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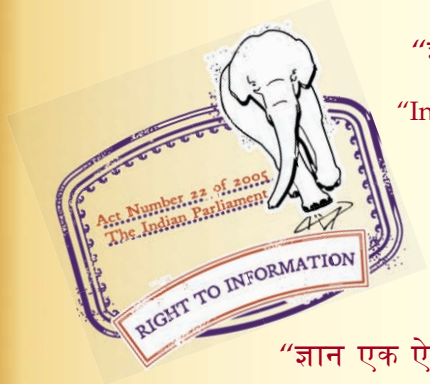

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Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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IS 12640 (Part 2) : 2008
IEC 61009-1 : 1996

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भाग 2 समेकित अतिधारा संरक्षण सहित सर्किट वियोजक

(पहला पुनरीक्षण)

Indian Standard

RESIDUAL CURRENT OPERATED CIRCUIT-BREAKERS FOR HOUSEHOLD AND SIMILAR USES

PART 2 CIRCUIT-BREAKERS WITH INTEGRAL OVERCURRENT PROTECTION (RCBOs)

(First Revision)

ICS 29.120.50

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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NATIONAL FOREWORD

This Indian Standard (Part 2) (First Revision) which is identical with IEC 61009-1 : 1996 'Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs) — Part 1: General rules' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Low-Voltage Switchgear and Controlgear Sectional Committee and approval of the Electrotechnical Division Council.

This standard was first published in 2000. This revision has been undertaken to align it with IEC 61009-1 : 1996 along with Amendment No.1 published in the year 2002 and its Corrigendum published in 2003.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60038 : 1983 IEC standard voltages	IS 12360 : 1988 Voltage bands for electrical installations including preferred voltages and frequency	Technically Equivalent
IEC 60050 (151) : 1978 International Electrotechnical Vocabulary (IEV) — Chapter 151 Electrical and magnetic devices	IS 1885 (Part 74) : 1993 Electrotechnical vocabulary: Part 74 Electric and magnetic devices	Identical
IEC 60050 (441) : 1984 International Electrotechnical Vocabulary (IEV) — Chapter 441: Switchgear, controlgear and fuses	IS 1885 (Part 17) : 1979 Electrotechnical vocabulary: Part 17 Switchgear and controlgear (*first revision*)	Technically Equivalent
IEC 60051 (all parts) Direct acting indicating analogue electrical measuring instruments and their accessories	IS 1248 : 2003 (all parts) Direct acting indicating analogue electrical measuring instruments and their accessories	do
IEC 60060-2 : 1994 High-voltage test techniques — Part 2: Measuring systems	IS 2071 (Part 3) : 1976 High-voltage test techniques: Part 3 Measuring devices (*first revision*)	do
IEC 60068-2-30 : 1980 Environmental testing — Part 2: Tests — Test Db and guidance: Damp heat, cyclic (12+12 hour cycle)	IS 9000 (Part 5/Sec 1 and 2) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 5 Damp heat (cyclic) test, Section 1 16+8h cycle; Section 2 12+12 h cycle	do
IEC 60364 Electric installations of buildings	SP 30 : 1985 National electrical code	do

(*Continued on third cover*)

CONTENTS

Indian Standard

RESIDUAL CURRENT OPERATED CIRCUIT-BREAKERS FOR HOUSEHOLD AND SIMILAR USES

PART 2 CIRCUIT-BREAKERS WITH INTEGRAL OVERCURRENT PROTECTION (RCBOs)

(First Revision)

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., 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 the operation under residual current conditions is based on IEC 61008.

The content of the present standard related to protection against overcurrents is based on IEC 60898.

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 IEC 60364.

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

NOTE 4 Surge arresters installed downstream of the general type of RCBOs and connected in common mode may cause unwanted tripping.

NOTE 5 RCBOs within the scope of the present standard are considered as suitable for isolation (see 8.1.3).

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 60364-4-443).

NOTE 6 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.

NOTE 7 For the time being, for RCBOs incorporated in, or intended only for plugs and socket-outlets, the requirements of this standard in conjunction with the requirements of IEC 600884-1 may be used, as far as applicable.

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 co-ordination 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 60038:1983, *IEC standard voltages*

IEC 60050(151):1978, *International Electrotechnical Vocabulary (IEV) – Chapter 151: Electrical and magnetic devices*

IEC 60050(441):1984, *Chapter 441: Switchgear, controlgear and fuses*

IEC 60051, *Direct acting indicating analogue electrical measuring instruments and their accessories*

IEC 60060-2:1994, *High-voltage test techniques – Part 2: Measuring Systems*

IEC 60068-2-28:1990, *Environmental testing – Part 2: Tests – Guidance for damp heat tests*

IEC 60068-2-30:1980, *Environmental testing – Part 2: Test Db and guidance: Damp heat, cyclic (12 + 12 hour cycle)*
Amendment 1 (1985)

IEC 60364: *Electrical installations of buildings*

IEC 60364-4-443:1995, *Part 4: Protection for safety – Chapter 44: Protection against overvoltages – Section 443: Protection against overvoltages of atmospheric origin or due to switching*

IEC 60364-5-53:1994, *Part 5: Selection and erection of electrical equipment – Chapter 53: Switchgear and controlgear*

IEC 60417:1973, *Graphical symbols for use on equipment. Index, survey and compilation of the single sheets*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Codes)*

IEC 60695-2-1/0:1994, *Fire hazard testing – Part 2: Test methods – Section 1/sheet 0: Glow-wire test methods – General*

IEC 60755:1983, *General requirements for residual current operated protective devices*

IEC 60884-1:1994, *Plugs and socket-outlets for household and similar purposes – Part 1: General requirements*

IEC 60898:1995, *Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations*

IEC 61008-1:1990, *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) – Part 1: General rules*

Amendment 1 (1992), Amendment 2 (1995)

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

3 Definitions

For the purpose of this standard, the following definitions apply.

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

NOTE 1 For glossary of symbols see annex IB.

NOTE 2 Reference to IEV definitions is also made when the terms "device" or "mechanical switching device" are replaced by the term "RCBO".

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 (IEV 101-04-34) 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
the 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
an electrical excitation quantity which, alone or in combination with other such quantities, shall be applied to a 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

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 note c of table 2)

3.3 Definitions relating to the operation and functions of residual current circuit-breakers

3.3.1
switching device
a device designed to make or break the current in one or more electric circuits
(IEV 441-14-01)

3.3.2
mechanical switching device
a switching device designed to close and open one or more electric circuits by means of separable contacts
(IEV 441-14-02)

3.3.3
fuse
a 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)

3.3.4
circuit-breaker
a 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)

3.3.5
residual current operated circuit-breaker
a mechanical switching device designed for making, carrying and breaking 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)
a 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)
a 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 60755 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.

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

IEV 441-16-22)

3.3.14
open position
the 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 a 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
a pole provided with an overcurrent release, hereafter referred to as protected pole

3.3.15.2
overcurrent unprotected pole
a 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 shall be indicated by the manufacturer.

3.3.15.3
switched neutral pole
a pole only intended to switch the neutral and not intended to have a short-circuit capacity

3.3.16
uninterrupted neutral
a 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 a RCBO)
all the conductive parts of a RCBO included in the current paths (see 4.3)

3.3.18
control circuit (of a RCBO)
a 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 a RCBO)
all the conductive parts of a 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 a RCBO
(IEV 151-04-03, modified)

3.4.2
overcurrent
any current exceeding the rated current

3.4.2.1
overload current
an 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
an 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
the 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
the 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, that is 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)
the 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
the 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
a 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
a 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
the current in a pole of a RCBO at the instant of initiation of the arc during a breaking process

(IEV 441-17-07)

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

3.4.8
applied voltage
the voltage which exists across the terminals of a pole of a RCBO just before the making of the current

(IEV 441-17-24)

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

(IEV 441-17-25)

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

(IEV 441-17-26)

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.

3.4.9.2
power-frequency recovery voltage
the recovery voltage after the transient voltage phenomena have subsided

(IEV 441-17-27)

3.4.10
opening time
the 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 Arcing time

3.4.11.1
arcing time of a pole
the 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)

3.4.11.2
arcing time of a multipole RCBO
the 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)
the interval of time between the beginning of the opening time of a RCBO and the end of the arcing time, in case of overcurrent

NOTE This definition is based on IEV 441-17-39.

3.4.13
***I²t* (Joule integral)**
the 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)

3.4.14
***I²t* characteristic of a RCBO**
a curve giving the maximum value of I^2t as a function of the prospective current under stated conditions of operation

3.4.15 Co-ordination between overcurrent protective devices in series

3.4.15.1
selectivity-limit current (I_s)
the current co-ordinate 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)
the current co-ordinate 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})
a specified value of current which the RCBO can carry for a specified time (conventional time) without operating

(IEV 441-17-22)

3.4.17
conventional tripping current (I_t)
a specified value of current which causes the RCBO to operate within a specified time (conventional time)

(IEV 441-17-23)

3.4.18
instantaneous tripping current
the minimum value of current which causes the circuit-breaker to operate automatically without intentional time-delay

3.4.19
clearance (see annex B)
the shortest distance in air between two conductive parts

NOTE For the purpose of determining a clearance to accessible parts, the accessible surface of an insulating enclosure shall 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.

3.4.20
creepage distance (see annex B)
the shortest distance along the surface of an insulating material between two conductive parts

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

3.4.21 Non-operating overcurrents in the main circuit

The definitions of limiting values of non-operating overcurrents are given in 3.4.21.1 and 3.4.21.2

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.

3.4.21.1
limiting value of overcurrent in case of a load through a 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 a RCBO with two current paths without causing it to operate

3.4.21.2
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

3.4.22
residual making and breaking capacity
value of the a.c. component of a residual prospective current which a RCBO can make, carry for its opening time and break under specified conditions of use and behaviour

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

3.4.23.1
U_x
minimum value of the line voltage at which a RCBO functionally dependent on line voltage still operates under specified conditions in case of decreasing line voltage (see 9.17.1)

3.4.23.2
U_y
minimum value of the line voltage below which a RCBO functionally dependent on line voltage opens automatically in the absence of any residual current

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 a RCBO

3.5.2
reference value of an influencing quantity
the 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
the 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
the 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
the temperature, determined under prescribed conditions, of the air surrounding the RCBO
(IEV 441-11-13)

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

3.5.7
reference ambient air temperature
the ambient air temperature on which the time-overcurrent characteristics are based

3.6 Definitions relating to terminals

NOTE These definitions may be modified when the work of Subcommittee 23F on terminals is completed.

3.6.1
terminal
a terminal is a conductive part of a RCBO, provided for re-usable electrical connection to external circuits

3.6.2
screw-type terminal
a 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
a 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). The clamping pressure may be applied directly by the shank of the screw or through an intermediate clamping element to which pressure is applied by the shank of the screw

NOTE Examples of pillar terminals are shown in figure IC.1 of annex IC.

3.6.4
screw terminal
a 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.2 of annex IC.

3.6.5
stud terminal
a screw-type terminal in which the conductor is clamped under a nut

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 Examples of stud terminals are shown in figure IC.2 of annex IC.

3.6.6
saddle terminal
a 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 of annex IC.

3.6.7
lug terminal
a 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 of annex IC.

3.6.8
screwless terminal
a connecting terminal for the connection and subsequent disconnection of one conductor or the dismountable 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
a 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

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
a tapping screw having an uninterrupted thread; it is not a function of this thread to remove material from the hole

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

3.6.11
thread cutting tapping screw
a tapping screw having an interrupted thread; it is a function of this thread to remove material from the hole

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

3.7 Conditions of operation

3.7.1
operation
the 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
an operation by which the RCBO is brought from the open position to the closed position
(IEV 441-16-08)

3.7.3
opening operation
an operation by which the RCBO is brought from the closed position to the open position
(IEV 441-16-09)

3.7.4
dependent manual operation
an 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
astored 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
a 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
(IEV 441-16-31)

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.

3.7.7
operating cycle
a 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
a succession of specified operations with specified time intervals

3.7.9
uninterrupted duty
duty in which the main contacts of a RCBO remain closed whilst carrying a steady current without interruption for long periods (which could be weeks, months, or even years)

3.8 Constructional elements

3.8.1
main contact
a contact included in the main circuit of a RCBO, intended to carry, in the closed position, the current of the main circuit

(IEV 441-15-07)

3.8.2
arcing contact
a 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
a contact included in a control circuit of a RCBO and mechanically operated by the RCBO

(IEV 441-15-09)

3.8.4
auxiliary contact
a 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)

3.8.5
release
a device, mechanically connected to (or integrated into) a RCBO which releases the holding means and permits the automatic opening of the RCBO

(IEV 441-15-17)

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

3.8.6
overcurrent release
a release which permits a RCBO to open with or without time-delay when the current in the release exceeds a predetermined value

(IEV 441-16-33)

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

3.8.7
inverse time-delay overcurrent release
an overcurrent release which operates after a time-delay inversely dependent upon the value of the overcurrent

(IEV 441-16-35)

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

3.8.8
direct overcurrent release
an overcurrent release directly energized by the current in the main circuit of a RCBO
(IEV 441-16-36)

3.8.9
overload release
an overcurrent release intended for protection against overloads
(IEV 441-16-38)

3.8.10
conductive part
a part which is capable of conducting current, although it may not necessarily be used for carrying service current
(IEV 441-11-09)

3.8.11
exposed conductive part
a 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)

3.9 Tests

3.9.1
type test
a test of one or more devices made to a certain design to show that the design meets certain requirements
(IEV 151-04-15)

3.9.2
routine tests
a test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria
(IEV 151-04-16)

4 Classification

RCBOs are classified:

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 532.2.2.2 of IEC 60364-5-53.

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 note to 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);
- RCBOs with increased resistance to unwanted tripping (S type as in table 2).

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 connections of which are not associated with the mechanical mounting;
- RCBOs the connections of which are associated with the mechanical mounting, for example:
  - plug-in type;
  - bolt-on type.

NOTE 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.

5 Characteristics of RCBOs

5.1 Summary of characteristics

The characteristics of a 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 (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);
- insulation co-ordination including clearances and creepage distances (see 5.2.10);

- 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 a 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 a 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.

5.2.2 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 section 523 of IEC 60364).

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.

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

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 a 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 a RCBO is the value of the ultimate short-circuit breaking capacity (see 3.4.6.1) assigned to that RCBO by the manufacturer.

NOTE A RCBO having a given rated short-circuit capacity I_{cn} has a corresponding service short-circuit capacity (I_{cs}) (see table 18).

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 a 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.

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

5.2.9.1 RCBO type AC

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

5.2.9.2 RCBO type A

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

5.2.9.3 Insulation co-ordination including clearances and creepage distances

Under consideration.

NOTE For the time being, clearances and creepage distances are given in 8.1.3.

5.3 Standard and preferred values

5.3.1 Preferred values of rated voltage (U_n)

Preferred values of rated voltage are as follows:

RCBO	Circuit supplying the RCBO	Rated voltage
Single-pole with one over-current protected pole and uninterrupted neutral	two-wire, phase to earthed middle conductor	120 V
Two-pole with one or two overcurrent protected poles	single phase, phase to neutral	230 V
	two-wire, phase to earthed middle conductor	120 V
	single phase, phase to neutral	230 V
Three-pole with three over-current protected poles	single phase, phase to phase	400 V
	three-phase three-wire	400 V
Three-pole with three over-current protected poles and uninterrupted neutral	three-phase four-wire	400 V
Four-pole with three or four overcurrent protected poles	three-phase four-wire	400 V

NOTE 1 In IEC 60038 the voltage values of 230 V and 400 V have been standardized. These values should progressively replace the values of 220 V and 240 V, and of 380 V and 415 V respectively.

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.

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 some countries 1 A is also considered as a standard value.

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

Standard values of rated frequency are: 50 Hz and 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 17.

5.3.8 Standard values of break time and non-actuating time for operation under residual current conditions

The standard values of maximum break time (3.3.10) and non-actuating time (see 3.3.11) for type AC RCBOs are given in table 2.

