

INTERNATIONAL STANDARD



Electromechanical contactors for household and similar purposes

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMECHANICAL CONTACTORS FOR HOUSEHOLD AND SIMILAR PURPOSES

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IEC 61095 has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low voltage, in conjunction with subcommittee 23E: Circuit-breakers and similar equipment for household use, of IEC technical committee 23: Electrical accessories. It is an International Standard.

This third edition cancels and replaces the second edition published in 2009. This edition constitutes a technical revision.

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

- a) addition of requirements for screwless terminals;
- b) addition of requirements for the switching of LED lamps. Contactors for domestic and similar applications can be used for controlling lighting loads which is increasingly using LED lamp technology. A specific category for contactors is created: AC-7d. Requirements and tests are added to cover this market development, mainly for making and breaking and conventional operational performance;
- c) addition of requirements for contactors with electronically controlled electromagnet. Household contactors with electronically controlled electromagnet are available for years on the market. To fully cover such device, requirements and tests are added, dealing mainly with operating limits, behaviour in abnormal conditions, breakdown of components, EMC tests, etc.
- d) Embedded software. More and more contactors are incorporating electronic circuits with embedded software. A reference is provided to guide the design of the software.

The text of this document is based on the following documents:

Draft	Report on voting
121A/566/FDIS	121A/573/RVD

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

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

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

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INTRODUCTION

This document gives requirements for contactors household and similar purposes, including contactors for distribution control in buildings.

Contactors for such purposes have particular requirements which include test sequences and sampling plans to facilitate testing.

Contactors according to this document are limited in the range of operational currents and operational voltages to values appropriate to the applications. Such contactors are for use in circuits of limited prospective short-circuit fault current for which they ~~need to be~~ are co-ordinated with an appropriate short-circuit protective device to provide suitable co-ordination.

This document defines in a single document the specific utilization category for a described application and states the relevant requirements. As far as possible, it is in line with the requirements contained in IEC 60947-4-1.

This document also applies to contactors which are components of an appliance, unless otherwise stated in the standard covering the relevant appliance.

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ELECTROMECHANICAL CONTACTORS FOR HOUSEHOLD AND SIMILAR PURPOSES

1 Scope

This document applies to electromechanical air break contactors for household and similar purposes provided with main contacts intended to be connected to circuits the rated voltage of which does not exceed 440 V AC (between phases) with rated operational currents less than or equal to 63 A for utilization category AC-7a, and 32 A for utilization categories AC-7b, AC-7c and AC-7d (expressed in rated power), and rated conditional short-circuit current less than or equal to 6 kA.

~~The contactors dealt with in this standard are not normally designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see 9.3.4) shall form part of the installation.~~

NOTE Today, most LED lamp manufacturers provide information in Watt. So, the main contactor characteristic for utilization category AC-7d is expressed in Watt to be directly applicable to the corresponding LED lamp load.

Specific requirements apply to contactors equipped with screwless-type terminals.

This document does not apply to

- contactors complying with IEC 60947-4-1;
- semiconductor contactors;
- contactors designed for special applications;
- auxiliary contacts of contactors. These are dealt with in IEC 60947-5-1.

This document states

- 1) the characteristics of contactors.
- 2) the conditions with which contactors ~~shall~~ comply with reference to:
 - a) their operation and behaviour;
 - b) their dielectric properties;
 - c) the degrees of protection provided by their enclosures, where applicable;
 - d) their construction;
 - e) their electromagnetic compatibility characteristics.
- 3) the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests.
- 4) the test sequences and the number of samples.
- 5) the information to be given with contactors or in the manufacturer's literature.

2 Normative references

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

IEC 60028:1925, *International standard of resistance for copper*

~~IEC 60050-151:2001, International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices~~

~~IEC 60050-441:1984, International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses
Amendment 1 (2000)~~

~~IEC 60050-604:1987, International Electrotechnical Vocabulary (IEV) – Chapter 604: Generation, transmission and distribution of electricity – Operation
Amendment 1 (1998)~~

~~IEC 60050-826:2004, International Electrotechnical Vocabulary (IEV) – Part 826: Electrical installations~~

IEC 60068-2-78:20012012, Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state

IEC 60073:2002, Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators

IEC 60085:2007, Electrical insulation – Thermal evaluation and designation

~~IEC 60099-1:1991, Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for a.c. systems
Amendment 1 (1999)~~

IEC 60112:20032020, Method for the determination of the proof and the comparative tracking indices of solid insulating materials

~~IEC 60216 (all parts), Electrical insulating materials – Properties of thermal endurance~~

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

IEC 60417-DB:2007⁴, Graphical symbols for use on equipment, available at <https://www.graphical-symbols.info/equipment>

IEC 60445:20062021, Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors

IEC 60447:2004, Basic and safety principles for man-machine interface, marking and identification – Actuating principles

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

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 60664-1:20072020, Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests

IEC 60695-2-10:20002021, Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure

⁴ – “DB” refers to the IEC on-line database.

