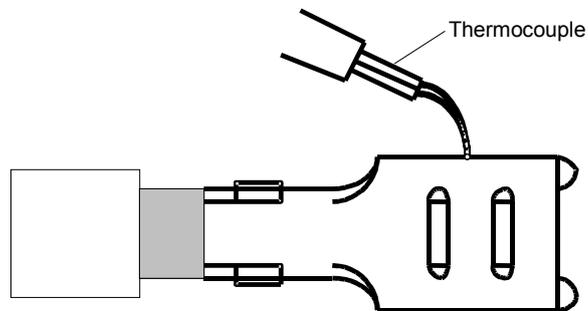
Table K.2 – Overload test forces

Push N	Pull N
96	88

No damage which could impair further use shall occur to the tab or to the RCBO in which the tab is integrated.

Add the following text to 9.8.3:

Fine-wire thermocouples shall be placed in such a way as not to influence the contact or the connection area. An example of placement is shown in Figure K.1.



IEC 503/12

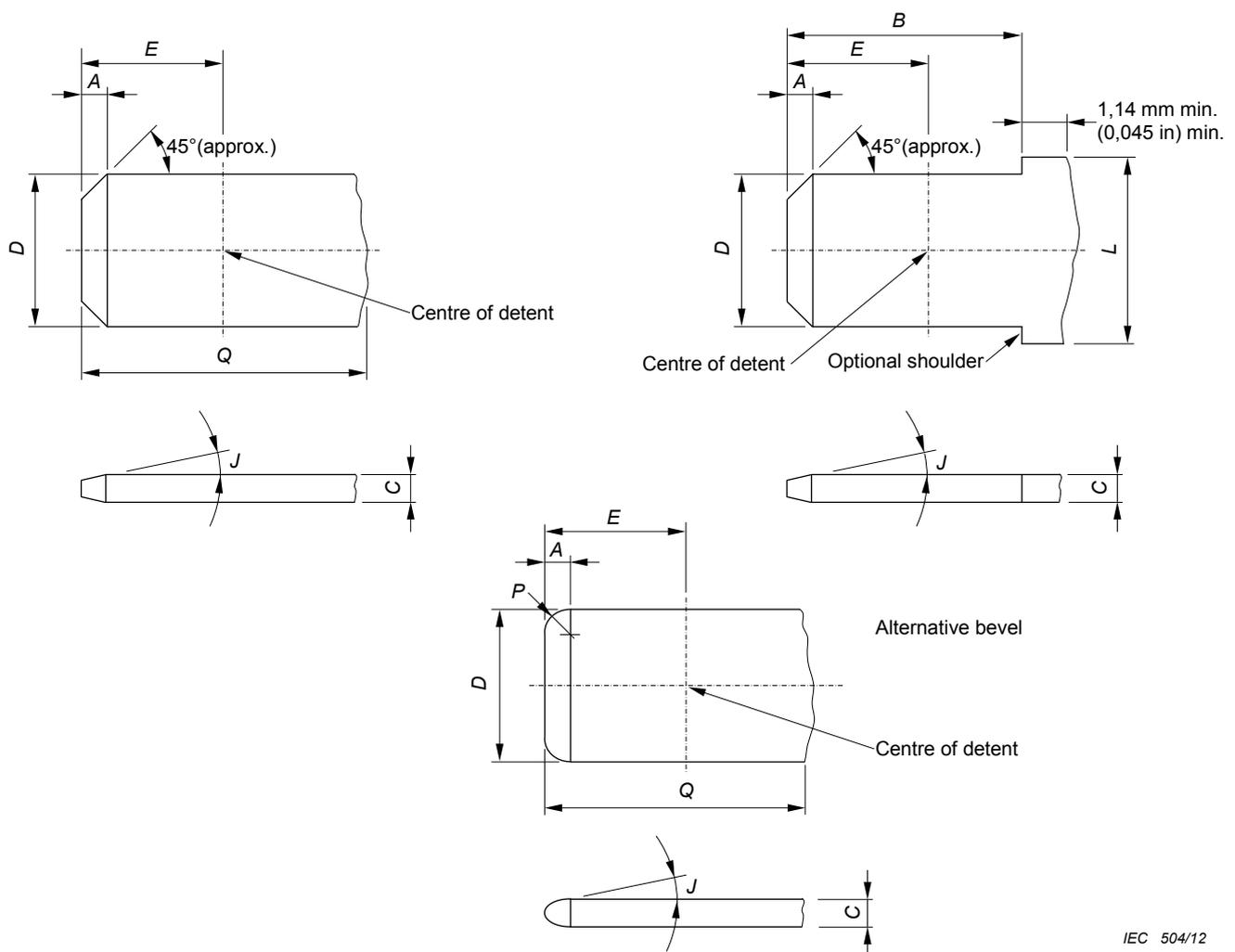
Figure K.1 – Example of position of the thermocouple for measurement of the temperature-rise