Table 2 – Standard values of break time and non-operating time for operating under residual current conditions

Type	I_n	$I_{\Delta n}$	Standard values of break time and non-operating time at a residual current (I_Δ) equal to: s					
	A	A	$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$ [a]	5 A,10 A, [b] 20 A, 50 A, 100 A, 200 A, 500 A	$I_{\Delta t}$ [c]	
General	Any value	Any value	0,3	0,15	0,04	0,04	0,04	Maximum break times
S	≥25	>0,030	0,5	0,2	0,15	0,15	0,15	Maximum break times
			0,13	*0,06*	0,05	–	0,04	Minimum non-actuating times *(no tripping)*

[a] For RCBOs of the general type with $I_{\Delta n} \leq 0{,}030$ A, 0,25 A may be used as an alternative to 5 $I_{\Delta n}$.

[b] The tests at 5 A, 10 A, 20 A, 50 A, 100 A, 200 A and 500 A are only performed during the verification of the correct operation according to 9.9.1.2 d), but in any case values exceeding the lower limit of the overcurrent instantaneous tripping range are not tested.

[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 type A RCBOs the maximum break times stated in table 2 shall also be valid, the current values (i.e. $I_{\Delta n}$, 2 $I_{\Delta n}$, 5 $I_{\Delta n}$, 0,25 A and 500 A), however, being increased, for the test of 9.21.1, by the factor 1,4 for RCBOs with $I_{\Delta n} > 0{,}01$ A and by the factor 2 for RCBOs with $I_{\Delta n} \leq 0{,}01$ A.

5.3.9 Standard ranges of overcurrent instantaneous tripping

Standard ranges of overcurrent instantaneous tripping are given in table 3.

Table 3 – 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 50 I_n

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, if the RCBO is designed only for one frequency (see 5.3.5);

f) rated residual operating current;

g) settings of residual operating current in case of 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 (symbol according to IEC 60051), 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);

q) operating means of the test device, by the letter T;

r) wiring diagram;

s) operating characteristic in presence of residual currents with d.c. components

- RCBOs of type AC with the symbol 
- RCBOs of type A with the symbol. 

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.

If, for small devices, the space available does not allow all the above data to be marked, at least the information under d), f) and n) shall be marked and visible when the device is installed. The information under a), b), c), h) 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 r) 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 "|" (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 circuit shall be indicated by the letter N.

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

NOTE The symbol  (IEC 60417-5017a)), previously recommended, shall be progressively superseded by the preferred symbol IEC 60417-5019 a), 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.

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 4.

Table 4 – 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 %

1) The maximum value of the mean daily temperature is +35 °C.
2) Values outside the range are admissible where more severe climatic conditions prevail, subject to agreement between manufacturer and user.
3) Higher relative humidities are admitted at lower temperatures (for example 90 % at 20 °C).
4) When a RCBO is installed in proximity of a strong magnetic field, supplementary requirements may be necessary.
5) The device shall be fixed without causing deformation liable to impair its functions.
6) The tolerance given apply unless otherwise specified in the relevant test.
7) Extreme limits of -20 °C et +60 °C are admissible during storage and transportation, and should be taken into account in the design of the device.

7.2 Conditions of installation

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

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.

In case of a 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 so mechanically coupled that all poles except the switched neutral, if any, make and break substantially together, whether operated manually or automatically.

A switched neutral pole (see 3.3.15.3) shall open after and close before the other pole(s).

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 be provided with means for indicating their closed and open positions, which shall be easily discernible from the front of the RCBO when fitted with its cover(s) or cover-plate(s), if any (see clause 6).

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 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 Provisionally in certain countries down 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 annex B)

Clearances and creepage distances shall be not less than the values shown in table 5, when the RCBO is mounted as for normal use.

NOTE A revision of the values of table 5 is under consideration.

Table 5 – Clearances and creepage distances

Description	Distance mm
Clearances [a]	
1. Between live parts which are separated when the RCBO is in the open position [b]	3
2. Between live parts of diffrent polarity [c] [d]	3
3. Between live parts and	
– metal operating means	3
– screws or other means for fixing covers which have to be removed when mounting the RCBO	3
– the surface on which the base is mounted [e]	6 (3)
– screws or other means for fixing the RCBO [e]	6 (3)
– metal covers or boxes [e]	6 (3)
– other accessible metal parts [f]	3
– metal frames supporting flush-type RCBOs	3
4. Between metal parts of the mechanism and	
– accessible metal parts [f]	3
– screws or other means for fixing the RCBO	3
– metal frames supporting flush-type RCBOs	3
Creepage distances [a]	
1. Between live parts which are separated when the RCBO is in the open position [b]	3
2. Between live parts of different polarity [c] [d]	
– for RCBOs having a rated voltage not exceeding 250 V	3
– for other RCBOs	4
3. Between live parts and	
– metal operating means	3
– screws or other means for fixing covers which have to be removed when mounting the RCBO	3
– screws or other means for fixing the RCBO [e]	6 (3)
– accessible metal parts [f]	3

a) Clearances and creepage distances of the secondary circuit and between the primary windings of the RCBO transformer are not considered.

b) Not applicable to auxiliary and control contacts.

c) Care should be taken for providing adequate spacing between live parts of different polarity of RCBOs of the plug-in mounted close to one another. Values are under consideration.

d) In some countries greater distances between terminals are used in accordance with national practices.

e) 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 dependent on the design of the RCBO only, so that they cannot be reduced when the RCBO is mounted in the most unfavourable position (even in a metallic enclosure), the values in brackets are sufficient.

f) Including a metal foil in contact with the surfaces of insulating material which are accessible after installation as for normal use. The foil is pushed into corners, grooves, etc., by means of a straight jointed test finger according to 9.6.

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 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 a RCBO.

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

NOTE 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 of:

- 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.

NOTE New requirements and appropriate tests for determining the resistance to corrosion are under consideration. These requirements should permit other materials to be used if suitably coated.

The requirements of this subclause do not apply to contacts, magnetic circuits, heater elements, bimetals, shunts, parts of electronic devices nor 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.

In this standard, only screw-type terminals for external copper conductors are considered.

NOTE Requirements for flat quick-connect terminations, screwless terminals and terminals for the connection of aluminium conductors are under consideration.

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 and by the tests of 9.5.

8.1.5.2 RCBOs shall be provided with terminals which shall allow the connection of copper conductors having nominal cross-sectional areas as shown in table 6.

NOTE Examples of possible designs of terminals are given in annex IC.

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

Rated current A		Range of nominal cross-section to be clamped * mm²	
Greater than	Up to and including	Rigid (solid or stranded) conductor	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	24 to 50	25 to 35

* 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.

NOTE For AWG cross-sections see annex ID.

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 a 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

RCBBs shall have adequate dielectric properties.

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

Compliance is checked by the tests of 9.7 and 9.20.

8.4 Temperature-rise

8.4.1 Temperature-rise limits

The temperature-rises of the parts of a RCBO specified in table 7, measured under the conditions specified in 9.8.2, shall not exceed the limiting values stated in that table.

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

Table 7 – Temperature-rise values

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

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

The test of reliability (se 9.22) is considered to be sufficient for checking indirectly the behaviour of the contacts with respect to undue temperature-rises in service.

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

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

8.4.2 Ambient air temperature

The temperature-rise limits given in table 7 are applicable only if the ambient air temperature remains between the limits given in table 4.

8.5 Operating characteristics

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

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 a RCBO is defined by the conditions and the values stated in table 8.

This table refers to a 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 note of table 8).

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.

In any case the variation of the test current of table 8 shall not 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 8 – 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 *	$t \geq 1$ h (for $I_n \leq 63$ A) $t \geq 2$ 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 *	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 *	$t \geq 0,1$ s	No tripping	Current established by closing an auxiliary switch
e	B C D	5 I_n 10 I_n 50 I_n	Cold *	$t < 0,1$ s	Tripping	Current established by closing an auxiliary switch
* The term "cold" means without previous loading, at the reference calibration temperature.						

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 a RCBO is 1,13 times its rated current.

c) Conventional tripping overcurrent (I_t)

The conventional tripping overcurrent of a 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 a 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 9.

Table 9 – 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 Behaviour of RCBOs in case of a single-phase overcurrent through a three-pole or four-pole RCBO

Three-pole and four-pole RCBOs shall not operate with single-phase overcurrent having a value equal to the lower limit of the overcurrent instantaneous tripping range according to type B, C or D, as applicable.

Compliance is checked by the test of 9.18.

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. RCBOs of the S-type 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 9.21.

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.

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 10.

Table 10 – 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 *	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
– Limiting values of the non-operating current under overcurrent conditions	9.18
– Resistance against unwanted tripping due to current surges	9.19
– Resistance of the insulation against an impulse voltage	9.20
– Behaviour of RCBOs in case of an earth fault current comprising a d.c. component	9.21
– Reliability	9.22
– Ageing of electronic components	9.23
* 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 4).

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 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 11 and is fixed on a dull black painted plywood board of about 20 mm thickness, the method of fixing being in compliance with the requirements relating to the indications of the manufacturer concerning mounting.

Table 11 – Test copper conductors corresponding to the rated currents

Rated current I_n A	$I_n \leq 6$	$6<I_n\leq13$	$13<I_n\leq20$	$20<I_n\leq25$	$25<I_n\leq32$	$32<I_n\leq50$	$50<I_n\leq63$	$63<I_n\leq80$	$80<I_n\leq100$	$100<I_n\leq125$
S mm²	1	1,5	2,5	4	6	10	16	25	35	50

NOTE 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 ± 5%.

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

For the tests of 9.8, 9.9, 9.10 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 length, with a tolerance of $^{+5}_{0}$ cm, 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 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 12.

The screws and nuts shall not be tightened in jerks.

The test is made with rigid conductors only, having the largest cross-sectional areas specified in table 6, solid or stranded, whichever is the more unfavourable. The conductor is moved each time the screw or nut is loosened.

Table 12 – Screw thread diameters and applied torques

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

Column I applies to screws without 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 terminals for external 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 6 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 12.

9.5.1 *The terminals are fitted with copper conductors of the smallest and largest cross-sections specified in table 6, solid or stranded, whichever is the more unfavourable.*

The conductor is inserted into the 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 permit the solid conductor or a strand (or strands) to escape.

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

Each conductor is then subjected to the pull shown in table 13.

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

Table 13 – Pulling forces

Cross-section of conductor accepted by the terminal *mm²*	*up to 4*	*up to 6*	*up to 10*	*up to 16*	*up to 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 6, solid or stranded, whichever is the more unfavourable, and the terminal screws are tightened with a torque equal to two-thirds of that shown in the appropriate column of table 12.*

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

The conductors shall show no undue damage or severed wires.

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

During the test, terminals shall not 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 a rigid stranded copper conductor having the make-up shown in table 14.

Table 14 – Conductor dimensions

Range of nominal cross-sections to be clamped mm²	Stranded conductor	
	Number of strands	Diameter of strands mm
1,0 to 2,5 *	7	0,67
1,0 to 4,0 *	7	0,85
1,5 to 6,0 *	7	1,04
2,5 to 10,0	7	1,35
4,0 to 16,0	7	1,70
10,0 to 25,0	7	2,14
16,0 to 35,0	19	1,53
25,0 to 50,0	Under consideration	Under consideration
* If the terminal is intended to clamp solid conductors only (see note of table 6), the test is not made.		

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

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

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

9.6 Verification of protection against electric shock

This requirement is applicable to those parts of 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 °C ± 2 °C, the RCBO being at this temperature.

RCBOs are subjected for 1 min to a force of 75 N, applied through the tip of a straight unjointed test finger 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 the of 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 à relative humidity maintained between 91 % and 95 %.

The temperature of the air in which the sample is placed is maintained within ±1 °C of any convenient value T between 20 °C and 30 °C.

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

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 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 and 9.7.3.

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 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 in contact with the outer surface of the internal enclosure of insulating material, if any;*

d) *between metal parts of the mechanism and the frame;*

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

e) *for 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 MΩ for the measurements according to a) and b);*
- *5 MΩ for the other measurements.*

9.7.3 *Dielectric strength of the main circuit*

After the RCBO has passed the tests of 9.7.2 the test voltage specified is applied for 1 min between the parts indicated in 9.7.2, 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 MΩ.

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

The voltage values to be applied are specified in table 15.

Table 15 – 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 9.7.5 and 9.7.6 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 in respect of 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 V* $^{+25}_{0}$ *V*

  NOTE This value is provisional.

- *maximum ripple : 5 %*

  where

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

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

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

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

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 7.

9.8.3 Measurement of the temperature of parts

The temperature of the different parts referred to in table 7 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 characteristic under residual current conditions

9.9.1.1 Test circuit

The RCBO is installed as for normal use.

The test circuit shall be of negligible inductance and correspond to figure 4a.

The instruments for the measurement of the residual current shall be at least of class 0,5 and shall show (or permit to determine) the true r.m.s. value.

The instruments for the measurement of time shall have a relative error not greater than 10 % of the measured value.

9.9.1.2 Off-load tests with residual sinusoidal alternating currents at the reference temperature of 20 °C ± 2 °C

The RCBO shall perform the tests of 9.9.1.2 a), 9.9.1.2 b), 9.9.1.2 c) (each one comprising five measurements) and 9.9.1.2 d), made respectively on one pole only, taken at random.

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

a) *Verification of the 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 $I_{\Delta no}$ and $I_{\Delta n}$.

b) *Verification of the correct operation at closing on 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 on the circuit 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.

In the case of RCBOs functionally dependent on line voltage, classified according to 4.1.2.2a), the control circuit of which is supplied from the line side of the main circuit, this verification does not take into account the time necessary to energize the RCBO. In this case, therefore, the verification is considered as made by establishing the residual current by closing S_1, the RCBO under test and S_2 being previously closed.

c) *Verification of the 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_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.

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

No value shall exceed the relevant specified limiting value.

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 $^{0}_{-5}$ %.

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.

The test is then repeated at the ambient temperatures of –5 °C and +40 °C.

The RCBO shall not trip during any of the tests.

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

The test circuit is calibrated successively to the following values of the residual current:

5 A, 10 A, 20 A, 50 A, 100 A and 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.

9.9.1.3 Verification of the correct operation with load at the reference temperature

The tests of 9.9.1.2 b) and 9.9.1.2 c) are repeated, the RCBOs being loaded with rated current as in normal service for a sufficient time so as to reach steady-state conditions.

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

In the case of RCBOs having multiple settings of residual operating current, the tests are made for each setting.

9.9.1.4 Tests at the temperature limits

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

a) *ambient temperature: –5 °C, off-load;*

b) *ambient temperature: +40 °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.

In the case of RCBOs having multiple settings of residual operating current, the tests are made for each setting.

NOTE Preheating may be carried out at reduced voltage but auxiliary circuits shall be connected to their normal operating voltage (particularly for components depending on line voltage).

9.9.1.5 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 8).*

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) *For RCBOs of the B-type*

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.

b) *For RCBOs of the C-type*

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.

c) *For RCBOs of the D-type*

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 50 I_n 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 °C ± 2 °C below the ambient air reference temperature until it has attained steady-state temperature.*

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

The RCBO shall trip within the conventional time.

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

A current equal to I_n is passed through all poles.

The RCBO shall not trip within the conventional time.

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 11.

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 specified in 9.7.3 but at a voltage equal to twice its rated voltage, for 1 min, however not less than 900 V and 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 4a.

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; they are summarized in table 16.

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, 9.12.13.2 and 9.12.12.1.*

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 18;*
- *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 16 – List of short-circuit tests

Kind of test	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 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 5, 6, 7, 8 and 9 respectively give diagrams of the circuits to be used for the tests concerning:

- *a single-pole RCBO with two current paths (figure 5);*
- *a two-pole RCBO (with one or two overcurrent protected poles) (figure 6);*
- *a three-pole RCBO (figure 7);*
- *a three-pole RCBO with four current paths (figure 8);*
- *a four-pole RCBO (figure 9).*

The resistances and reactances of the impedances Z and Z_1 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_1 taking approximately 0,6 % of the current through the reactor.

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 6.

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 5 to 9, as applicable.

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 D 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 current sensors O_1 are connected on the load side of the RCBO D.