IEC 60695-2-11:20002021, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end products (GWEPT)*

IEC 60695-11-10:19992013, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*
~~Amendment 1 (2003)~~

~~IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*~~

IEC 60947-4-1:20002018, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*
~~Amendment 1 (2002)~~
~~Amendment 2 (2005)~~

IEC 60947-5-1:20032016, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

IEC 61000-4-34, *Electromagnetic compatibility (EMC) – Part 4-34: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current more than 16 A per phase*

IEC 61140:20012016, *Protection against electric shock – Common aspects for installation and equipment*
~~Amendment 1 (2004)~~

IEC 61180:2016, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

CISPR 14-1:2020, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

ISO 7000:20042019, *Graphical symbols for use on equipment – ~~Index and synopsis~~ Registered symbols*

ISO 2039-2:1987, *Plastics – Determination of hardness – Part 2: Rockwell hardness*

3 Terms and definitions

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

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

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

3.1 General terms

3.1.1

overcurrent

current exceeding the rated current

[SOURCE: IEC 60050-441:1984, 441-11-06]

3.1.2

short-circuit

accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal to or close to zero

[SOURCE: IEC 60050-151:2001, 151-12-04]

3.1.3

short-circuit current

overcurrent resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[SOURCE: IEC 60050-441:1984, 441-11-07]

3.1.4

overload

operating conditions in an electrically undamaged circuit, which cause an overcurrent

[SOURCE: IEC 60050-441:1984, 441-11-08]

3.1.5

overload current

overcurrent occurring in an electrically undamaged circuit

3.1.6

ambient air temperature

temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

Note 1 to entry: For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

[SOURCE: IEC 60050-441:1984, 441-11-13]

3.1.7

conductive part

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

[SOURCE: IEC 60050-441:1984, 441-11-09]

3.1.8**exposed conductive part**

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

Note 1 to entry: Typical exposed conductive parts are walls of enclosures, operating handles, etc.

[SOURCE: IEC 60050-441:1984, 441-11-10]

3.1.9**electric shock**

physiological effect resulting from an electric current through a human or ~~animal body~~ livestock

[SOURCE: IEC 60050-826:2022, 826-12-01]

3.1.10**live part**

conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-826:2022, 826-12-08, modified — Rewording of the definition and addition of a Note 1 to entry.]

3.1.11**protective conductor** (identification: PE)

conductor provided for purposes of safety

EXAMPLE Protection against electric shock.

Note 1 to entry: In an electrical installation, the conductor identified PE is normally also considered as protective earthing conductor.

[SOURCE: IEC 60050-826:2022, 826-13-22, modified — Rewording of the definition, addition of a new example and a new Note 1 to entry.]

3.1.12**neutral conductor**

conductor electrically connected to the neutral point and capable of contributing to the distribution of electric energy

[SOURCE: IEC 60050-826:2021, 826-14-07]

3.1.13**PEN conductor**

conductor combining the functions of both a protective earthing conductor and a neutral conductor

[SOURCE: IEC 60050-826:2022, 826-13-25]

3.1.14**PEM conductor**

conductor combining the functions of both a protective earthing conductor and a mid-point conductor

[SOURCE: IEC 60050-826:2022, 826-13-26]

3.1.15

PEL conductor

conductor combining the functions of both a protective earthing conductor and a line conductor

[SOURCE: IEC 60050-826:2022, 826-13-27]

3.1.16

enclosure

part providing a specified degree of protection of equipment against certain external influences and a specified degree of protection against approach to or contact with live parts and moving parts

Note 1 to entry: This definition is similar to IEC 60050-441:1984, 441-13-01, which applies to assemblies.

[SOURCE: IEC 60050-441:1984, 441-13-01, modified — Rewording of the definition and new Note 1 to entry.]

3.1.17

integral enclosure

enclosure which forms an integral part of the equipment

3.1.18

utilization category

<switching device or fuse> combination of specified requirements related to the condition in which the switching device or the fuse fulfils its purpose, selected to represent a characteristic group of practical applications

Note 1 to entry: The specified requirements ~~may~~ can concern e.g. the values of making capacities (if applicable), breaking capacities and other characteristics, the associated circuits and the relevant conditions of use and behaviour.

[SOURCE: IEC 60050-441:1984, 441-17-19]

3.2 Switching devices

3.2.1

switching device

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

Note 1 to entry: A switching device ~~may~~ can perform one or both of these operations.

[SOURCE: IEC 60050-441:1984, 441-14-01, modified — Addition of a Note 1 to entry.]

3.2.2

mechanical switching device

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

Note 1 to entry: Any mechanical switching device ~~may~~ can be designated according to the medium in which its contacts open and close, e.g. air, SF₆, oil.

[SOURCE: IEC 60050-441:1984, 441-14-02]

3.2.3

semiconductor switching device

switching device designed to make and/or break the current in an electric circuit by means of the controlled conductivity of a semiconductor

Note 1 to entry: This definition differs from IEC 60050-441:1984, 441-14-03 since a semiconductor switching device is also designed for breaking the current.

[SOURCE: IEC 60050-441:1984, 441-14-03, modified — Addition of “and/or break” and new Note 1 to entry.]

3.2.4

fuse

device that, by the fusing of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time

Note 1 to entry: The fuse comprises all the parts that form the complete device

[SOURCE: IEC 60050-441:1984, 441-18-01]

3.2.5

circuit-breaker

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

[SOURCE: IEC 60050-441:1984, 441-14-20, modified — “Duration” replaced with “time”.]