Table K.3 – Dimensions of tabs

Nominal size mm		<i>A</i>	<i>B</i> min	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>	<i>J</i>	<i>M</i>	<i>N</i>	<i>P</i>	<i>Q</i> min
		6,3 × 0,8	Dimple	1,0		0,84	6,40	4,1	2,0	12 °	2,5	2,0
0,7	7,8			0,77	6,20	3,6	1,6	8 °	2,2	1,8	0,7	8,9
Hole	1,0			0,84	6,40	4,7	2,0	12 °			1,8	
	0,5		7,8	0,77	6,20	4,3	1,6	8 °			0,7	8,9

NOTE 1 For the dimensions *A* to *Q* refer to Figures K.2 to K.5.

NOTE 2 Where two values are shown in one column, they give the maximum and the minimum dimension.



NOTE 1 Bevel A of 45 ° need not be a straight line if it is within the confines shown.

NOTE 2 Dimension L is not specified and may vary by the application (for example fixing).

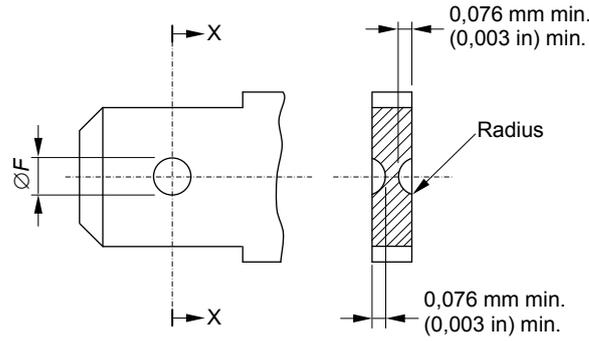
NOTE 3 Dimension C of tabs can be produced from more than one layer of material provided that the resulting tab complies in all respects with the requirements of this standard. A radius on the longitudinal edge of the tab is permissible.

NOTE 4 The sketches are not intended to govern the design except with regard to the dimensions shown.

NOTE 5 The thickness C of the male tab may vary beyond Q or beyond $B + 1,14 \text{ mm}$ (0,045 in)

NOTE 6 All portions of the tabs are flat and free of burrs or raised plateaus, except that there may be a raised plateau over the stock thickness of 0,025 mm (0,001 in) per side, in an area defined by a line surrounding the detent and distant from it by 1,3 mm (0,051 in).

Figure K.2 – Dimensions of male tabs

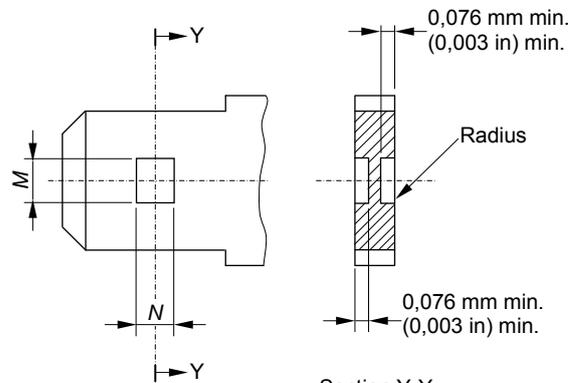


Section X-X

IEC 505/12

Detent shall be located within 0,076 mm (0,003 in) of the centre-line of the tab.

Figure K.3 – Dimensions of round dimple detents (see Figure K.2)

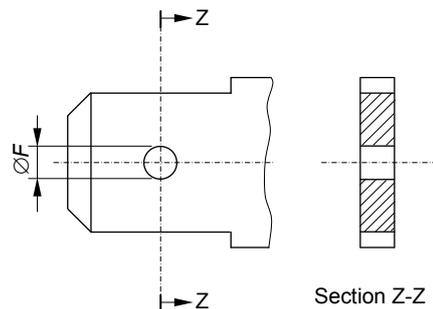


Section Y-Y

IEC 506/12

Detent shall be located within 0,13 mm (0,005 in) of the centre-line of the tab.