The voltage sensors O_2 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:* $^{+5}_{0}$ %
- *Frequency:* ± 5 %
- *Power factor:* $^{0}_{-0,05}$
- *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 17.

Table 17 – 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 5 to 9.*

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 17 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 5 to 9.*

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 17, an impedance Z_2 is inserted as shown in figures 5 to 9.*

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 10.

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 A2 of figure 10).

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 such 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 of annex C.

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

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

NOTE 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 5 to 9.

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 The data for other voltages are under consideration.

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

For higher short-circuit currents up to I_{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 should be installed there. These RCBOs (or other devices) should be supplied as in normal use, but via F' and R' as defined in 9.12.9.1 and connected as shown in the appropriate figures 5 to 9.

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 such longer time 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, 3 and 4.

9.12.11.2 Test at reduced short-circuit currents

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 the connections of which are shown in figure 5.

NOTE For two-pole RCBOs with two current paths, for three-pole RCBOs with three current paths and for four-pole RCBOs with four current paths, one of the poles is connected in the test circuit of figure 5 in place of the uninterrupted neutral.

The RCBO is caused to open automatically nine times, the circuit being closed six times by the auxiliary switch A 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 auxiliary switch A is synchronized with respect to the voltage wave so that the six points of initiation for the opening operations are equally distributed over the half-wave with a tolerance of ± 5°.

9.12.11.3 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 17.

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 17.

Single-pole RCBOs are tested in a circuit the diagram of which is shown in figure 5.

Two-pole RCBOs are tested in a circuit, the diagram of which is shown in figure 6, both poles being in the circuit irrespective of the number of overcurrent protected poles.

Three-pole RCBOs and four-pole RCBOs with three overcurrent protected poles are tested in a circuit the diagrams of which are shown in figures 7, 8 and 9, as applicable.

For three-pole RCBOs with three current paths, no connection is made between the neutral of the supply and the common point, if any, 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 auxiliary switch A is synchronized with respect to the voltage wave so that the six points of initiation for the opening operations are equally distributed over the half-wave with a tolerance of ± 5°.

The sequence of operations shall be as specified in 9.12.11.2.

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 18.

Table 18 – Ratio between service short-circuit capacity (I_{cs}) and rated short-circuit capacity (I_{cn}) – (factor *k*)

I_{cn}	*k*
≤ 6 000 A	1
> 6 000 A ≤ 10 000 A	0,75 *
> 10 000 A	0,5 **
* Minimum value of I_{cs}: 6 000 A ** 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 17.*

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 directio

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

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

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

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

The synchronization tolerance shall be ± 5°.

This test procedure is shown in table 19.

Table 19 – 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 auxiliary switch A is synchronized with respect to the voltage wave so that the circuit is closed on any point x° on the wave for the "O" operation on the first sample.

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

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

This test procedure is shown in table 20.

Table 20 – Test procedure for I_{cs} in the case of three- and four-pole RCBOs

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

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 auxiliary switch A is synchronized with respect to the voltage wave so that the circuit is closed on the point 15° on the wave for the "O" operation on the first sample.

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

The synchronization tolerance shall be ± 5°.

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

The test procedure is shown in table 21.

Table 21 – 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 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, of withstanding a dielectric strength test according to 9.7.3, but at a voltage 500 V less than the value prescribed therein, and without previous humidity treatment.*

The dielectric strength test shall be carried out between 2 h and 24 h after the short-circuit test.

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 1 h.

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

9.12.12.2 *After the tests of 9.12.11.4 c), the RCBOs shall be capable, without maintenance, of withstanding a dielectric strength test according to 9.7.3, at a test voltage of 900 V, and without previous humidity treatment.*

Moreover, these RCBOs shall be capable of tripping, when loaded with 2,8 I_n, within the time corresponding to 2,55 I_n, but greater than 0,1 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 switched neutral, 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 have not to 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 device A 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 auxiliary switch A is synchronized with respect to the voltage wave so that the point of initiation is 45° ± 5°.

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

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

After the test carried out in accordance with 9.12.13, the RCBO D 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 treament, 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 11. 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, B 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 12 to 14.*

The head of the striking element has a hemispherical face of radius 10 mm and is of polyamide having a Rockwell hardness of HR 100. The striking element has a mass of 150 g ± 1 g and is rigidly fixed to the lower end of a steel tube with an external diameter of 9 mm and a wall thickness of 0,5 mm, which is pivoted at its upper end in such a way that it swings only in a vertical plane.

The axis of the pivot is 1 000 mm ± 1 mm above the axis of the striking element.

For determining the Rockwell hardness of the polyamide of the head of the striking element, the following conditions apply:

- *diameter of the ball: 12,7 mm ± 0,0025 mm;*
- *initial load: 100 N ± 2 N;*
- *overload: 500 N ± 2,5 N.*

NOTE 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 x 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 14.

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 15, which is fixed to the mounting support.

Panel mounting-type RCBOs are mounted in a test device, as shown in figure 16, 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 15 or 16, as applicable.

RCBOs for rail mounting are mounted on their appropriate rail which is rigidly fixed to the mounting support, as shown in figure 17.

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 12.

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 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 Damage to the appearance, small dents which do not reduce the creepage distances or clearances below the values specified in 8.1.3 and 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 without jerks for 1 min on the forward surface of the RCBO, immediately followed by an upward vertical force of 50 N for 1 min (figure 17).

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 18, except that, where applicable, the insulating parts necessary to retain in position terminals for protective conductors in a box, shall be tested as specified in 9.14.3.*

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

The test is made in a heating cabinet at a temperature of 125 °C ± 2 °C.

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

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

9.14.3 *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 °C ± 2 °C or at a temperature of 40 °C ± 2 °C plus the highest temperature rise determined for the relevant part during the test of 9.6, 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 in accordance with clauses 4 to 10 of IEC 60695-2-1 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 °C ± 15 °C;*
- *for all other external parts made of insulating material, by the test made at a temperature of 650 °C ± 10 °C.*

NOTE For the purpose of this test, bases of surface-type 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 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 one sample.

In case of doubt, the test shall be repeated on two further samples.

The test is made by applying the glow-wire once.

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).

The tip of the glow-wire shall be applied to the specified surface of the test sample taking into account the conditions of the intended use under which a heated or glowing element may come into contact with the sample.

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

- *either there is no visible flame and no sustained glowing;*
- *or flames and glowing on the sample extinguish themselves within 30 s after the removal of the glow-wire.*

There shall be no ignition of the tissue paper or scorching of the pine wood board.

9.16 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.*

At each test the RCBO shall operate. After the test, it 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_y (see 3.4.23.2) 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 1 when a residual current equal to $I_{\Delta n}$ is applied in case of drop of the 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 which is 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 4a 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 9) 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 4a.

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

NOTE For RCBOs having multiple settings, the test is made at the lowest setting.

The RCBO is connected according to figure 19, the test switch S_1 being open.

The resistance R is adjusted so as to obtain a current equal to 0,8 times the lower limit of the overcurrent instantaneous tripping range according to type B, C, or D, as applicable.

NOTE For the purpose of this current adjustment the RCBO may be replaced by connections of negligible impedance.

The test switch S_1, being initially open, is closed and re-opened after 1 s.

The test is repeated three times for each possible combination of the current paths, the interval between two successive closing operations being at least 1 min.

The RCBO shall not open.

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

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 23. An example of a circuit diagram for the connection of the RCBO is shown in figure 24.

One pole of the RCBO, chosen at random, shall be submitted to 10 applications of the surge current. The polarity of the surge wave shall be inverted after every two applications. The interval between two consecutive applications shall be about 30 s.

The current impulse shall be measured by appropriate means and adjusted using an additional RCBO of the same type with the same I_n and the same $I_{\Delta n}$, to meet the following requirements:

- peak value: 200 A $^{+10}_{0}$ %

  or 25 A $^{+10}_{0}$ % for RCBOs with $I_{\Delta n} \leq 10$ mA
- virtual front time: 0,5 µs ± 30 %
- period of the following oscillatory wave: 10 µs ± 20 %
- each successive 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 25. An example of a test circuit for the connection of the RCBO is shown in figure 26.

One pole of the RCBO, chosen at random, shall be submitted to 10 applications of the surge current. The polarity of the surge current wave shall be inverted after every two applications. The interval between two consecutive applications shall be about 30 s.

The current impulse shall be measured by appropriate means and adjusted using an additional RCBO of the same type with the same I_n and the same $I_{\Delta n}$, to meet the following requirements:

- peak value: 3 000 A $^{+10}_{0}$ %
- virtual front time: 8 µs ± 20 %
- virtual time to half value: 20 µs ± 20 %
- peak of reverse current: less than 30 % of peak value

The current should be adjusted to the asymptotic current shape. For the tests on other samples of the same type with the same I_n and the same $I_{\Delta n}$, the reverse current, if any, should not exceed 30 % of the peak value.

9.19.2.2 Test results for S-type RCBOs

During the tests, the RCBO shall not trip.

After the 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 Verification of resistance of the insulation against an impulse voltage

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

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

- *± 5 % for the peak value;*
- *± 30 % for the front time;*
- *± 20 % for the time to half value.*

A first series of tests is made at an impulse voltage of 6 kV peak, the impulses being applied between the phase pole(s), connected together, and the neutral pole (or path) of the RCBO.

A second series of tests is made at an impulse voltage of 8 kV peak, the impulses being applied between the metal support connected to the terminal(s) intended for the protective conductor(s), if any, and the phase pole(s) and the neutral pole (or path) connected together.

NOTE 1 The surge impedance of the test apparatus should be 500 Ω; a substantial reduction of this value is under consideration.

NOTE 2 The values of 6 kV and 8 kV are provisional.

In both cases, five positive impulses and five negative impulses are applied, the interval between consecutive impulses being at least 10 s.

No unintentional disruptive discharge shall occur.

If, however, only one such disruptive discharge occurs, 10 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.

NOTE 3 The expression "unintentional disruptive discharge" is used to cover the phenomena associated with the failure of insulation under electric stress, which include a drop in the voltage and the flowing of current.

NOTE 4 Intentional discharges cover discharges of any incorporated surge arresters.

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

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

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

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

The test conditions of 9.9.1.1 and 9.9.1.5 apply, except that the test circuits shall be those shown in figures 4b and 4c, as applicable.

9.21.1 Type A residual current devices

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

The test shall be performed according to figure 4b.

The auxiliary switches S_1 and S_2 and the RCBO D shall be switched on. 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.

At every 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 (and the relevant break time) shall be in accordance with table 22.

Table 22 – Tripping current ranges for type A RCBOs

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

9.21.1.2 Verification of the correct operation in case of suddenly appearing residual pulsating direct currents

The RCBO shall be tested according to figure 4b.

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.

NOTE In the case of RCBOs functionally dependent on line voltage, classified according to 4.1.2.2 a), the control circuit of which is supplied from the line side of the main circuit, this verification does not take into account the time necessary to energize the RCBO. In this case, therefore, the verification is considered as made by establishing the residual current by closing S_1, the RCBO under test and S_2 being previously closed.

The test is carried out at each value of residual current specified in table 2, according to the type of RCBO.

Two measurements of break time are made at each value of $I_{\Delta n}$ multiplied by 1,4 for RCBOs with $I_{\Delta n} > 0,01$ A and multiplied by 2 for RCBOs with $I_{\Delta n} \leq 0,01$ A, at a current delay angle $\alpha = 0°$, 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.

9.21.1.3 Verification at the reference temperature of the correct operation with load

The tests of 9.21.1.1 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 4b.

9.21.1.4 Verification of the 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 4c with a half-wave rectified residual current (current delay angle $\alpha = 0°$) 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 current reaches a value not exceeding 1,4 $I_{\Delta n}$ + 6 mA or 2 $I_{\Delta n}$ + 6 mA respectively.

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 60068-2-28.

9.22.1.1 Testing chamber

The chamber shall be constructed as stated in clause 3 of IEC 60068-2-30. Condensed water shall be continuously drained from the chamber and not used again until it has been repurified. Only distilled water shall be used for the maintenance of chamber humidity.

Before entering the chamber, the distilled water shall have a resistivity of not less than 500 Ωm and a pH value of 7,0 ± 0,2. During and after the test the resistivity should be not less than 100 Ωm and the pH value should remain within 7,0 ± 1,0.

9.22.1.2 Severity

The cycles are effected under the following conditions:

- *upper temperature:* 55 °C ± 2 °C
- *number of cycles :* 28.

9.22.1.3 Testing procedure

The test procedure shall be in accordance with clause 4 of IEC 60068-2-30 and with IEC 60068-2-28.

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 20)*

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

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

b) *or by adjusting the temperature of the test chamber to 25 °C ± 3 °C after the introduction of the RCBO and maintaining it at this level until temperature stability is attained.*

During the stabilization of temperature by either method, the relative humidity shall be within the limits prescribed for standard atmospheric conditions for testing (see table 4).

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 °C ± 3 °C.

3) *Description of the 24-hour cycle (see figure 21)*

a) *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 h ± 30 min and at a rate within the limits defined by the shaded area in figure 21.

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

NOTE The condition that condensation shall 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.

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

During this period, the relative humidity shall be 93 % ± 3 % except for the first and the last 15 min when it shall be between 90 % and 100 %.

Condensation shall not occur on the RCBO during the last 15 minutes.

c) *The temperature shall then fall to 25 °C ± 3 °C within 3 h to 6 h.*

The rate of fall for the first 1 h 30 min shall be such that, if maintained as indicated in figure 21, it would result in a temperature of 25 °C ± 3 °C being attained in 3 h ± 15 min.

During the temperature fall period, the relative humidity shall be not less than 95 %, except for the first 15 minutes when it shall be not less than 90 %.

d) *The temperature shall then be maintained at 25 °C ± 3 °C with a relative humidity not less than 95 % until the 24-*hour 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 6, 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 12. 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 °C ± 2 °C, to 28 cycles, each cycle comprising 21 h with current passing and 3 h without current. The current is interrupted by an auxiliary switch, the RCBO being not operated.

For four-pole RCBOs with 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

NOTE 1 A revision of this test in under consideration.

The RCBO is placed for a period of 168 h in an ambient temperature of 40 °C ± 2 °C and loaded with the rated current. The voltage on the electronic parts shall be 1,1 times the rated voltage.

After this test, the 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 2 An example for the test circuit of this verification is given in figure 22.