3.2.6

~~(mechanical)~~ **contactor**

contactor

mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

Note 1 to entry: The term “operated otherwise than by hand” means that the device is intended to be controlled and kept in working position from one or more external supplies.

~~NOTE 2 — In French, a contactor the main contacts of which are closed in the position of rest is usually called “rupteur”. The word “rupteur” has no equivalent in the English language.~~

Note 2 to entry: A household contactor can have a handle as additional means for operation. In some countries, contactors can be controlled by a signal from the energy supplier during off-peak hours. An end user is allowed to open or close manually the contactor if necessary.

Note 3 to entry: A contactor is usually intended to operate frequently.

[SOURCE: IEC 60050-441:1984, 441-14-33, modified — Addition of Notes to entry.]

3.2.7

electromagnetic contactor

contactor, in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by an electromagnet

Note 1 to entry: The electromagnet can be electronically controlled.

3.2.8

electronically controlled electromagnet

electromagnet in which the coil is controlled by a circuit with active electronic elements

3.2.9

latched contactor

contactor, the moving elements of which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized

Note 1 to entry: The latching, and the release of the latching, ~~may~~ can be mechanical, electromagnetic, pneumatic, etc.

Note 2 to entry: Because of the latching, the latched contactor actually acquires a second position of rest and, according to 3.2.6 is not, strictly speaking, a contactor. However, since the latched contactor in both its utilization and its design is more closely related to contactors in general than to any other classification of switching device, it is considered proper to require that it complies with the specifications for contactors wherever they are appropriate.

[SOURCE: IEC 60050-441:1984, 441-14-34]

3.2.10

semiconductor contactor

solid state contactor

device which performs the function of a contactor by utilizing a semiconductor switching device

Note 1 to entry: A semiconductor contactor ~~may~~ can also contain mechanical switching devices.

3.2.11

pilot switch

non-manual control switch actuated in response to specified conditions of an actuating quantity

Note 1 to entry: The actuating quantity ~~may~~ can be pressure, temperature, velocity, liquid level, elapsed time, etc.

[SOURCE: IEC 60050-441:1984, 441-14-48]

3.2.12

push-button

control switch having an actuator intended to be operated by force exerted by a part of the human body, usually the finger or palm of the hand, and having stored energy (spring) return

[SOURCE: IEC 60050-441:1984, 441-14-53]

3.2.13

short-circuit protective device

SCPD

device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them

3.2.14

surge arrester

device designed to protect the electrical apparatus from high transient overvoltages and to limit the duration and frequently the amplitude of the follow-on current

[SOURCE: IEC 60050-614:2016, 614-03-51, modified — Addition of “to protect the electrical apparatus from high transient overvoltages and”.]

3.3 Parts of switching devices

3.3.1

pole

<switching device> portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

Note 1 to entry: A switching device is called single-pole if it has only one pole. If it has more than one pole, it ~~may~~ **can** be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[SOURCE: IEC 60050-441:1984, 441-15-01]

3.3.2

main circuit

<switching device> all the conductive parts of a switching device included in the circuit which it is designed to close or open

[SOURCE: IEC 60050-441:1984, 441-15-02]

3.3.3

control circuit

<switching device> all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[SOURCE: IEC 60050-441:1984, 441-15-03]

3.3.4

auxiliary circuit

<switching device> all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit and the control circuits of the device

Note 1 to entry: Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they ~~may~~ **can** be part of the control circuit of another switching device.

[SOURCE: IEC 60050-441:1984, 441-15-04]

3.3.5

contact

<mechanical switching device> conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:1984, 441-15-05]

3.3.6

contact

contact (piece)

one of the conductive parts forming a contact

[SOURCE: IEC 60050-441:1984, 441-15-06]

3.3.7

main contact

contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[SOURCE: IEC 60050-441:1984, 441-15-07]

3.3.8

control contact

~~contact included in a control circuit of a mechanical switching device and mechanically operated by this device~~

~~[IEV 441-15-09]~~

3.3.8

auxiliary contact

contact included in an auxiliary circuit and mechanically operated by the switching device

[SOURCE: IEC 60050-441:1984, 441-15-10]

3.3.9

auxiliary switch

<mechanical switching device> switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[SOURCE: IEC 60050-441:1984, 441-15-11]

3.3.10

"a" contact

make contact

control or auxiliary contact which is closed when the main contacts of the mechanical switching device are closed and open when they are open

[SOURCE: IEC 60050-441:1984, 441-15-12]

3.3.11

"b" contact

break contact

control or auxiliary contact which is open when the main contacts of the mechanical switching device are closed and closed when they are open

[SOURCE: IEC 60050-441:1984, 441-15-13]

3.3.12

release

<mechanical switching device> device, mechanically connected to a mechanical switching device, which releases the holding means and permits the opening or the closing of the switching device

Note 1 to entry: A release can have instantaneous, time-delay, etc. operation.

[SOURCE: IEC 60050-441:1984, 441-15-17]

3.3.13

actuating system

<mechanical switching device> whole of the operating means of a mechanical switching device which transmits the actuating force to the contact pieces

Note 1 to entry: The operating means of an actuating system ~~may~~ can be mechanical, electromagnetic, hydraulic, pneumatic, thermal, etc.