Figure K.4 – Dimensions of rectangular dimple detents (see Figure K.2)

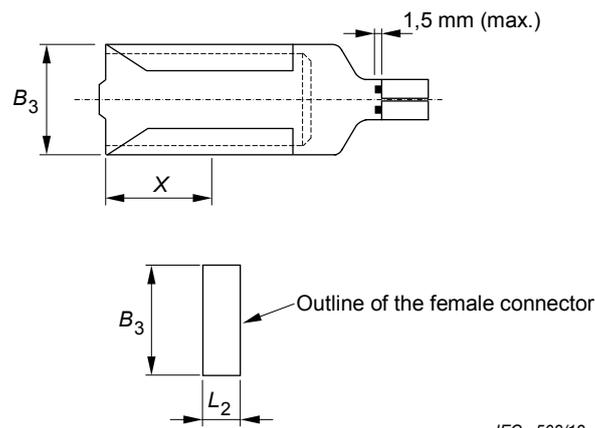


Section Z-Z

IEC 507/12

Detent shall be located within 0,076 mm (0,003 in) of the centre-line of the tab.

Figure K.5 – Dimensions of hole detents



Dimensions B_3 and L_2 are mandatory.

NOTE 1 For determining female connector dimensions varying from B_3 and L_2 it is necessary to refer to the tab dimensions in order to ensure that in the most onerous conditions the engagement (and detent, if fitted) between tab and female connector is correct.

NOTE 2 If a detent is provided, the dimension X is at manufacturer's discretion in order to meet the requirements of the performance clauses.

NOTE 3 Female connectors should be so designed that undue insertion of the conductor into the crimping area is visible or prevented by a stop in order to avoid any interference between the conductor and a fully inserted tab.

NOTE 4 The sketches are not intended to govern the design except as regards the dimensions shown.

Figure K.6 – Dimensions of female connectors

Table K.4 – Dimensions of female connectors

Tab size mm	Dimensions of female connector mm	
	B_3 max	L_2 max
6,3 × 0,8	7,8	3,5

K.10 Reference documents

IEC 61210, *Connecting devices – Flat quick-connect terminations for electrical copper conductors – Safety requirements*

Annex L (normative)

Specific requirements for RCBOs with screw-type terminals for external untreated aluminium conductors and with aluminium screw-type terminals for use with copper or with aluminium conductors

L.1 Scope

This annex applies to RCBOs within the scope of this standard, equipped with screw-type terminals of copper – or of alloys containing at least 58 % of copper (if worked cold) or at least 50 % of copper (if worked otherwise), or of other metal or suitably coated metal, no less resistant to corrosion than copper and having mechanical properties no less suitable – for use with untreated aluminium conductors, or with screw-type terminals of aluminium material for use with copper or aluminium conductors.

In this annex, copper-clad and nickel-clad aluminium conductors are considered as aluminium conductors.

NOTE 1 In AT, AU and DE, the use of aluminium screw-type terminals for use with copper conductors is not allowed.

- In Austria, Switzerland and Germany, terminals for aluminium conductors only are not allowed.
- In Spain, the use of aluminium conductors is not allowed for final circuits in household and similar installations e.g. offices, shops..
- In Denmark, the minimum cross-sectional area for aluminium conductors is 16 mm².

NOTE 2 The numbering in this annex follows that of the main body of the text. Hence, the numbering is not necessarily continuous. Any content which is not explicitly mentioned, applies, without modification.

L.2 Normative references

Clause 2 applies with the following addition:

IEC 61545:1996, *Connecting devices – Devices for the connection of aluminium conductors in clamping units of any material and copper conductors in aluminium bodied clamping units*

L.3 Definitions

As a complement to Clause 3, the following additional definitions apply for the purpose of this annex.

L.3.1 treated conductor

contact area of a conductor that has had its oxide layer on the outside strands scraped away and/or has had a compound added to improve connectability and/or prevent corrosion

L.3.2 untreated/unprepared conductor

conductor which has been cut and the insulation of which has been removed for insertion into a terminal

Note 1 to entry: A conductor, the shape of which is arranged for introduction into a terminal or the strands of which are twisted to consolidate the end, is considered to be an unprepared conductor.

L.3.3**equalizer**

arrangement used in the test loop to ensure an equipotentiality point and uniform current density in a stranded conductor, without adversely affecting the temperature of the conductor(s)

L.3.4**reference conductor**

continuous length of the same type and size conductor as that used in the terminal unit under test and connected in the same series circuit. It enables the reference temperature and, if required, reference resistance to be determined

L.3.5**stability factor Sf**

measure of temperature stability of a terminal unit during the current cycling test

L.4 Classification

Clause 4 applies.

L.5 Characteristics of RCBOs

Clause 5 applies.

L.6 Marking and other product information

In addition to Clause 6, the following requirements apply:

The terminal marking defined in Table L.1 shall be marked on the RCBO, near the terminals.

The other information concerning the number of conductors, the screw torque values (if different from Table 14) and the cross-sections shall be indicated on the RCBO.