Figure 1 – Thread-forming tapping screw (3.6.10)

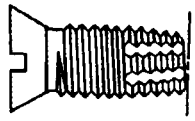
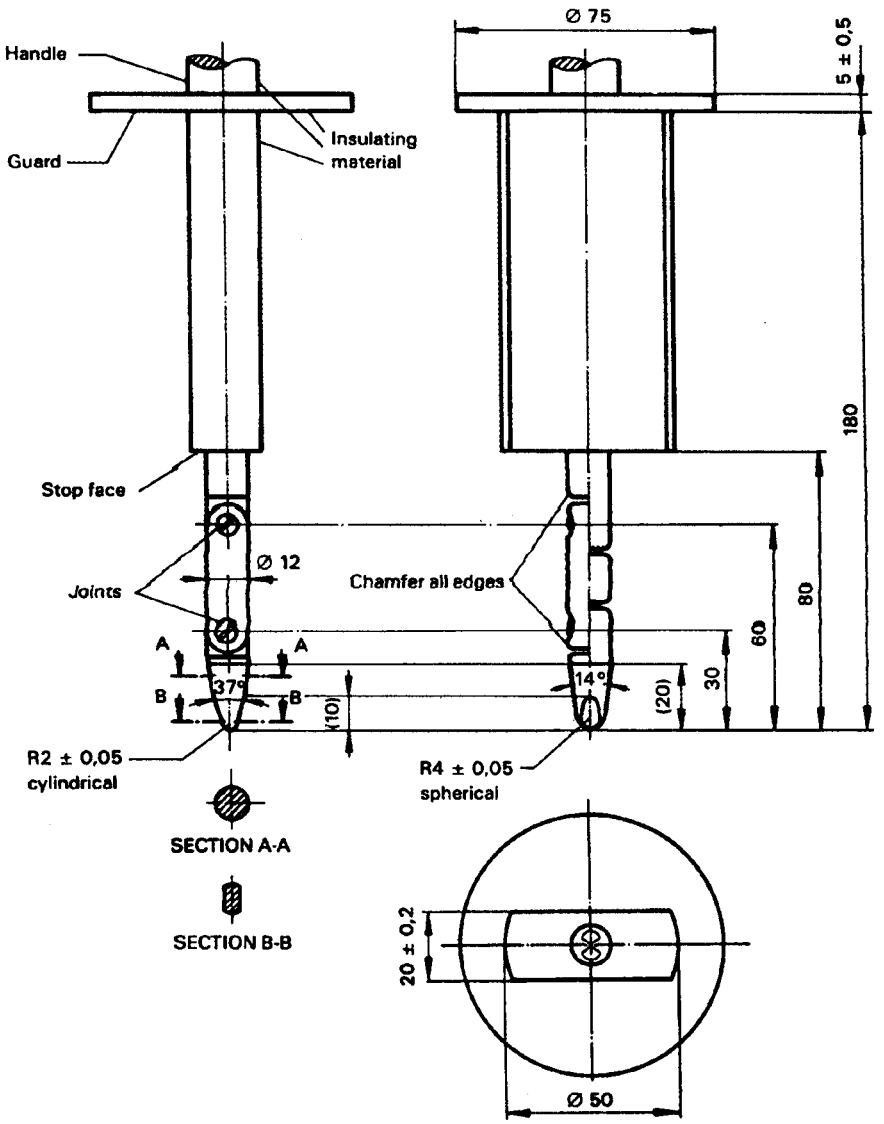


Figure 2 – Thread-cutting tapping screw (3.6.11)



Material : metal, except where otherwise specified
Linear dimensions in millimetres
Tolerances on dimensions without specific tolerance:

on angles: $^{0}_{-10}$,

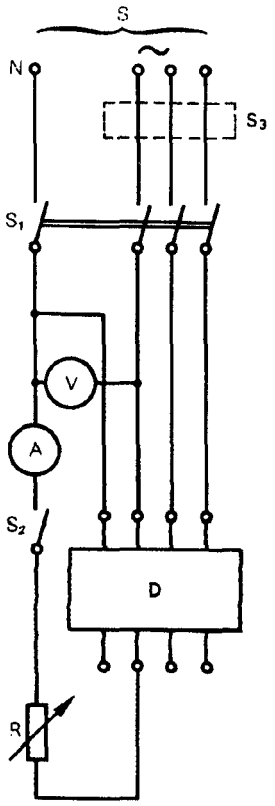
on linear dimensions:

up to 25 mm: $^{0}_{-0,05}$

over 25 mm: ±0.2

Both joints shall permit movement in the same plane and the same direction through an angle of 90° with a 0° to +10° tolerance.

Figure 3 – Jointed test finger (9.6)

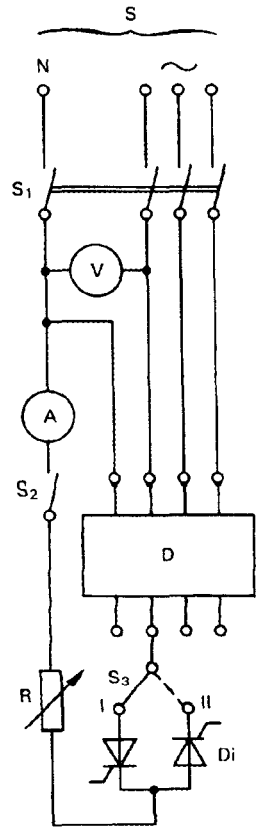


S = Supply
V = Voltmeter
A = Ammeter
S_1 = All-pole switch
S_2 = Single-pole switch
S_3 = Switch operating all phases but one
D = RCBO under test
R = Variable resistor

NOTE S_3 remains closed except for the test of 9.17.3.

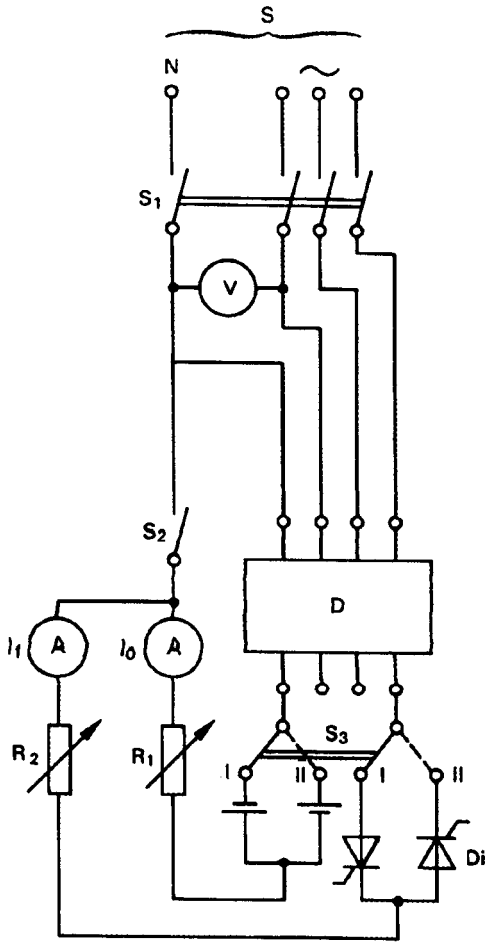
Figure 4a – Test circuit for the verification of

- **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**



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 4b – Test circuit for the verification of the correct operation of RCBOs, in the case of residual pulsating direct currents



S = Supply
V = Voltmeter
A = Ammeter (measuring r.m.s. values)
D = RCBO under test
D_i = Thyristors
R_1, R_2 = Variable resistors
S_1 = All-pole switch
S_2 = Single-pole switch
S_3 = Two-way, double pole switch

Figure 4c – Test circuit for the verification of the correct operation of RCBOs in the case of residual pulsating direct currents superimposed by a smooth direct residual current

N = neutral conductor

S = supply

Z = adjustable impedance

D = RCBO under test

G_1 = temporary connections for calibration

G_2 = connections for the test with rated conditional short-circuit current

A = device making the short circuit

O_1 = recording current sensor

O_2 = recording voltage sensor

F = device for the detection of a fault current

R_1 = resistor for shunting reactor

R_2 = resistor limiting the current in the device F

Z_1 = additional adjustable impedance to obtain current below the rated conditional *short-circuit current*

Z_2 = adjustable impedance for the calibration of I_Δ

S_1 = auxiliary switch

B and C = points of connection of the grid(s) shown in annex C

Explanation of letter symbols used in figures 5 to 9

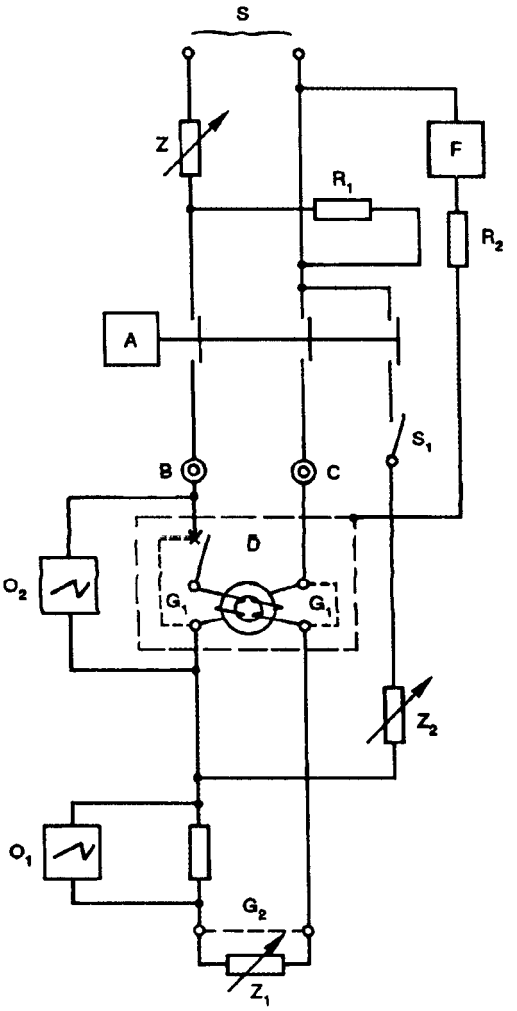


Figure 5 – Test circuit for the verification of the rated short-circuit capacity of a single-pole RCBO with two-current paths (9.12)

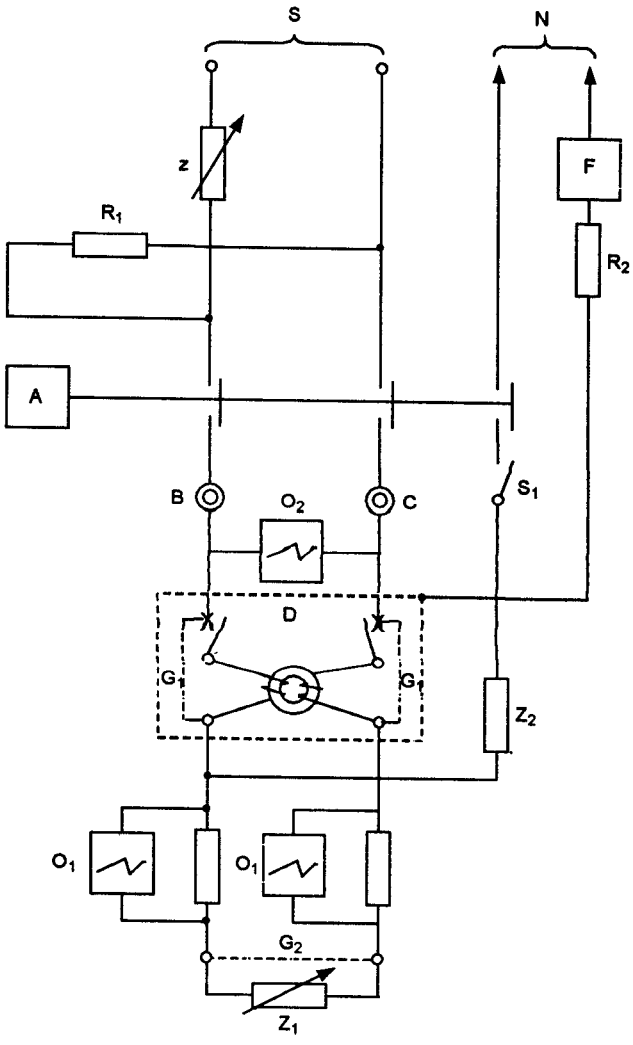


Figure 6 – Test circuit for the verification of the rated short-circuit capacity of a two-pole RCBO, in case of a single-phase circuit (9.12)

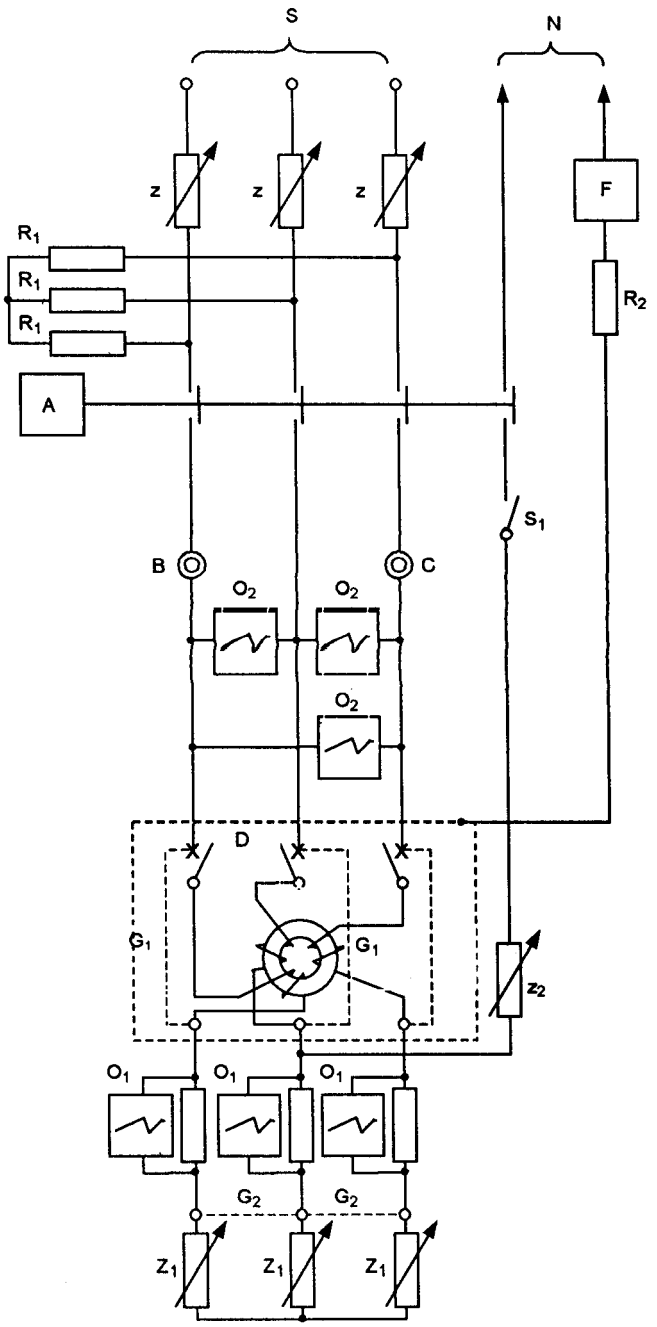


Figure 7 – Test circuit for the verification of the rated short-circuit capacity of a three-pole RCBO on a three-phase circuit (9.12)

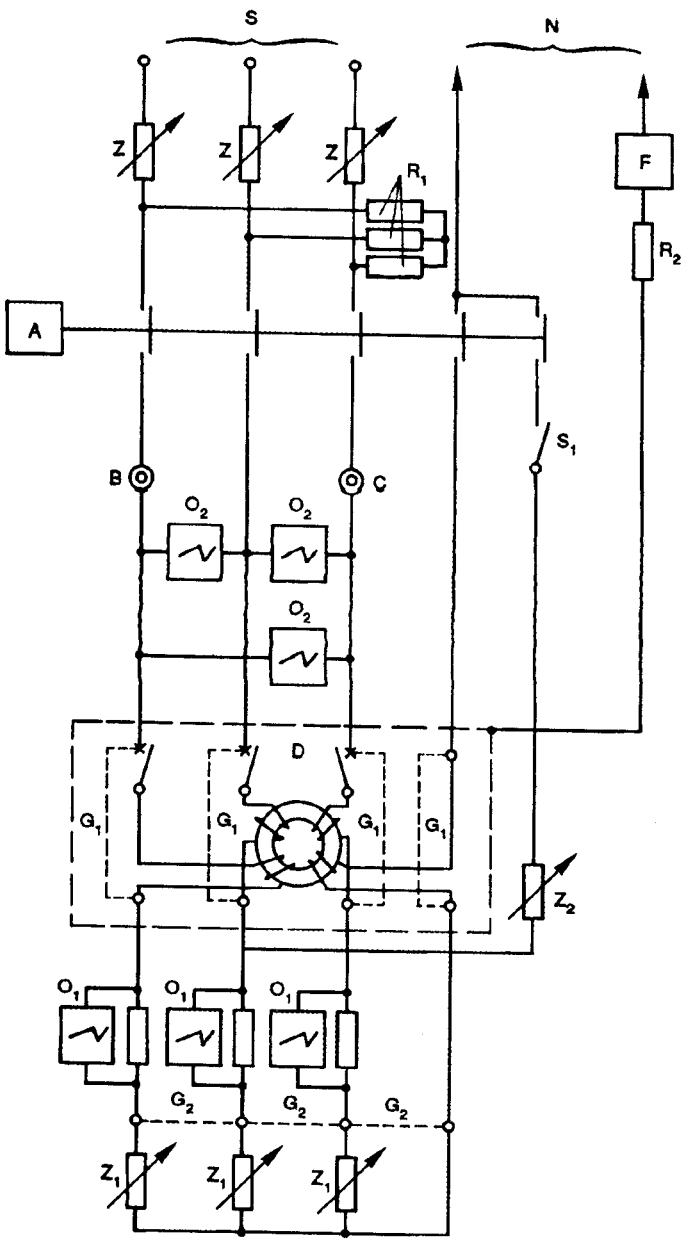


Figure 8 – Test circuit for the verification of the rated short-circuit capacity of a three-pole RCBO with four current paths on a three-phase circuit with neutral (9.12)