3.3.14

actuator

part of the actuating system to which an external actuating force is applied

Note 1 to entry: The actuator ~~may~~ can take the form of a handle, knob, push-button, roller, plunger, etc.

[SOURCE: IEC 60050-441:1984, 441-15-22]

3.3.15

position indicating device

part of a mechanical switching device which indicates whether it is in the open, closed, or, where appropriate, earthed position

[SOURCE: IEC 60050-441:1984, 441-15-25]

3.3.16

terminal

conductive part of a device provided for electrical connection to external circuits

3.3.17

screw-type terminal

terminal intended for the connection and disconnection of conductors or for the interconnection of two or more conductors, the connection being made, directly or indirectly, by means of screws or nuts of any kind

3.3.18

screwless-type terminal

terminal intended for the connection and disconnection of conductors or for the interconnection of two or more conductors, the connection being made, directly or indirectly, by means of springs, wedges, eccentrics or cones, etc.

3.3.19

universal terminal

terminal for the connection and disconnection of all types of conductors (solid, stranded and flexible)

[SOURCE: IEC 60998-2-2:2002, 3.101.1, modified – "(rigid and flexible)" replaced with "(solid, stranded and flexible)".]

3.3.20

non-universal terminal

terminal for the connection and disconnection of a certain kind of conductor only (for example, solid conductors only or solid and stranded conductors only)

[SOURCE: IEC 60998-2-2:2002, 3.101.2, modified – "rigid [solid and stranded]" replaced with "solid and stranded".]

3.3.21

push-wire terminal

non-universal terminal in which the connection is made by pushing in solid or stranded conductors

[SOURCE: IEC 60998-2-2:2002, 3.101.3, modified – "rigid (solid or stranded)" replaced with "solid or stranded".]

3.3.22

thread-forming tapping screw

tapping screw having an uninterrupted thread

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

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

3.3.23

thread-cutting tapping screw

tapping screw having an interrupted thread

Note 1 to entry: The thread is intended to remove material from the hole.

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

3.3.24

clamping unit

part of a terminal necessary for the mechanical clamping and the electrical connection of the conductor(s)

3.3.25

unprepared conductor

conductor which has been cut and the insulation of which has been removed for insertion into a terminal

Note 1 to entry: A conductor, the shape of which is arranged for introduction into a terminal or the strands of which are twisted to consolidate the end is considered to be an unprepared conductor.

3.3.26

prepared conductor

~~conductor, the strands of which are soldered or the end of which is fitted with a cable lug, eyelet, etc.~~

a conductor the end of which is fitted with an attachment such as eyelet, sleeve or cable lug

[SOURCE: IEC 60050-442:1998, 442-01-27]

3.3.27

solid conductor

conductor consisting of a single wire

Note 1 to entry: The cross-section of the solid conductor can be circular or shaped.

Note 2 to entry: Solid conductor is defined as class 1 conductor in IEC 60228, or by IEC TR 60344, or equivalent AWG/kcmil.

[SOURCE: IEC 60050-461:2008, 461-01-06, modified – In Note 1 to entry, "may" changed to "can", and Note 2 to entry has been added.]

3.3.28

stranded conductor

conductor consisting of a number of wires, all or some of which are wound in a helix

Note 1 to entry: Stranded conductor is defined as class 2 conductor in IEC 60228, or by IEC TR 60344, or equivalent AWG/kcmil.

[SOURCE: IEC 60050-151:2001, 151-12-36, modified – Note 1 to entry has been added.]

3.3.29**rigid conductor**

solid or stranded conductor having wires of such diameters, or so assembled, that the conductor is not suitable for use in a flexible cable.

[SOURCE: IEC 60947-1:2020, 3.5.31]

3.3.30**flexible conductor**

stranded conductor having wires of diameters small enough and so assembled that the conductor is suitable for use in a flexible cable

Note 1 to entry: Flexible conductor is defined as class 5 or class 6 conductor in IEC 60228, or by IEC TR 60344, or equivalent AWG/kcmil.

[SOURCE: IEC 60050-461:2008, 461-01-11, modified – Note 1 to entry has been added.]

3.4 Operation of switching devices**3.4.1****operation**

<mechanical switching device> transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a circuit-breaker, this ~~may~~ can be a closing operation or an opening operation.

Note 2 to entry: If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[SOURCE: IEC 60050-441:1984, 441-16-01]

3.4.2**operating cycle**

<mechanical switching device> succession of operations from one position to another and back to the first position through all other positions, if any

[SOURCE: IEC 60050-441:1984, 441-16-02]

3.4.3**operating sequence**

<mechanical switching device> succession of specified operations with specified time intervals

[SOURCE: IEC 60050-441:1984, 441-16-03]

3.4.4**automatic control**

~~control of an operation without human intervention, in response to the occurrence of predetermined conditions~~

~~[IEV 441-16-05]~~

3.4.4**closing operation**

<mechanical switching device> operation by which the device is brought from the open position to the closed position

[SOURCE: IEC 60050-441:1984, 441-16-08]

3.4.5

opening operation

<mechanical switching device> operation by which the device is brought from the closed position to the open position

[SOURCE: IEC 60050-441:1984, 441-16-09]

3.4.6

closed position

<mechanical switching device> position in which the predetermined continuity of the main circuit of the device is secured

[SOURCE: IEC 60050-441:1984, 441-16-22]

3.4.7

open position

<mechanical switching device> position in which the predetermined dielectric withstand voltage requirements are satisfied between open contacts in the main circuit of the device

Note 1 to entry: This definition differs from IEC 60050-441:1984, 441-16-23 to meet the requirements of dielectric properties.