Table L.1 – Marking for terminals

Conductor types accepted	Marking
Copper only	None
Aluminium only	Al
Aluminium and copper	Al/Cu

The manufacturer shall state in his catalogue that, for the clamping of an aluminium conductor the tightening torque shall be applied with appropriate means.

L.7 Standard conditions for operation in service and for installation

Clause 7 applies.

L.8 Requirements for construction and operation

Clause 8 applies, with the following exceptions:

Add the following text at the end of 8.1.5.2:

For the connection of aluminium conductors, RCBOs shall be provided with screw-type terminals allowing the connection of conductors having nominal cross-sections as shown in Table L.2.

Terminals for the connection of aluminium conductors and terminals of aluminium for the connection of copper or aluminium conductors shall have mechanical strength adequate to withstand the tests of 9.4, with the test conductors tightened with the torque indicated in Table 14, or with the torque specified by the manufacturer, which shall never be lower than that specified in Table 14.

Table L.2 – Connectable cross-sections of aluminium conductors for screw-type terminals

Rated Current ^{a)} A	Range of nominal cross-sections ^{b)} to be clamped mm ²
Up to and including 13	1 to 4
Above 13 up to and including 16	1 to 6
Above 16 up to and including 25	1,5 to 10
Above 25 up to and including 32	2,5 to 16
Above 32 up to and including 50	4 to 25
Above 50 up to and including 80	10 to 35
Above 80 up to and including 100	16 to 50
Above 100 up to and including 125	25 to 70

^{a)} It is required that, for current ratings up to and including 50 A, terminals be designed to clamp solid conductors as well as rigid stranded conductors; the use of flexible conductors is permitted. Nevertheless, it is permitted that terminals for conductors having cross-sections from 1 mm² up to 10 mm² be designed to clamp solid conductors only.

^{b)} Maximum wire sizes of Table 5, increased according to Table D.2 of IEC 61545:1996.

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

8.1.5.4

Replace the text of 8.1.5.4 by the following:

Terminals shall allow the conductors to be connected without special preparation.

Compliance is checked by inspection and the tests of L.9.

L.9 Tests

Clause 9 applies, with the following modifications/additions:

For the tests which are influenced by the material of the terminal and the type of conductor that can be connected, the test conditions of Table L.3 are applied.

Additionally the test of L.9.2 is carried out on terminals separated from the RCBO.

Table L.3 – List of tests according to the material of conductors and terminals

Material of terminals	Material according to 8.1.4.4 a)	Al a)	
		Cu	Al
Material of conductor (Table L.1)	Al Use Tables L.2 and L.5	Cu Use Tables 8 and 13	Al Use Tables L.2 and L.5
9.4 Reliability of screws	Use Tables L.2, L.5 and 14	Use Tables 8, 13 and 14	Use Tables L.2, L.5 and 14
9.5.1 Pull-out test b)	Use Tables L.2, L.5 and 14	Use Tables 8, 13 and 14	Use Tables L.2, L.5 and 14
9.5.2 Damage of the conductor	Use Tables L.2, L.5 and 14	Use Tables 8, 13 and 14	Use Tables L.2, L.5 and 14
9.5.3 Insertion of the conductor	Use Table L.4	Use Table 16	Use Table L.4
9.8 Temperature rise	Use Table L.5	Use Table 13	Use Table L.5
9.22 Verification of reliability	Use Table L.5	Use Table 13	Use Table L.5
L.9.2 Cycling test	Use Table 14	Use Table 14	Use Table 14
<p>a) Use test sequences A and B and number of samples defined in Annex C. For RCBOs which are able to be connected to Al or Cu conductors, the test sequences and number of samples have to be doubled (one for the Cu conductor and one for the Al conductor)</p> <p>b) For the pull-out test of 9.5.1, the value for 70 mm² wire is under consideration.</p>			

Table L.4 – Connectable conductors and their theoretical diameters

Metric					AWG				
Rigid			Flexible (copper only)		Rigid			Flexible (copper only)	
S	Solid	Stranded	S			Solid a)	Class B stranded a)		Classes b) I, K, M stranded
mm ²	Ø mm	Ø mm	mm ²	Ø mm	Gauge	Ø mm	Ø mm	Gauge	mm
1,0	1,2	1,4	1,0	1,5	18	1,07	1,23	18	1,28
1,5	1,5	1,7	1,5	1,8	16	1,35	1,55	16	1,50
2,5	1,9	2,2	2,5	2,3 ^{c)}	14	1,71	1,95	14	2,08
4,0	2,4	2,7	4,0	2,9 ^{c)}	12	2,15	2,45	12	2,70
6,0	2,9	3,3	4,0	2,9 ^{c)}	10	2,72	3,09		
10,0	3,7	4,2	6,0	3,9	8	3,43	3,89	10	3,36
16,0	4,6	5,3	10,0	5,1	6	4,32	4,91	8	4,32
25,0		6,6	16,0	6,3	4	5,45	6,18	6	5,73
35,0		7,9	25,0	7,8	2	6,87	7,78	4	7,25
					1	7,72	8,85		
50,0		9,1	35	9,2	0	8,51	9,64		12,08
70,0		12,0	50	12	00	9,266	10,64		