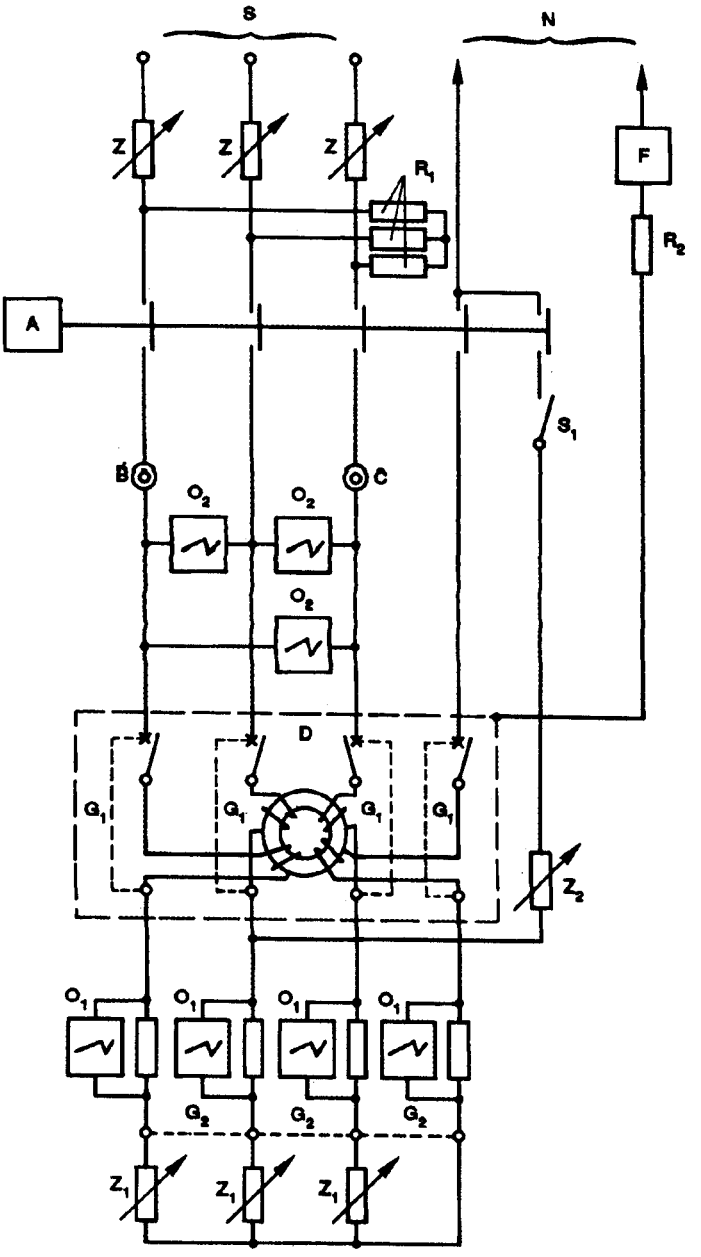


Figure 9 – Test circuit for the verification of the rated short-circuit capacity of a four-pole RCBO on a three-phase circuit with neutral (9.12)

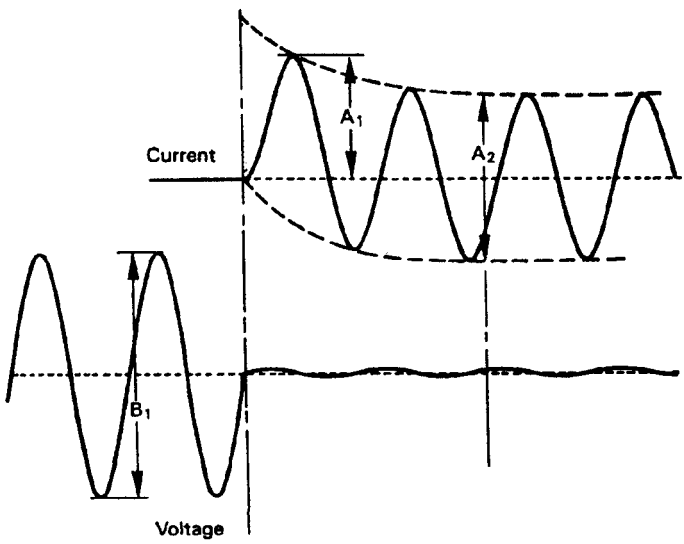
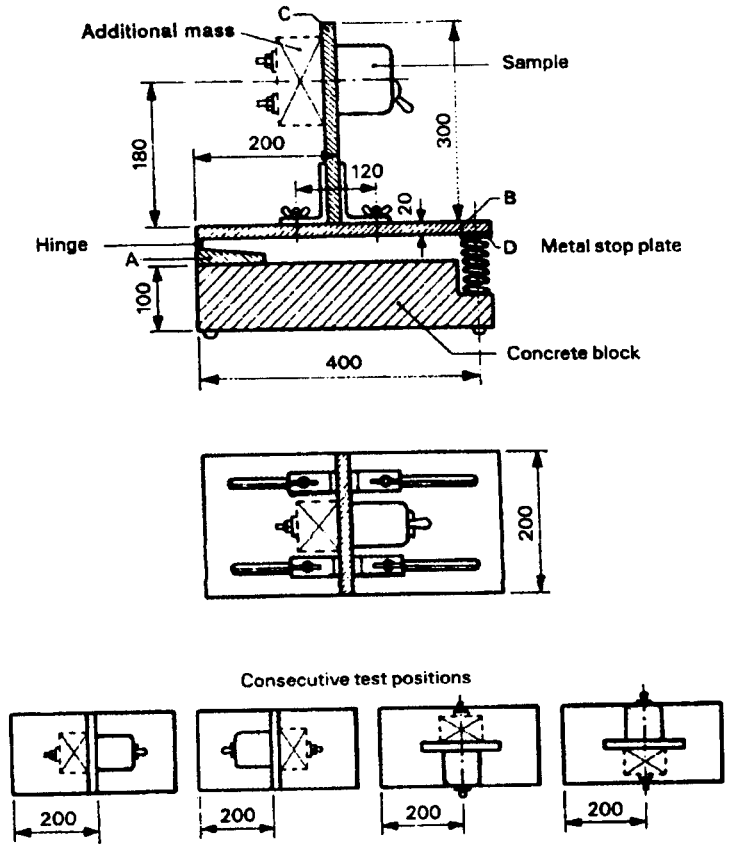
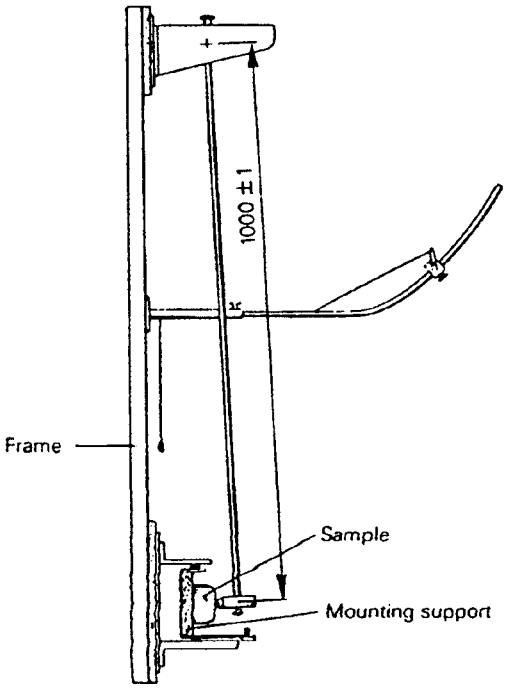


Figure 10 – Example of calibration record for short-circuit test



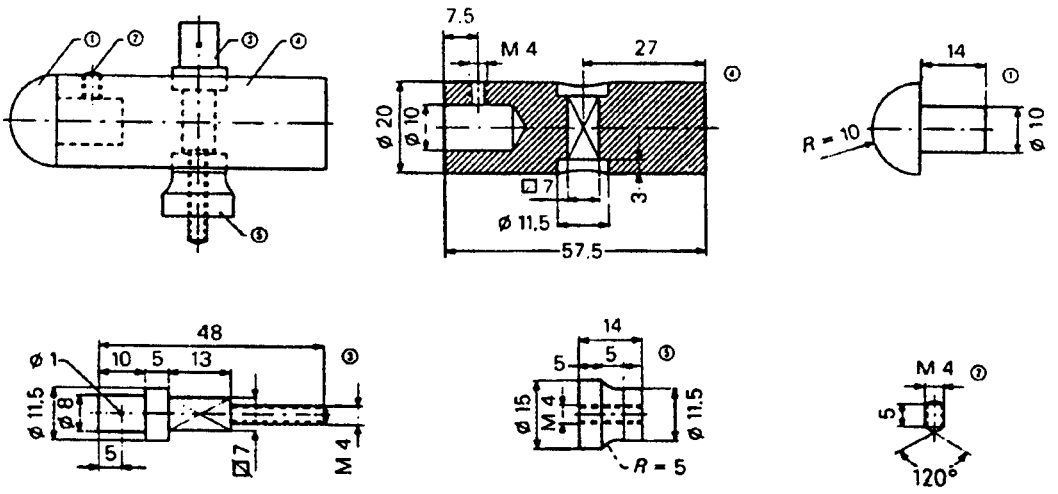
Dimensions in millimetres

Figure 11 – Mechanical shock test apparatus (9.13.1)



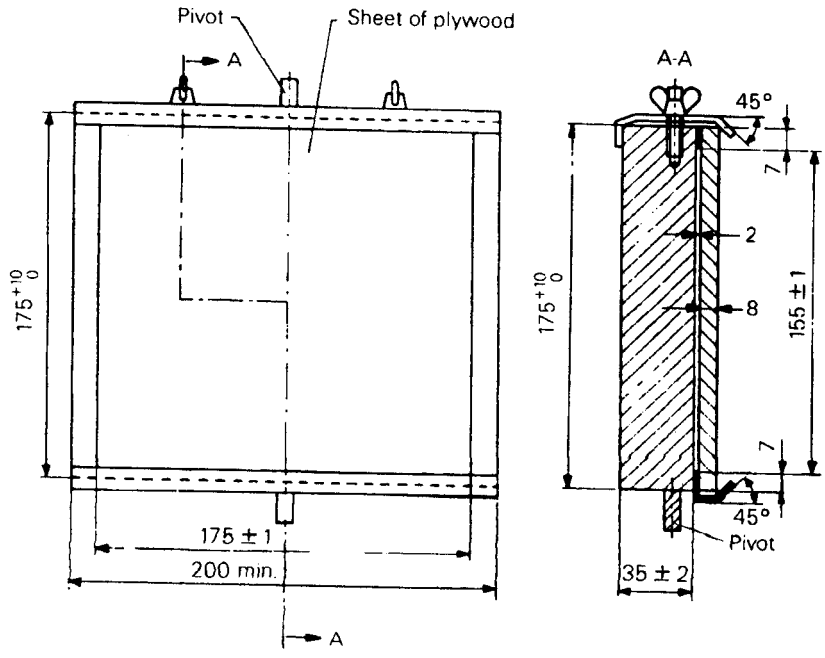
Dimensions in millimetres

Figure 12 – Mechanical impact test apparatus (9.13.2.1)



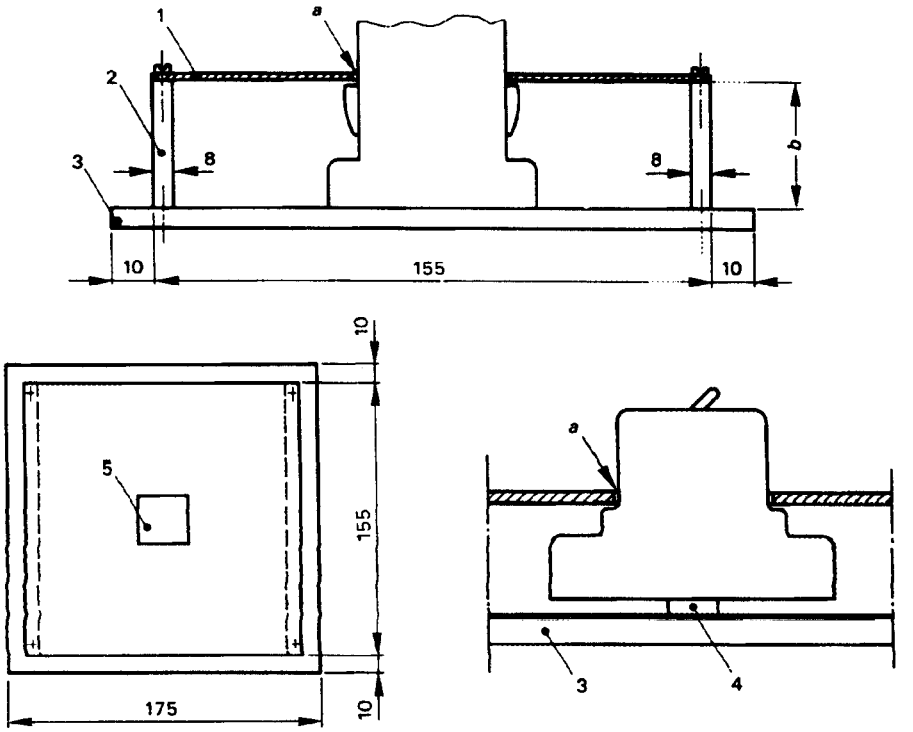
Dimensions in millimetres

Figure 13 – Striking element for pendulum impact test apparatus (9.13.2.1)



Dimensions in millimetres

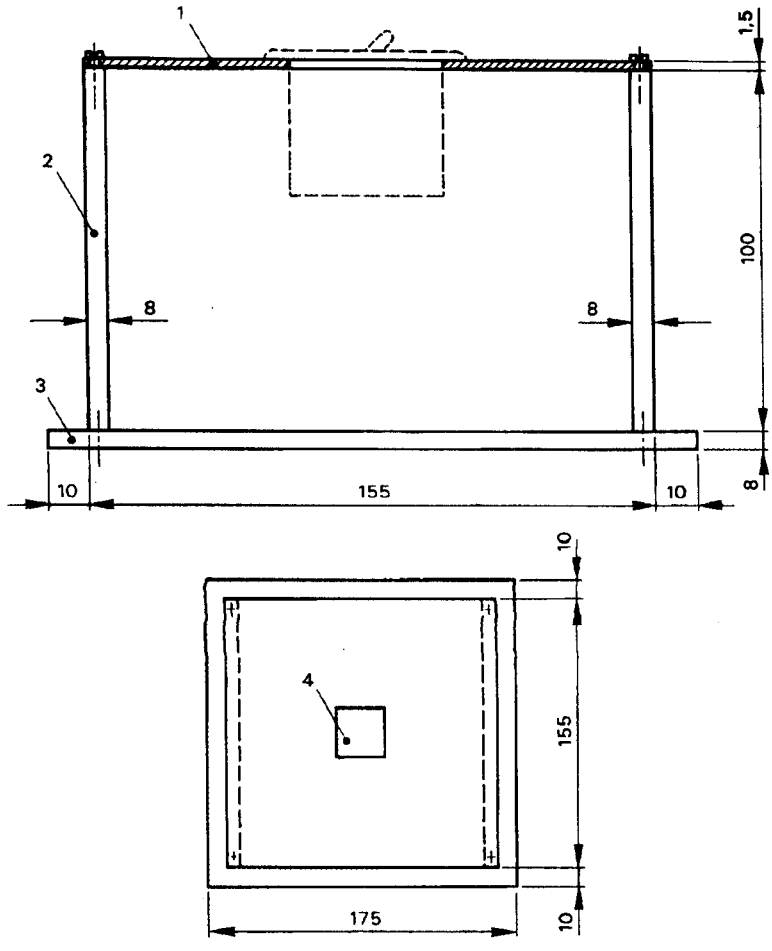
Figure 14 – Mounting support for sample for mechanical impact test (9.13.2.1)