[SOURCE: IEC 60050-441:1984, 441-16-23, modified — Replacement of “clearance” with “dielectric withstand voltage requirements are satisfied”.]

3.4.8

position of rest

<contactor> position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized

[SOURCE: IEC 60050-441:1984, 441-16-24]

3.4.9

inching

jogging

energizing a motor or solenoid repeatedly for short periods to obtain small movements of the driven mechanism

3.4.10

plugging

stopping or reversing a motor rapidly by reversing the motor primary connections while the motor is running

3.5 Characteristic quantities

3.5.1

nominal value

value of a quantity used to designate and identify a component, device, equipment, or system

Note 1 to entry: The nominal value is generally a rounded value.

[SOURCE: IEC 60050-151:2001, 151-16-09]

3.5.2

limiting value

in a specification of a component, device, equipment, or system, the greatest or smallest admissible value of a quantity

[SOURCE: IEC 60050-151:2001, 151-16-10]

3.5.3

rated value

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.5.4

rating

set of rated values and operating conditions

[SOURCE: IEC 60050-151:2001, 151-16-11]

3.5.5

prospective current

<of a circuit and with respect to a switching device or a fuse> current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

Note 1 to entry: The method to be used to evaluate and to express the prospective current is specified in the relevant publications.

[SOURCE: IEC 60050-441:1984, 441-17-01]

3.5.6

prospective peak current

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

Note 1 to entry: The definition assumes that the current is made by an ideal switching device, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, e.g. polyphase circuits, it further assumes that the current is made simultaneously in all poles, even if only the current in one pole is considered.

[SOURCE: IEC 60050-441:1984, 441-17-02]

3.5.7

maximum prospective peak current

<AC circuit> prospective peak current when initiation of the current takes place at the instant which leads to the highest possible value

Note 1 to entry: For a multipole device in a polyphase circuit, the maximum prospective peak current refers to a single pole only.

[SOURCE: IEC 60050-441:1984, 441-17-04]

3.5.8

breaking current

<switching device or fuse> current in a pole of a switching device or in a fuse at the instant of initiation of the arc during a breaking process

Note 1 to entry: For AC the current is expressed as the symmetrical RMS value of the AC component.

[SOURCE: IEC 60050-441:1984, 441-17-07, modified — Addition of a new Note 1 to entry.]

3.5.9

breaking capacity

<switching device or fuse> value of prospective current that a switching device or a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

Note 1 to entry: The voltage to be stated and the conditions to be prescribed are dealt with in the relevant product standard.

Note 2 to entry: For AC, the current is expressed as the symmetrical RMS value of the AC component.

Note 3 to entry: For short-circuit breaking capacity, see 3.5.11.

[SOURCE: IEC 60050-441:1984, 441-17-08, modified — Addition of Notes 2 and 3 to entry.]

3.5.10

making capacity

<switching device> value of prospective making current that a switching device is capable of making at a stated voltage under prescribed conditions of use and behaviour

Note 1 to entry: The voltage to be stated and the conditions to be prescribed are dealt with in the relevant product standard.

Note 2 to entry: For short-circuit making capacity, see 3.5.12.

[SOURCE: IEC 60050-441:1984, 441-17-09, modified — Addition of a new Note 2 to entry.]

3.5.11

short-circuit breaking capacity

breaking capacity for which the prescribed conditions include a short-circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:1984, 441-17-11]

3.5.12

short-circuit making capacity

making capacity for which prescribed conditions include a short circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:1984, 441-17-10]

3.5.13

joule integral

I^2t

integral of the square of the current over a given time interval

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

[SOURCE: IEC 60050-441:1984, 441-18-23, modified — Deletion of Notes to entry.]

3.5.14

cut-off current

let-through current

maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

Note 1 to entry: This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

[SOURCE: IEC 60050-441:1984, 441-17-12]

3.5.15

applied voltage

<switching device> voltage which exists across the terminals of a pole of a switching device just before the making of the current

Note 1 to entry: This definition applies to a single-pole device. For a multipole device, it is the phase-to-phase voltage across the supply terminals of the device.

[SOURCE: IEC 60050-441:1984, 441-17-24, modified — New Note 1 to entry.]

3.5.16

recovery voltage

voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current

Note 1 to entry: This voltage ~~may~~ can be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power frequency voltage or the steady-state recovery voltage alone exists.

Note 2 to entry: This definition applies to a single-pole device. For a multipole device it is the phase-to-phase voltage across the supply terminals of the device.

[SOURCE: IEC 60050-441:1984, 441-17-25, modified — New Note 2 to entry.]

3.5.17

transient recovery voltage

TRV

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

Note 1 to entry: The transient voltage ~~may~~ can be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit, the switching device or the fuse. It includes the voltage shift of the neutral of a polyphase circuit.