NOTE Diameters of the largest rigid and flexible conductors are based on IEC 60228 and, for AWG conductors, on ASTM B 172-71, ICEA S-19-81, ICEA S-66-524, ICEA S-68-516.

a) Nominal diameter + 5 %.

b) Largest diameter + 5 % for any of the three classes I, K, M.

c) Dimensions for class 5 flexible conductors only, according to IEC 60228.

L.9.1 Test conditions

Subclause 9.1 applies, except that the Al conductors to be connected are taken from Table L.5.

Table L.5 – Cross sections (S) of aluminium test conductors corresponding to the rated currents

S mm ²	I _n A
1,5	I _n ≤ 6
2,5	6 < I _n ≤ 13
4	13 < I _n ≤ 20
6	20 < I _n ≤ 25
10	25 < I _n ≤ 32
16	32 < I _n ≤ 50
25	50 < I _n ≤ 63
35	63 < I _n ≤ 80
50	80 < I _n ≤ 100
70	100 < I _n ≤ 125

L.9.2 Current cycling test

L.9.2.1 General

This test verifies the stability of the screw-type terminal by comparing the temperature performance with that of the reference conductor under accelerated cycling conditions.

This test is carried out on separate terminals.

L.9.2.2 Preparation

The test is performed on four specimens, each one made by a couple of terminals, assembled in a manner which represents the use of the terminals in the RCBO (see examples shown in Figures L.2 to L.6). The screw-type terminals which have been removed from the product shall be attached to the conducting parts of the same cross-section, shape, metal and finish as that on which they are mounted on the product. The screw-type terminals shall be fixed to the conducting parts in the same manner (position, torque, etc.) as on the product. If one specimen fails during the test, four other specimens shall be tested and no other failures are admitted.

L.9.2.3 Test arrangement

The general arrangement of the samples shall be as shown in Figure L.1.

Ninety per cent of the value of torque stated by the manufacturer or, if not stated, selected in Table 11 shall be used for the test specimens.

The test is carried out with conductors according to Table L.5. The length of the test conductor from the point of entry to the screw-type terminal specimens to the equalizer (see L.3.3) shall be as in Table L.6.

Table L.6 – Test conductor length

Conductor cross section	Conductor wire size	Minimum conductor length
mm ²	AWG	mm
$S \leq 10,0$	≤ 8	200
$16,0 \leq S \leq 25,0$	6 to 3	300
$35,0 \leq S \leq 70,0$	2 to 00	460

Test conductors are connected in series with a reference conductor of the same cross-section.

The length of the reference conductor shall be approximately at least twice the length of the test conductor.

Each free end of the test and reference conductor(s) not connected to a screw-type terminal specimen shall be welded or brazed to a short length of an equalizer of the same material as the conductor and of cross section not greater than that given in Table L.7. All strands of the conductor shall be welded or brazed to make an electrical connection with the equalizer.

Tool-applied compression type terminations without welding may be used for the equalizer if acceptable to the manufacturer and if the same performance is provided.

Table L.7 – Equalizer and busbar dimensions

Range of test current A	Maximum cross section mm ²	
	Al	Cu
0 – 50	45	45
51 – 125	105	85
126 – 225	185	155

The separation between the test and reference conductors shall be at least 150 mm.

The test specimen shall be suspended either horizontally or vertically in free air by supporting the equalizer or busbar by non-conductive supports so as not to subject the screw-type terminal to a tensile load. Thermal barriers shall be installed midway between the conductors which shall extend $25 \text{ mm} \pm 5 \text{ mm}$ widthways and $150 \text{ mm} \pm 10 \text{ mm}$ lengthways beyond the screw-type terminals (see Figure L.1). Thermal barriers are not required provided the specimens are separated by at least 450 mm. The specimens shall be located at least 600 mm from the floor, wall or ceiling.

The test specimens shall be located in a substantially vibration-free and draught-free environment and at an ambient temperature between 20 °C and 25 °C. Once the test is started, the maximum permissible variation is $\pm 1 \text{ K}$ provided the range limitation is not exceeded.