Dimensions in millimetres

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 15 – Example of mounting an unenclosed RCBO for mechanical impact test (9.13.2.1)



Dimensions in millimetres

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 16 – Example of mounting of panel mounting type RCBO for the mechanical impact test (9.13.2.1)

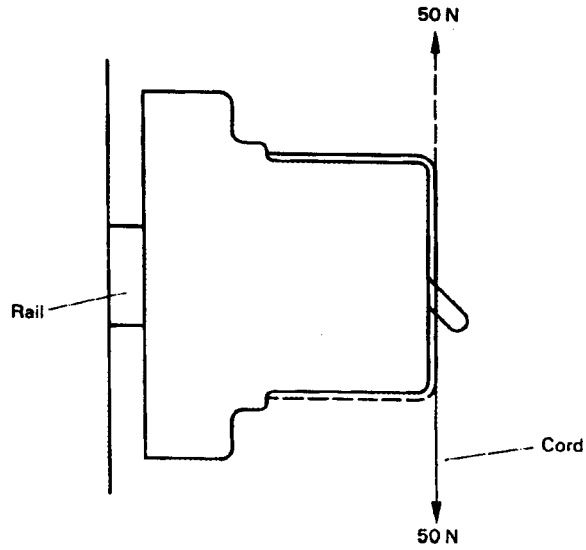


Figure 17 – Application of force for mechanical impact test of rail mounted RCBO (9.13.2.2)

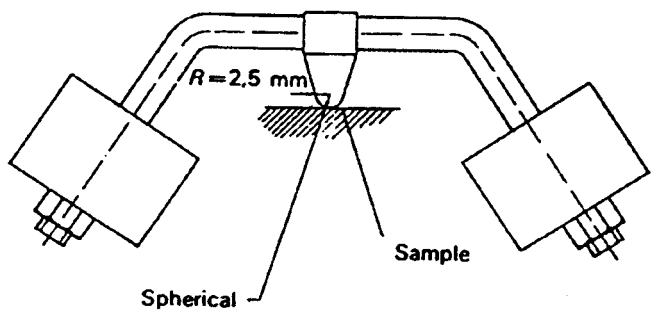
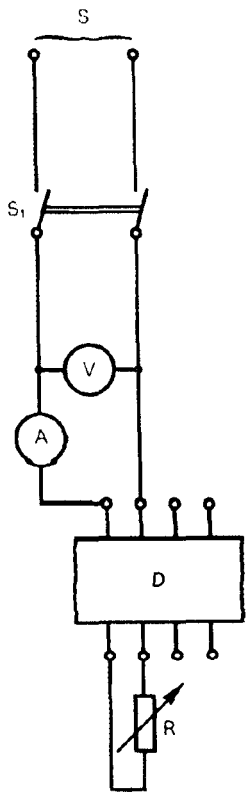


Figure 18 – Ball-pressure test apparatus (9.14.2)



S = Supply
S_1 = Two-pole switch
V = Voltmeter
A = Ammeter
D = RCBO
R = Variable resistor

Figure 19 – Test circuit for the verification of the limiting value of overcurrent in case of a single-phase load through a three-pole or four-pole RCBO (9.18)

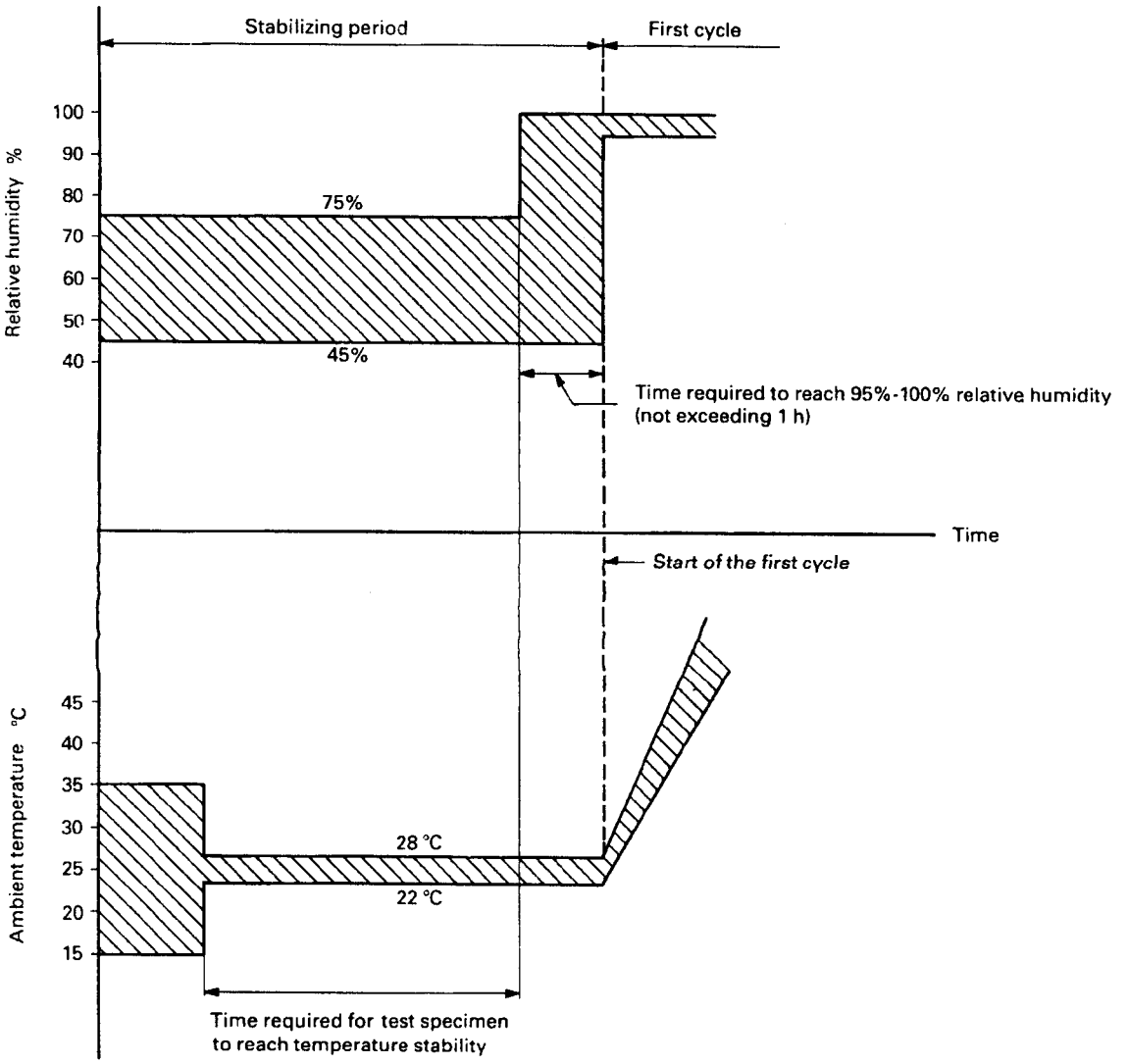


Figure 20 – Stabilizing period for reliability test (9.22.1.3)

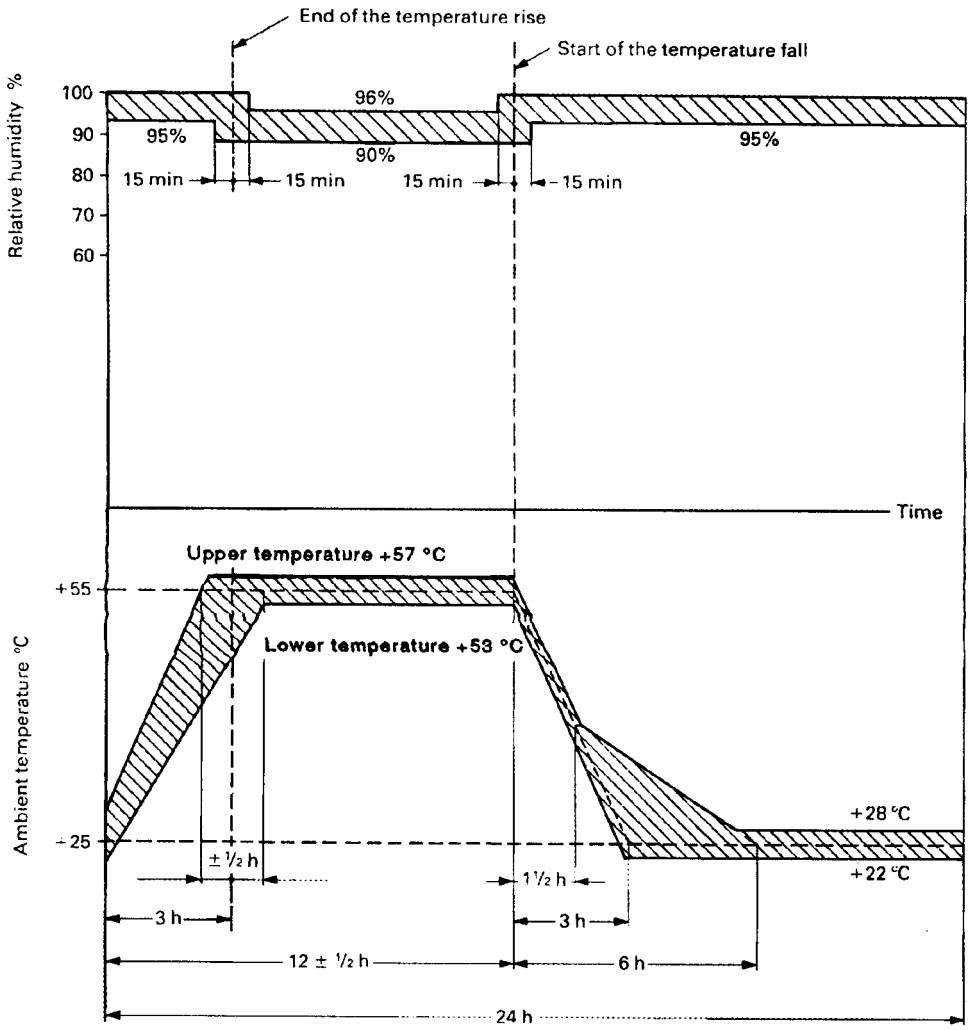


Figure 21 – Reliability test cycle (9.22.1.3)

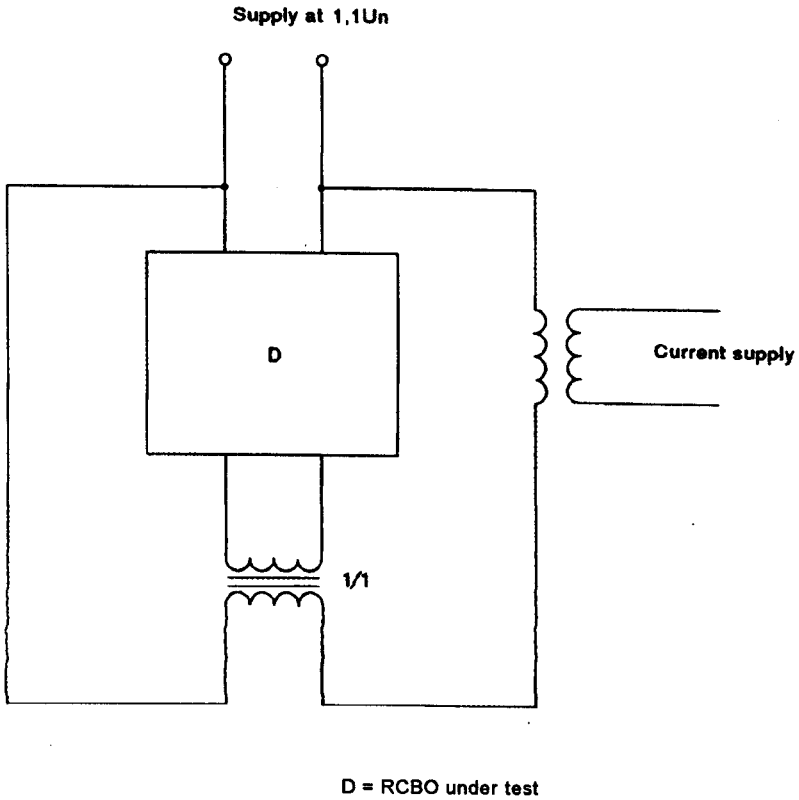


Figure 22 – Example of a test circuit for verification of ageing of electronic components (9.23)

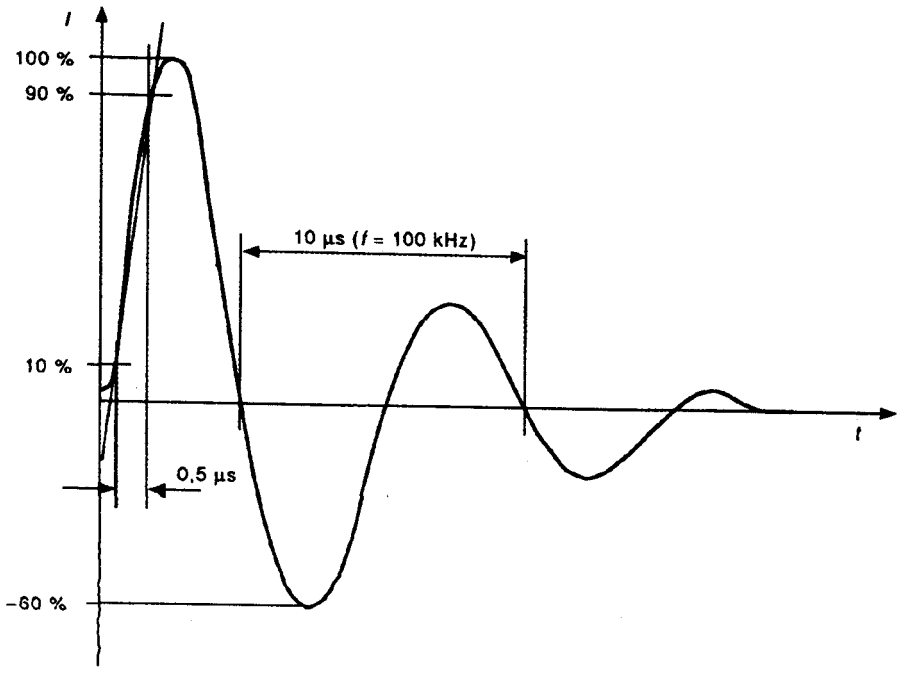
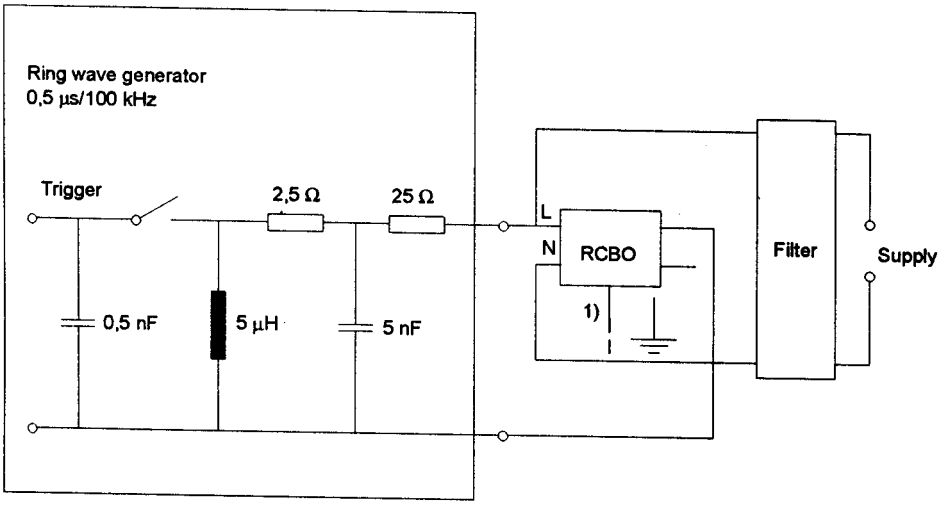


Figure 23 – Damped oscillator current wave, 0,5 µs/100 kHz



1) If the RCBO has an earthing terminal, it should be connected to the neutral terminal, if any, and if so marked on the RCBO or, that failling, to any phase terminal.