[SOURCE: IEC 60050-441:1984, 441-17-26, modified — Replacement in the note of “and the switching device” with the “switching device or the fuse”.]

3.5.18

power-frequency recovery voltage

recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:1984, 441-17-27]

3.5.19

DC steady-state recovery voltage

recovery voltage in a DC circuit after the transient voltage phenomena have subsided, expressed by the mean value where ripple is present

[SOURCE: IEC 60050-441:1984, 441-17-28]

3.5.20

clearance

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

[SOURCE: IEC 60050-441:1984, 441-17-31]

3.5.21

creepage distance

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

Note 1 to entry: A joint between two pieces of insulating material is considered part of the surface.

3.5.22

working voltage

highest RMS value of the AC voltage or the highest value of the DC voltage which ~~may~~ can occur (locally) across any insulation at rated supply voltage, transients being disregarded, in open circuit conditions or under normal operating conditions

3.5.23

impulse withstand voltage

highest peak value of an impulse voltage, of prescribed form and polarity, which does not cause breakdown under specified conditions of test

3.5.24

power-frequency withstand voltage

RMS value of a power-frequency sinusoidal voltage which does not cause breakdown under specified conditions of test

3.5.25

pollution

any addition of foreign matter, solid, liquid or gaseous (ionized gases) that ~~may~~ can affect dielectric strength or surface resistivity

3.5.26

pollution degree

<environmental conditions> conventional number based on the amount of conductive or hygroscopic dust, ionized gas or salt and on the relative humidity and its frequency of occurrence, resulting in hygroscopic absorption or condensation of moisture leading to reduction in dielectric strength and/or surface resistivity

Note 1 to entry: The pollution degree of the micro-environment to which equipment is exposed ~~may~~ can be different from that of the macro-environment where the equipment is located because of protection offered by means such as an enclosure or internal heating to prevent absorption or condensation of moisture.

Note 2 to entry: For the purposes of this document, the pollution degree is that of the micro-environment.

3.5.27

micro-environment

<clearance or creepage distance> ambient conditions which surround the clearance or creepage distance under consideration

Note 1 to entry: The micro-environment of the creepage distance or clearance and not the environment of the equipment determines the effect on the insulation. The micro-environment ~~may~~ can be better or worse than the environment of the equipment. It includes all factors influencing the insulation such as climatic and electromagnetic conditions, generation of pollution, etc.

3.5.28

overvoltage category

<in a circuit or within an electrical system> conventional number based on limiting (or controlling) the values of prospective transient overvoltages occurring in a circuit (or within an electrical system having different nominal voltages) and depending on the means employed to influence the overvoltages

Note 1 to entry: In an electrical system, the transition from one overvoltage category to one of a lower category is obtained through appropriate means complying with interface requirements, such as an overvoltage protective device or a series-shunt impedance arrangement capable of dissipating, absorbing, or diverting the energy in the associated surge current, to lower the transient overvoltage value to that of the desired lower overvoltage category.

3.5.29

co-ordination of insulation

correlation of insulating characteristics of electrical equipment with the expected overvoltages and the characteristics of overvoltage protective devices on the one hand, and with the expected micro-environment and the pollution protective means on the other hand

3.5.30

homogeneous field

uniform field

electric field which has an essentially constant voltage gradient between electrodes, such as that between two spheres where the radius of each sphere is greater than the distance between them

3.5.31**inhomogeneous field****non-uniform field**

electric field which does not have an essentially constant voltage gradient between electrodes

3.5.32**tracking**

progressive formation of conducting paths which are produced on the surface of a solid insulating material, due to the combined effects of electric stress and electrolytic contamination on that surface

3.5.33**comparative tracking index****CTI**

numerical value of the maximum voltage in volts at which a material withstands 50 drops of a test solution without tracking

Note 1 to entry: The value of each test voltage and the CTI ~~should be~~ are divisible by 25.

Note 2 to entry: This definition is based on 3.5 of IEC 60112:2003 ~~2020~~.

4 Classification

Subclause 5.2 gives all data which ~~may~~ can be used as criteria for classification.

5 Characteristics of contactors**5.1 Summary of characteristics**

The characteristics shall be stated in the following terms, where such terms are applicable:

- type of contactor (see 5.2);
- rated and limiting values for main circuits (see 5.3);
- utilization category (see 5.4);
- control circuits (see 5.5);
- auxiliary circuits (see 5.6);
- co-ordination with short-circuit protective devices (see 5.7).

5.2 Type of contactor**5.2.1 General**

The following shall be stated (see also Clause 6):

5.2.2 Number of poles**5.2.3 Method of control**

- automatic (by pilot switch or sequence control);
- non-automatic (e.g. by hand operation or by push-buttons);
- semi-automatic (i.e. partly automatic, partly non-automatic).

5.3 Rated and limiting values for main circuits**5.3.1 General**

The rated values established for a contactor shall be stated in accordance with 5.3.2 to 5.4 and 5.7, ~~but it may not be necessary to establish all the listed values.~~

5.3.2 Rated voltages

5.3.2.1 General

A contactor is defined by the rated voltages given in 5.3.2.2 to 5.3.2.4.

5.3.2.2 Rated operational voltage (U_e)

A rated operational voltage of a contactor is a value which, combined with a rated operational current, determines the application of the contactor and to which the relevant tests and the utilization categories are referred.