L.9.2.4 Temperature measurement

Temperature measurements are made by means of thermocouples, using a wire having a cross-section of not more than $0,07 \text{ mm}^2$ (approximately 30 AWG).

For screw-type terminals, the thermocouple shall be located on the conductor entry side of the screw-type terminal, close to the contact interface.

For the reference conductor, the thermocouples shall be located midway between the ends of the conductor, and under its insulation.

Positioning of the thermocouples shall not damage the screw-type terminal or the reference conductor.

NOTE 1 Drilling of a small hole and subsequent fastening of the thermocouple is an acceptable method, provided that the performance is not affected and that it is agreed by the manufacturer.

The ambient temperature shall be measured with two thermocouples in such a manner as to achieve an average and stable reading in the vicinity of the test loop without undue external influence. The thermocouples shall be located in a horizontal plane intersecting the specimens, at a minimum distance of 600 mm from them.

NOTE 2 A satisfactory method for achieving a stable measurement is, for example, to attach the thermocouple to unplated copper plates approximately 50 mm × 50 mm, having a thickness between 6 mm and 10 mm.

L.9.2.5 Test method and acceptance criteria

NOTE 1 Evaluation of performance is based on both the limit of screw-type terminal temperature rise and the temperature variation during the test.

The test loop shall be subjected to 500 cycles of 1 h current-on and 1 h current-off, starting at an a.c. current equal to 1,12 times the test current value determined in Table L.8. Near the end of each current-on period of the first 24 cycles, the current shall subsequently be adjusted to raise the temperature of the reference conductor to 75 °C.

At the 25th cycle the test current shall be adjusted for the last time and the stable temperature shall be recorded as the first measurement. There shall be no further adjustment of the test current for the remainder of the test.

Temperatures shall be recorded for at least one cycle of each working day, and after approximately 25, 50, 75, 100, 125, 175, 225, 275, 350, 425, and 500 cycles.

The temperature shall be measured during the last 5 min of the current-on time. If the size of the set of test specimens or the speed of the data acquisition system is such that not all measurements can be completed within 5 min, the current-on time shall be extended as necessary to complete such measurements.

After the first 25 cycles the current-off time may be reduced to a time 5 min longer than the time necessary to all terminal assemblies for cooling down to a temperature between ambient temperature T_a and $T_a + 5$ K during the current-off period. Forced-air cooling may be employed to reduce the off time, if acceptable to the manufacturer. In that case it shall be applied to the entire test loop and the resulting temperature of the forced air shall not be lower than the ambient air temperature.

The stability factor S_f for each of the 11 temperature measurements is to be determined by subtracting the average temperature deviation D from the 11 values of the temperature deviation d .

The temperature deviation d for the 11 individual temperature measurements is obtained by subtracting the associated reference conductor temperature from the screw-type terminal temperature.

NOTE 2 The value of d is positive if the screw-type temperature is higher than that of the reference conductor and negative if it is lower.

For each screw-type terminal

- the temperature rise shall not exceed 110 K;
- the stability factor Sf shall not exceed ± 10 °C.

An example of calculation for one screw-type terminal is given in Table L.9.