Figure 24 – Test circuit for the ring wave test at RCBOs

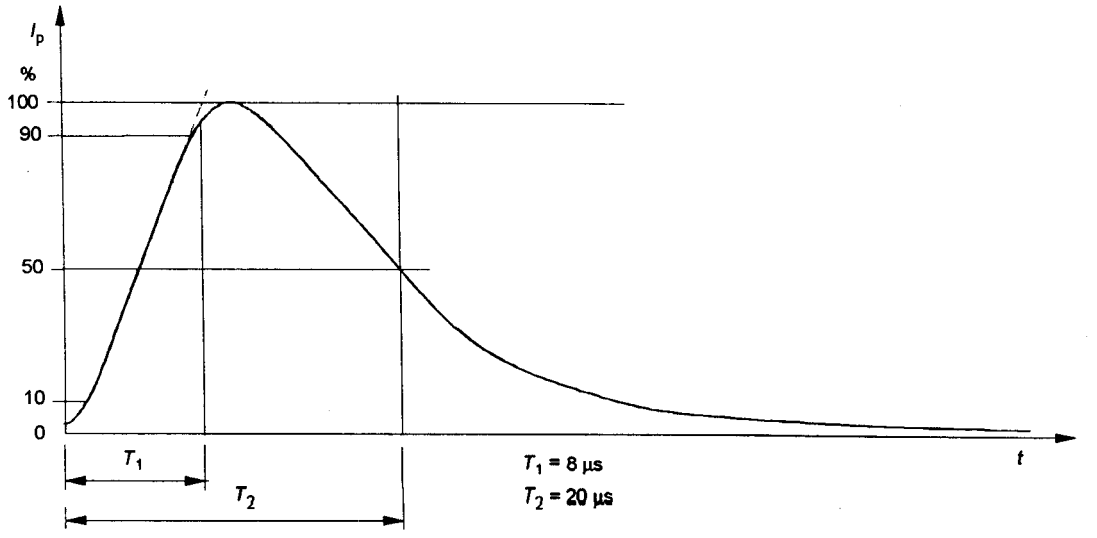
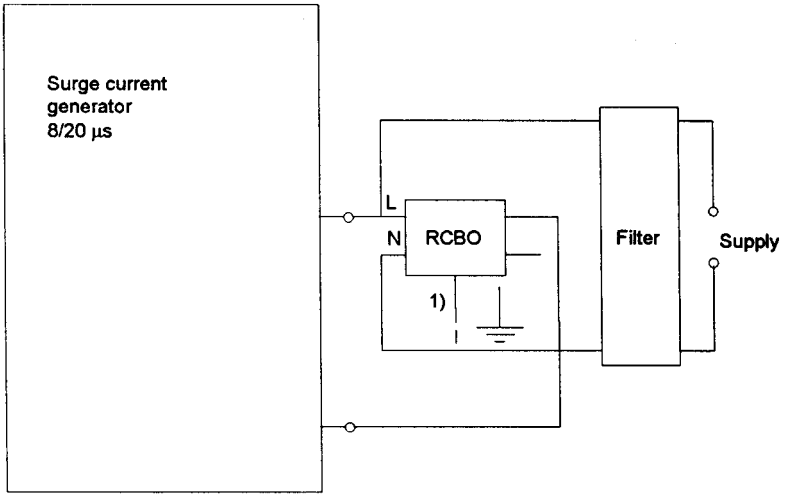


Figure 25 – Surge current impulse 8/20 µs



1) If the RCBO has an earthing terminal, it should be connected to the neutral terminal, if any, and if so marked on the RCBO or, that failling, to any phase terminal.

Figure 26 – Test circuit for the surge current testo at RCBOs

Annex A
(normative)

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

The term certification denotes:

- either declaration of conformity by the manufacturer, or
- third party certification, e.g. by an independent testing station.

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	6 8.1.1 8.1.2 9.3 8.1.3 8.1.6 9.11 9.4 9.5 9.6 9.14 8.1.3 9.15	Marking General Mechanism Indelibility of marking Clearances and creepage distances (external parts only) Non-interchangeability Trip-free mechanism Reliability of screws, current-carrying parts and connections Reliability of terminals for external conductors Protection against electric shock Resistance to heat Clearance and creepage distances (internal parts) Resistance to abnormal heat and to fire
B	9.7 9.8 9.20 9.22.2 9.23	Dielectric properties Temperature-rise Resistance of insulation against an impulse voltage Reliability at 40 °C Ageing of electronic components
C	9.10 9.12.11.2 (and 9.12.12)	Mechanical and electrical endurance Performance at reduced short-circuit currents
D_0	9.9.1	Operating characteristics under residual current conditions
D_1	9.17 9.19 9.21 9.12.13 9.16	Behaviour in case of failure of the line voltage Behaviour in case of surge currents D.C. components Performance at $I_{\Delta m}$ Test device
E_0	9.9.2 9.18	Overcurrent operating characterictics Limiting value of overcurrent in case of a single-phase load through a 3-pole or 4-pole RCBO
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)

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.

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 samples which shall pass the tests[a) b)]	Maximum number of samples for repeated tests[c)]
A	1	1	–
B	3	2	3
C	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

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 reults 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.

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:

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 having the same classification according to behaviour due to d.c. components (4.6) and the same classification according to time-delay (4.7), 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 the number of poles [a]		
	2-poles [b] [c]	3-poles [d] [f]	4-poles [e]
A	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 $I_{\Delta n}$
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 for all other ratings of $I_{\Delta n}$ with max. I_n		
F_0	3 max. rating I_n min. rating $I_{\Delta n}$ 3 [g] min. rating I_n max. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$ 3 [g] min. rating I_n max. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$ 3 [g] min. rating I_n max. rating $I_{\Delta n}$
F_1	3 max. rating I_n min. rating $I_{\Delta n}$ 3 [g] min. rating I_n max. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$ 3 [g] min. rating I_n max. rating $I_{\Delta n}$	3 max. rating I_n min. rating $I_{\Delta n}$ 3 [g] 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 $I_{\Delta n}$

[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, these samples are not required.

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	$E_0 + B^{a)}$	–	$(E_0 + E_1) + F$
D-type	$E_0 + B^{a)}$	$(E_0 + E_1) + F$	–

a) For this sequence only the tests of 9.8 and 9.9.2.2 are required.

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 applicables 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

In determining clearances and creepage distances, it is recommended that the following points should be considered.

If a clearance or creepage distance is influenced by one or more metal parts, the sum of the sections should have at least the prescribed minimum value.

Individual sections less than 1 mm in length should not be taken into consideration in the calculation of the total length of clearances and creepage distances.

In determining creepage distance

- grooves at least 1 mm wide and 1 mm deep should be measured along their contour;
- grooves having any dimension less than these dimensions should be neglected;
- ridges at least 1 mm high
  - are measured along their contour, if they are integral parts of a component of insulating material (for instance by moulding, welding or cementing);
  - are measured along the shorter of the two following paths: along the joint or along the profile of the ridge, if the ridges are not integral parts of a component of insulating material.

The application of the foregoing recommendations is illustrated by the following figures:

- figures B.1, B.2 and B.3 indicate the inclusion or exclusion of a groove in a creepage distance;
- figures B.4 and B.5 indicate the inclusion or exclusion of a ridge in a creepage distance;
- figure B.6 illustrates how to take into account a joint when the ridge is formed by an inserted insulating barrier, the outside profile of which is longer than the length of the joint;
- figures B.7, B.8, B.9 and B.10 illustrate how to determine the creepage distance in the case of fixing means situated in recesses in insulating parts of insulating material.

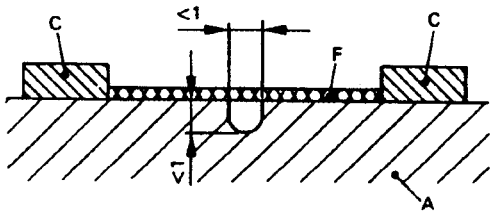


FIGURE B1

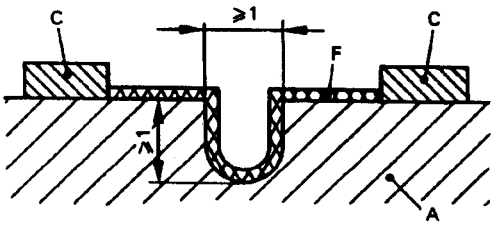


FIGURE B2

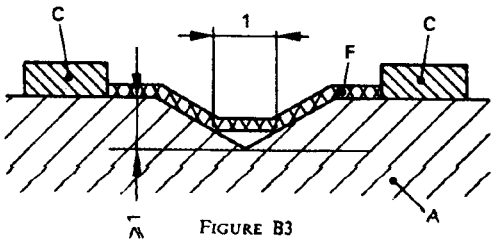


FIGURE B3

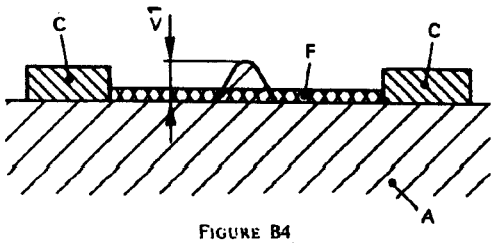


FIGURE B4

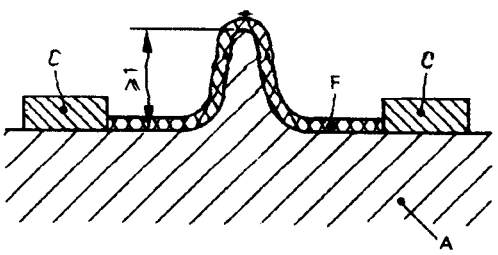


FIGURE B5

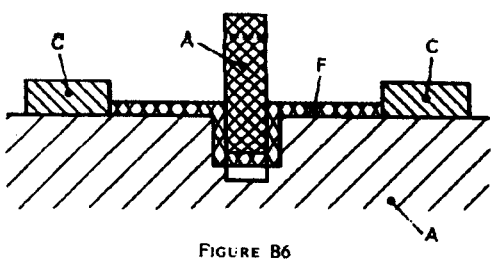


FIGURE B6

A = insulating material C = conducting part F = creepage distance

Figures B.1 to B.6 – Illustrations of the application of creepage distances

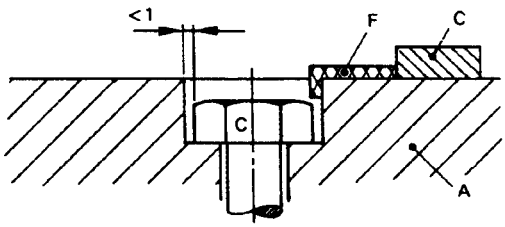


FIGURE B7

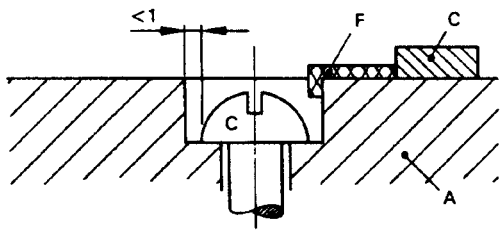


FIGURE B8

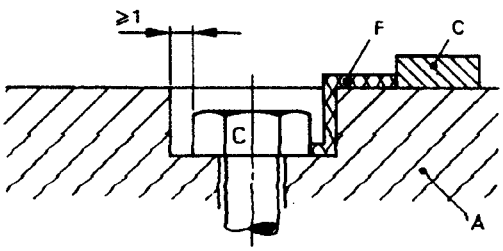


FIGURE B9

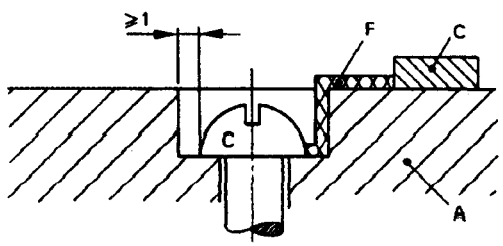


FIGURE B10

Dimensions in millimetres

A = insulating material C = conducting part F = creepage distance

Figures B.7 to B.10 – Illustrations of the application of creepage distances

Annex C
(normative)

Arrangement for the detection of the emission of ionized gases during short-circuit tests

The device under test is mounted as shown in figure C.1, which may require adapting to the specific design of the device, and in accordance with the manufacturer's instructions.

When required (i.e. during "O" operations), a clear polyethylene sheet (0,05 ± 0,01) mm 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 × 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 ± 0,05 g/cm³

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.

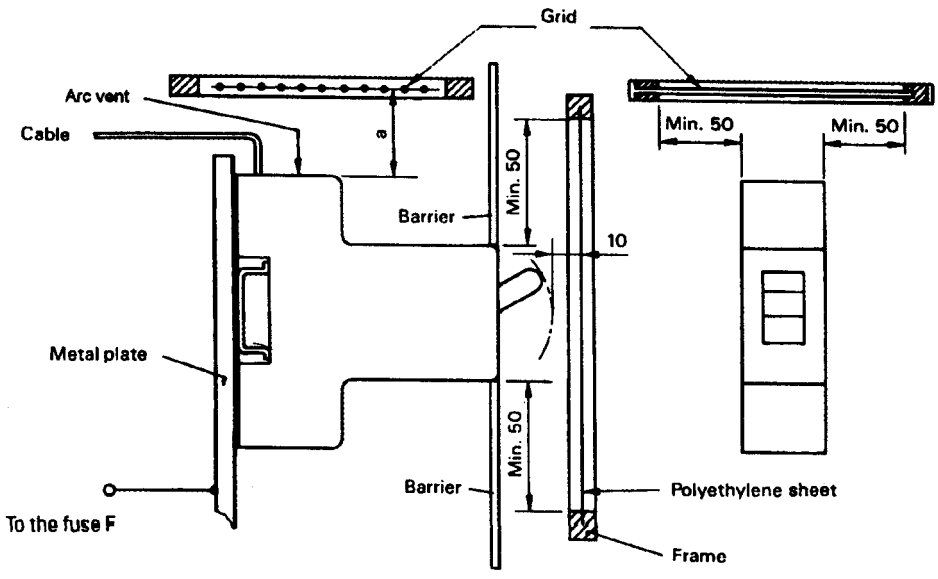
When required, a grid (or grids) according to figure C.2 is (are) placed at a distance of "a" mm from each arc vent side of the device.

The grid circuit (see figure C.3) shall be connected to the points B and C (see figures 5 to 9).

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

Figure C.1 – Test arrangement

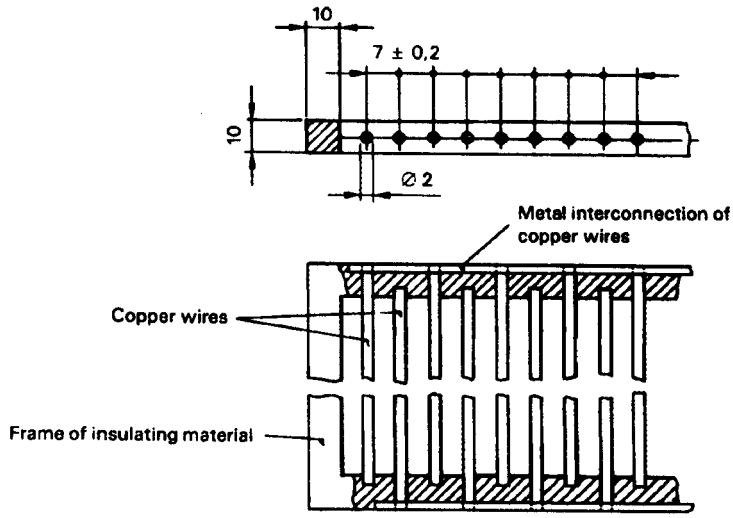


Figure C.2 – Grid

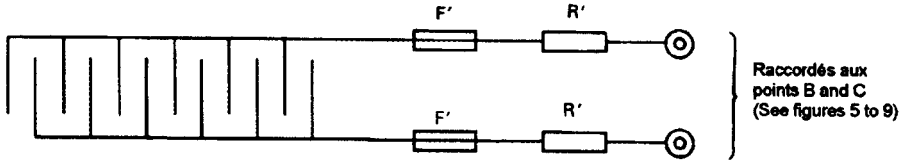


Figure C.3 – Grid circuit

Annex D
(normative)

Routine tests

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.1 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.2 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.3 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 5:

NOTE 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 411.1.3.3 of IEC 60364-4-41.