For a single-pole contactor, the rated operational voltage is generally stated as the voltage across the pole.

For a multipole contactor, it is generally stated as the voltage between phases.

NOTE 1 A contactor ~~may~~ can be assigned a number of combinations of rated operational voltages and rated operational currents or powers for different duties and utilization categories.

NOTE 2 A contactor ~~may~~ can be assigned a number of rated operational voltages and associated making and breaking capacities for different duties and utilization categories.

NOTE 3 Attention is drawn to the fact that the operational voltage ~~may~~ can differ from the working voltage (see 3.5.22) within a contactor.

5.3.2.3 Rated insulation voltage (U_i)

The rated insulation voltage of a contactor is the value of voltage to which dielectric tests voltage and creepage distances are referred.

In no case shall the maximum value of the rated operational voltage exceed that of the rated insulation voltage.

NOTE For contactors without a specified rated insulation voltage, the highest value of the rated operational voltage is considered to be the rated insulation voltage.

5.3.2.4 Rated impulse withstand voltage (U_{imp})

The peak value of an impulse voltage of prescribed form and polarity which the contactor is capable of withstanding without failure under specified conditions of test and to which the values of the clearances are referred.

The rated impulse withstand voltage of a contactor shall be equal to or higher than the values stated for the transient overvoltages occurring in the circuit in which the contactor is fitted.

NOTE Preferred values of rated impulse withstand voltage are given in Table 16.

5.3.3 Currents or powers

5.3.3.1 General

A contactor is defined by the currents given in 5.3.3.2 to 5.3.3.4.

5.3.3.2 Conventional free air thermal current (I_{th})

The conventional free air thermal current is the maximum value of test current to be used for temperature-rise tests of an unenclosed contactor in free air (see 9.3.3.3).

The value of the conventional free air thermal current shall be at least equal to the maximum value of the rated operational current (see 5.3.3.4) of the unenclosed contactor in eight-hour duty (see 5.3.5.2).

Free air is understood to be air in normal indoor conditions, reasonably free from draughts and external radiation.

NOTE 1 This current is not a rating and is not mandatorily marked on the contactor.

NOTE 2 An unenclosed contactor is a contactor supplied by the manufacturer without an enclosure or a contactor supplied by the manufacturer with an integral enclosure which is not normally intended to be the sole contactor protective enclosure. An unenclosed contactor is characterised by IP00.

5.3.3.3 Conventional enclosed thermal current (I_{the})

The conventional enclosed thermal current is the value of current stated by the manufacturer to be used for the temperature-rise tests of the contactor when mounted in a specified enclosure. Such tests shall be in accordance with 9.3.3.3 and are mandatory if the contactor is described as an enclosed contactor in the manufacturer's catalogues and normally intended for use with one or more enclosures of specified type and size (see Note 2 of 5.3.3.2).

The value of the conventional enclosed thermal current shall be at least equal to the maximum value of the rated operational current (see 5.3.3.4) of the enclosed contactor in eight-hour duty (see 5.3.5.2).

If the contactor is normally intended for use in unspecified enclosures, the test is not mandatory if the test for conventional free air thermal current (I_{th}) has been made. In this case, the manufacturer shall be prepared to give guidance on the value of the enclosed thermal current or the derating factor.

NOTE 1 This current is not a rating and is not mandatorily marked on the contactor.

NOTE 2 An enclosed contactor is a contactor normally intended for use with a specified type and size of enclosure or intended for use with more than one type of enclosure.

5.3.3.4 Rated operational currents (I_e) or rated ~~operational~~ powers

A rated operational current of a contactor is stated by the manufacturer and takes into account the rated operational voltage (see 5.3.2.2), the conventional free air or enclosed thermal current, the rated frequency (see 5.3.4), the rated duty (see 5.3.5), the utilization category (see 5.4) and the type of protective enclosure, if any.

In the case of a contactor for the direct switching of individual motors or LED lamps, the indication of a rated operational current ~~may can~~ be replaced or supplemented by an indication of the maximum rated power ~~output~~, at the rated operational voltage considered, of the ~~motor~~ load for which the contactor is intended. The manufacturer shall be prepared to state the relationship assumed between the operational current and the ~~operational~~ power.

5.3.4 Rated frequency

The supply frequency for which a contactor is designed and to which the other characteristic values correspond.

NOTE The same contactor ~~may can~~ be assigned a number or a range of rated frequencies.

5.3.5 Rated duties

5.3.5.1 General

The rated duties considered as normal are given in 5.3.5.2 to 5.3.5.5.

5.3.5.2 Eight-hour duty (continuous duty)

A duty in which the main contacts of a contactor remain closed while carrying a steady current long enough for the contactor to reach thermal equilibrium but not for more than eight hours without interruption.

NOTE 1 This is the basic duty on which the conventional thermal currents I_{th} and I_{the} of the contactor are determined.

NOTE 2 Interruption means breaking the current by operating the contactor.

5.3.5.3 Intermittent periodic duty or intermittent duty

A duty with on-load periods, during which the main contacts of a contactor remain closed, having a definite relation to off-load periods, both periods being too short to allow the contactor to reach thermal equilibrium.