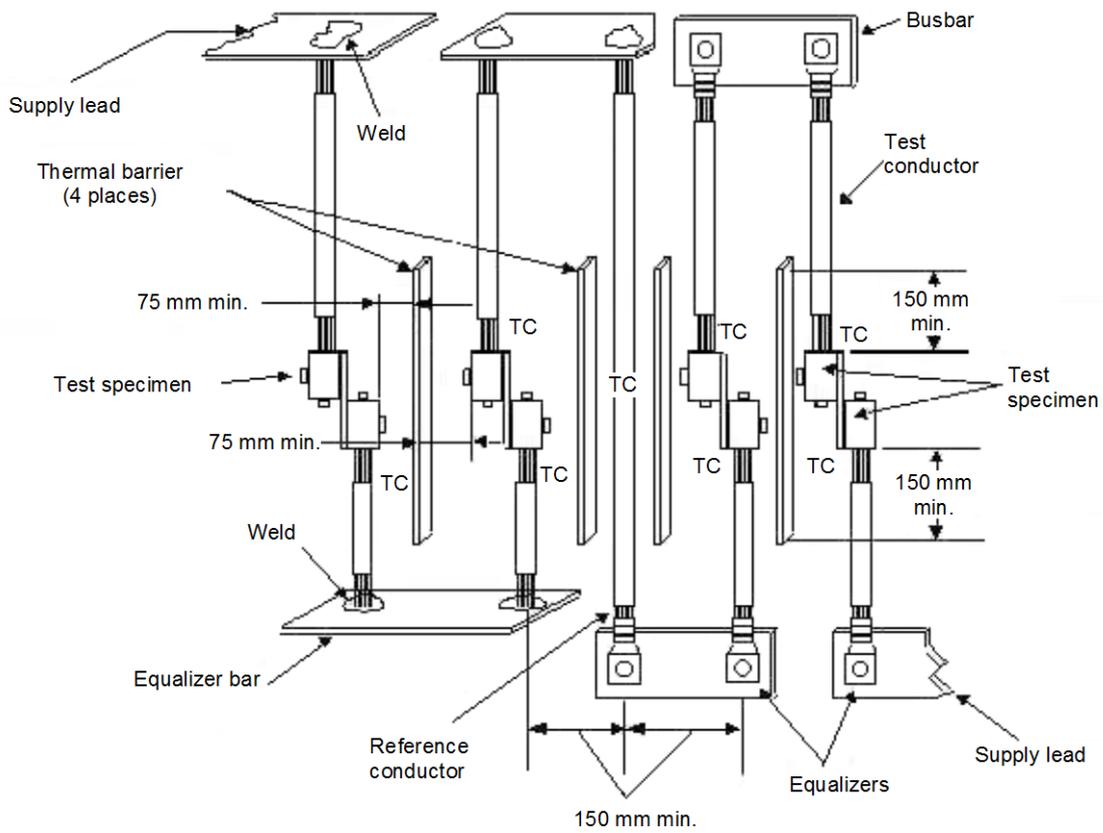
Table L.8 – Test current as a function of rated current

Metric sizes			AWG		
Rated current	Al conductor size	Test current	Rated current	Al conductor size	Test Current
A	mm ²	A	A	N °	A
$0 \leq I_n \leq 15$	2,5	26	$0 < I_n \leq 15$	12	30
$15 < I_n \leq 20$	4	35	$15 < I_n \leq 25$	10	40
$20 < I_n \leq 25$	6	46	$25 < I_n \leq 40$	8	53
$25 < I_n \leq 32$	10	60	$40 < I_n \leq 50$	6	69
$32 < I_n \leq 50$	16	79	$50 < I_n \leq 65$	4	99
$50 < I_n \leq 65$	25	99	$65 < I_n \leq 75$	3	110
$65 < I_n \leq 80$	35	137	$75 < I_n \leq 90$	2	123
$80 < I_n \leq 100$	50	171	$90 < I_n \leq 100$	1	152
$100 < I_n \leq 125$	70	190	$100 < I_n \leq 120$	0	190

Table L.9 – Example of calculation for determining the average temperature deviation D

Temperature measurement	Cycle number	Temperatures		Temperature deviation $d = a - b$	Stability factor $Sf = d - D$
		Screw-type terminal a °C	Reference conductor b °C		
1	25	79	78	1	0,18
2	50	80	77	3	2,18
3	75	78	78	0	-0,82
4	100	76	77	-1	-1,82
5	125	77	77	0	-0,82
6	175	78	77	1	0,18
7	225	79	76	3	2,18
8	275	78	76	2	1,18
9	350	77	78	-1	-1,82
10	425	77	79	-2	-2,82
11	500	81	78	3	2,18

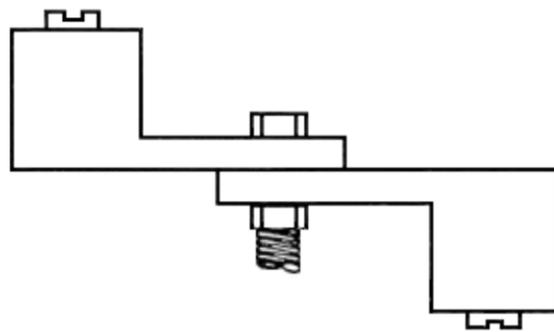
$$\text{Average temperature deviation } D = \frac{\sum d}{\text{number of measurements}} = \frac{9}{11} = 0,82$$



TC Thermocouple

IEC 509/12

Figure L.1 – General arrangement for the test



IEC 510/12

NOTE The conducting part may be bolted, soldered or welded.