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 of 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)

Co-ordination between RCBOs and separate fuses associated in the same circuit

The information given in annex D of IEC 60898 to ensure co-ordination between circuit-breakers and separate fuses associated in the same circuit may also be applicable to ensure co-ordination 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.1.1 Scope

This annex applies to RCBOs consisting of a circuit-breaker complying with the requirements of IEC 60898 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.2 Definitions

Add the following definition to clause 3 of this standard:

3.3.23
r.c. unit
a 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.3 Marking and other product information

G.3.1 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.3.2 Marking

G.3.2.1 Marking of the circuit-breaker

Marking of the circuit-breaker shall be in accordance with IEC 60898.

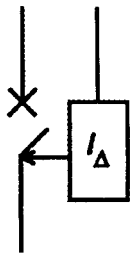
G.3.2.2 Marking of the r.c. unit

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. 60 A max.)
- the symbol



NOTE It is recommended that the references of the circuit-breakers with which the r.c. unit can be assembled be marked.

G.3.2.3 Marking of the assembled circuit-breaker and r.c. unit (RCBO)

The following marking specified in G.3.2.2 shall not be visible after assembly:

- c)
- maximum rated current of the circuit-breaker with which the r.c. unit may be assembled;
- k)

Marking l) of the r.c. unit, if applicable, shall remain visible after assembly.

G.3.3 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;
- method of assembly;
- need for checking operation after assembly to verify the mechanical operation;
- verification of the tripping operation by use of test button.

G.4 Constructional requirements

G.4.1 General

The design shall be such that:

a) it shall be possible to assemble the RCBO on site only once; and

b) any disassembly shall leave permanent visible damage.

G.4.2 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.4.3 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.4.4 Electrical compatibility

It shall not be possible to assemble a circuit-breaker of a given rated voltage with a r.c. unit of a lower rated voltage.

It shall not be possible to assemble a circuit-breaker of a given rated current with a r.c. unit of a lower maximum current marking (see G.3.2.2).

The terminals of the r.c. unit shall be able to clamp the range of nominal cross-sections of conductors specified in table IV of IEC 60898 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 a r.c. unit so as to result in a lower short-circuit performance.

G.5 Type tests and verifications

G.5.1 Tests on circuit-breakers

The circuit-breakers shall comply with the type tests of IEC 60898.

G.5.2 Tests on r.c. units

The r.c. units shall comply with the following type tests specified in table 10 of 9.1.1 of this standard:

tests of 9.3, 9.4, 9.5, 9.11 (if applicable), 9.14 and 9.15.

G.5.3 Tests on assembled circuit-breaker and r.c. unit (RCBO)

The type tests specified in table 10 of 9.1.1 of this standard apply to RCBOs covered by this annex except as follows:

- 9.3, 9.5, 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 A, and of 9.12.11.4 b).

G.5.4 Verification of marking and constructional requirements of RCBOs

Compliance with the requirements of G.3.1, G.3.2, G.3.3, G.4.1, G.4.2 and G.4.4 shall be checked by inspection and manual test, as applicable.

Compliance with the requirements of G.4.3 is checked in particular by verifying that in any position of the circuit-breaker and the r.c unit to be assembled, different from the correct one, assembly is not possible. This applies also to different positions of the operating and any coupling means.

G.6 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
(normative)

List of tests, additional test sequences and numbers of samples for verification of compliance of RCBOs with the requirements of electromagnetic compatibility (EMC)

This annex indicates all tests and test sequences to be performed on RCBOs for verifying their electromagnetic compatibility.

Clause H.1 reports the references of the tests already contained in IEC 61009-1 and included in the test sequences and minimum performances conditions specified in annex A.

Clause H.2 specifies the additional tests, the number of samples, the test sequences and the minimum conditions required for the complete verification of compliance of RCBOs with the EMC requirements.

Test conditions and EMC performance criteria are indicated in the EMC product family standard for RCDs: future IEC 61543.

Electromagnetic compatibility of RCBOs

H.1 EMC tests already included in the product standard

Table H.1 gives, in the third column, the tests already included in the test sequences of annex A ensuring an adequate level of immunity from the electromagnetic disturbances indicated in the second column. The first column gives the corresponding references of tables 1 and 2 of IEC 61543.

Table H.1

Reference of tables 1 and 2 of IEC 61543	Electromagnetic phenomena	Tests of IEC 61009-1
T 1.3	Voltage amplitude variations	9.9.1.5 and 9.17
T 1.4	Voltage unbalance	9.9.1.5 and 9.17
T 1.5	Power frequency variations	9.2
T 1.8	Radiated magnetic field	9.12 and 9.18
T 2.4	Current oscillatory transients	9.19

H.2 Additional tests of EMC product family standards to be applied

The following tests of IEC 61543 shall be carried out according to the table H.2.

Unless otherwise specified, each test sequence is carried out on three new samples.

If all samples submitted according to the fifth column of table H.2 pass the tests, compliance with the standard is met. If only the minimum number given in the sixth column passes the tests, additional samples as shown in the seventh column shall be tested and all shall then satisfactorily complete the test sequence.

Table H.2

Test sequence	Table of IEC 61543	Reference condition of IEC 61543	Phenomena	Number of samples	Minimum number of samples which shall pass the tests	Maximum number of samples for repeated tests
H.2.1 *	4	1.1	Harmonics, interharmonics	3 $I_{\Delta n\ min}$ any I_n	2	3
	4	1.2	Signalling voltages			
	5	2.3	Conducted unidirectional transients of the ms and µs time scale			
H.2.2	5	2.1 and 2.5	Conducted oscillatory voltages or currents	3 $I_{\Delta n\ min}$ any $I_{\Delta n}$	2	3
	5	2.2	Conducted unidirectional transients of the ns time scale (burst)			
H.2.3	6	3.1	Electrostatic discharges	3 $I_{\Delta n\ min}$ any $I_{\Delta n}$	2	3
* For devices containing a continuously operating oscillator, the test of CISPR 14 shall be carried out on the samples prior to the tests of this sequence.						
NOTE On request of the manufacturer the same set of samples may be subjected to more than one test sequence.						

Annex IA
(informative)

Methods of 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:

IA.1 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 Nepierian logarithms.

The time-constant L/R can be ascertained from the above formula as follows:

a) measure the value of i_{do} at the instant of short-circuit and the value of i_d at another instant t before the contact separation;

b) determine the value of $e^{-Rt/L}$ by dividing i_d by i_{do};

c) from a table of values of e^{-x} determine the value of $-x$ corresponding to the ratio of i_d/i_{do};

d) the value x represents Rt/L from which L/R is obtained.

IA.2 Determine the angle φ from:

$$\varphi = \arctan \omega L/R$$

where w 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)

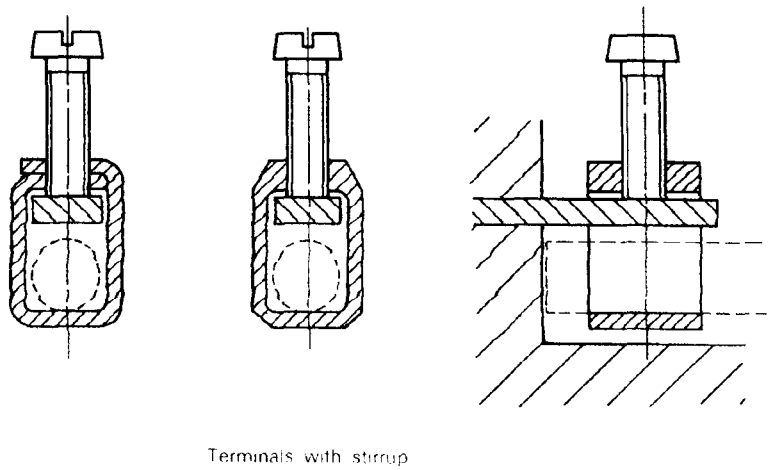
Glossary of symbols

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 a RCBO functionally dependent on line voltage still operates	U_χ
Limiting value of the line voltage below which a RCBO functionally dependent on line voltage opens automatically	U_y

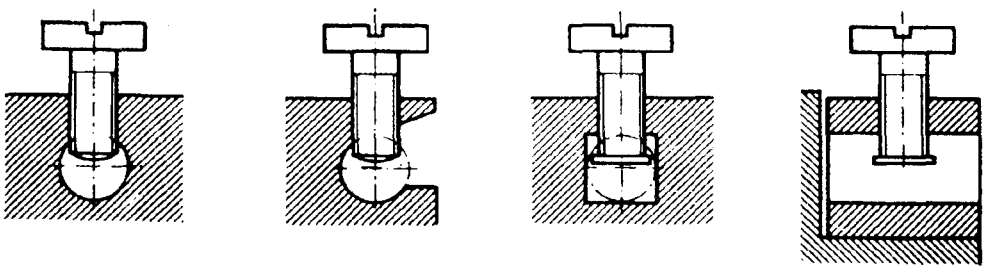
Annex IC
(informartive)

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).



Terminals with stirrup

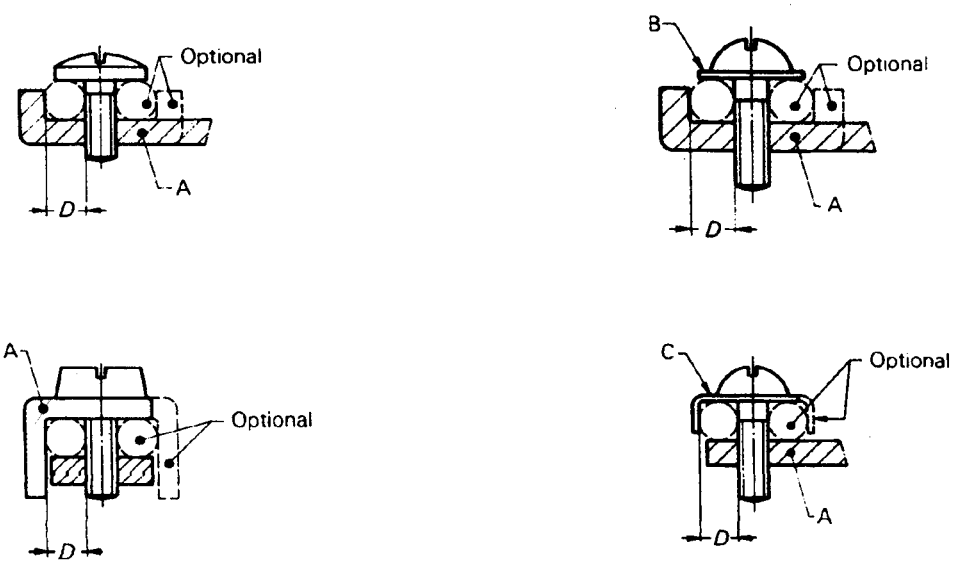


Terminals without pressure plate

Terminals with pressure plate

The part of the terminal containing the threaded hole and the part of the terminal against which the conductor is clamped by the screw may be two separate parts, as in the case of a terminal provided with a stirrup.

Figure IC.1 – Examples of pillar terminals



Screw terminals

Screw not requiring washer or clamping plate

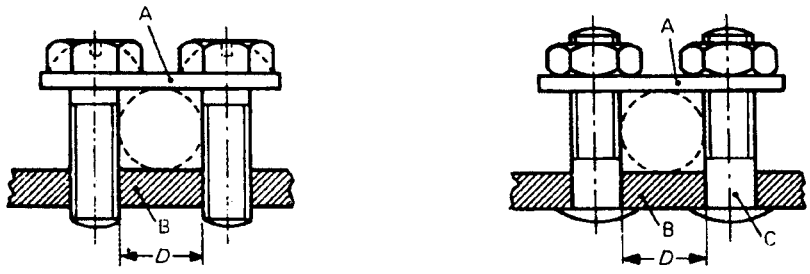
Screw requiring washer, clamping plate or anti-spread devices

Stud terminals

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

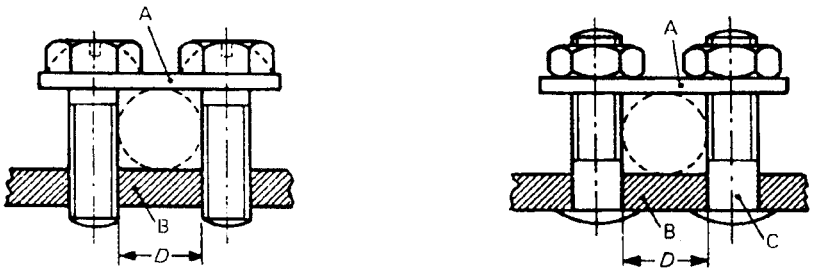
Figure IC.2 – Example of screw terminals and stud terminals



A Saddle
B Fixed part
C Stud
D Conductor space

The two faces of the saddle may be of different shapes to accomodate conductors of either small of 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



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 mm²	AWG	
	Size	Cross-sectional area mm²
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	
	9.20	Resistance of insulation against impulse voltages	Also carried out between each pole in turn
Y1	9.9.1.4	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 $I_{\Delta n}$.

(*Continued from second cover*)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60417 : 2002 Graphical symbols for use on equipment	IS 12032 (Part 7) : 1987 Graphical symbols for diagrams in the field of electrotechnology: Part 7 Switchgear, controlgear and protective devices	Technically Equivalent
IEC 60529 : 1989 Degrees of protection provided by enclosures (IP Code)	IS 12063 : 1987 Classification of degrees of protection provided by enclosures of electrical equipment	do
IEC 60695-2-1/0 : 1994 Fire hazard testing — Part 2: Test methods – Section 1/Sheet 0: Glow-wire test methods — General	IS 11000 (Part 2/Sec 1) : 1984 Fire hazard testing: Part 2 Test methods — Section 1 Glow-wire test and guidance	do
IEC 60884-1 : 1994 Plugs and socket-outlets for household and similar purposes — Part 1: General requirements	IS 1293 : 2005 Plugs and socket-outlets of rated voltage up to and including 250 volts and rated current up to 16 amperes (*third revision*)	do
IEC 60898 : 1995 Circuit-breakers for over-current protection for household and similar installations	IS 8828 : 1996 Circuit-breakers for over current protection for household and similar installations (*second revision*)	Identical
IEC 61008-1 : 1996 Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs) — Part 1: General rules	IS 12640 (Part 1) : 2008 Residual current operated circuit-breakers for household and similar uses: Part 1 Circuit-breakers without integral overcurrent protection (RCCBs) (*first revision*)	do
IEC 61543 : 1995 Residual current-operated protective devices (RCDs) for household and similar use — Electromagnetic compatibility	IS 14614 : 1998 Residual current-operated protective devices (RCDs) for household and similar use — Electromagnetic compatibility	do

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60068-2-28 : 1979	Environmental testing — Part 2: Tests — Guidance for damp heat tests
IEC 60364-4-443 : 1995	Electrical installations of buildings — Part 4: Protection for safety — Chapter 44: Protection against overvoltages — Section 443: Protection against overvoltages of atmospheric origin or due to switching
IEC 60364-5-53 : 1994	Electrical installations of buildings — Part 5: Selection and erection of electrical equipment — Chapter 53: Switchgear and controlgear
IEC 60417 : 1973	Graphical symbols for use on equipment index, survey and compilation of the single sheets
IEC 60755 : 1983	General requirements for residual current operated protective devices

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

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Review of Indian Standards

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Amendments Issued Since Publication

Amendment No.	Date of Issue	Text Affected

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