Figure L.2

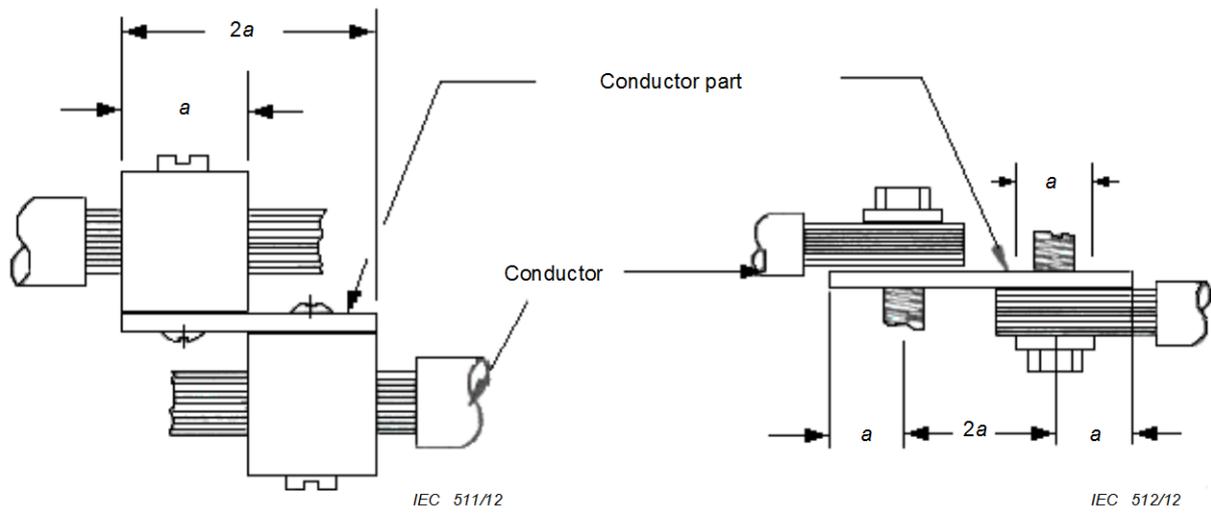


Figure L.3

Figure L.4

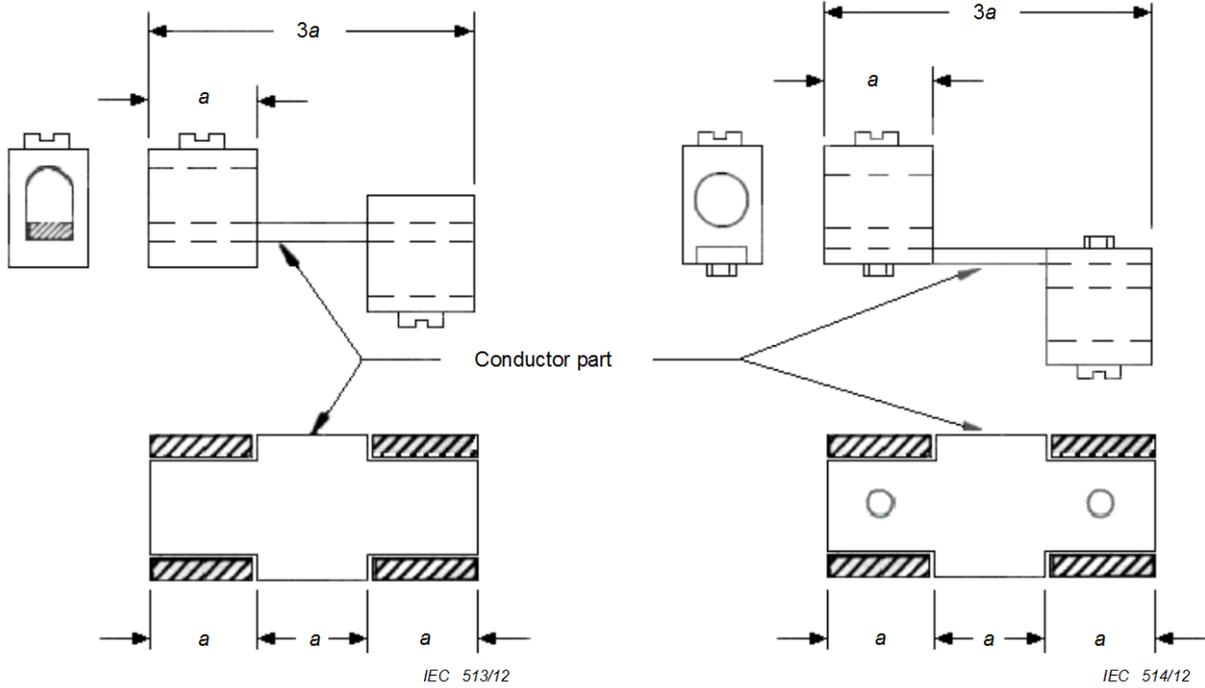


Figure L.5

Figure L.6

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⁶ The 1983 edition has been cancelled and replaced by IEC 60755:2008.

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