Intermittent duty is characterized by the value of the current, the duration of the current flow and by the on-load factor which is the ratio of the in-service period to the entire period, often expressed as a percentage.

According to the number of operating cycles which they are capable of carrying out per hour, contactors are divided into the following preferred classes:

- class 1: 1 operating cycle per hour;
- class 3: 3 operating cycles per hour;
- class 12: 12 operating cycles per hour;
- class 30: 30 operating cycles per hour;
- class 120: 120 operating cycles per hour;
- class 300: 300 operating cycles per hour;
- class 1 200: 1 200 operating cycles per hour.

A contactor intended for intermittent duty ~~may~~ can be designated by the characteristics of intermittent duty.

EXAMPLE An intermittent duty comprising a current flow of 32 A for 2 min within every 5 min ~~may~~ can be stated as: 32 A, class 12, 40 %.

5.3.5.4 Temporary duty

Duty in which the main contacts of a contactor remain closed for periods insufficient to allow the contactor to reach thermal equilibrium, the on-load periods being separated by off-load periods of sufficient duration to restore equality of temperature with the cooling medium.

5.3.5.5 Periodic duty

A type of duty in which operation, whether at constant or variable load, is regularly repeated.

5.3.6 Normal load and overload characteristics

5.3.6.1 General

This subclause gives general requirements concerning ratings under normal load and overload conditions.

Detailed requirements are given in 8.2.4.

5.3.6.2 Ability to withstand motor switching overload currents

A contactor intended for switching motors shall be capable of withstanding the thermal stresses due to starting and accelerating a motor to normal speed and due to operating overloads.

Requirements to meet these conditions are given in 8.2.4.4.

5.3.6.3 Rated making capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.2. The rated making and breaking capacities are only valid when the contactor is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.6.4 Rated breaking capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.2. The rated making and breaking capacities are only valid when the contactor is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.6.5 Conventional operational performance

Specified as a series of making and breaking operations in 8.2.4.3.

5.3.7 Rated conditional short-circuit current

The rated conditional short-circuit current of a contactor is the value of prospective current stated by the manufacturer, that the contactor, protected by a short-circuit protective device specified by the manufacturer, can withstand satisfactorily for the operating time of this device under the test conditions specified in 9.3.4.

The details of the specified short-circuit protective device shall be stated by the manufacturer.

NOTE The rated conditional short-circuit current is expressed by the RMS value of the AC component.

5.4 Utilization category

5.4.1 General

The utilization category of a contactor defines the intended application and is characterized by one or more of the following service conditions:

- current(s), expressed as multiple(s) of the rated operational current;
- voltage(s), expressed as multiple(s) of the rated operational voltage;
- power-factor.

The standard utilization categories are given in Table 1.

Each utilization category is characterized by the values of the currents, voltages, power-factors and other data of Table 7 and Table 9 and by the test conditions specified in this document.

It is therefore unnecessary to specify separately the rated making and breaking capacities as these values depend directly on the utilization category as shown in Table 7.

Unless otherwise stated, contactors of utilization category AC-7b are designed on the basis of the starting characteristics of the motors compatible with the making capacities of Table 7. When the starting current of a motor, with stalled rotor, exceeds these values, the operational current should be decreased accordingly.

5.4.2 Assignment of utilization categories based on the results of tests

A contactor which has been tested for one utilization category or at any combination of parameters (such as highest operational voltage and current, etc.) can be assigned another utilization category without testing provided that the test currents, voltages, power-factors, number of operating cycles, ON and OFF times given in Table 7 and Table 9 and the test circuit for the assigned utilization category are not more severe than those at which the contactor has been tested and the temperature-rise has been verified at a current not less than the highest assigned rated operational current in continuous duty.

Table 1 – Utilization categories

Utilization categories ^a	Typical ~~applications~~ loads
AC-7a	Slightly inductive ~~loads~~
AC-7b	Motor ~~loads~~ ^b
AC-7c	Switching of compensated electric discharge lamp control ^c
AC-7d	LED lamp
^a Contactors ~~may~~ can have other utilization categories, in which case they shall comply with the requirements of IEC 60947-4-1 for such categories. ^b The AC-7b category ~~may~~ can be used for occasional inching (jogging) or plugging for limited time periods; during such limited time periods the number of operations should not exceed 5/min or more than 10 in a 10-minute period. ^c This category is similar to a capacitive switching category AC-6b as defined in IEC 60947-4-1 for the switching of capacitor banks, the characteristic being very dependent on the capacitance value of the lamp circuit.	

5.5 Control circuits

The characteristics of control circuits are:

- kind of current;
- rated frequency;
- rated control circuit voltage U_c (nature and frequency);
- rated control supply voltage U_s (nature and frequency), where applicable;
- suitability to be connected to SELV circuits.

NOTE A distinction has been made above between the control circuit voltage, which would appear across the "a" contacts (see 3.3.10) in the control circuit, and the control supply voltage, which is the voltage applied to the input terminals of the control circuit of the contactor and which ~~may~~ can be different from the control circuit voltage owing to the presence of built-in transformers, rectifiers, resistors, etc.

The rated control circuit voltage and rated frequency, if any, are the values on which the operating and temperature-rise characteristics of the control circuit are based.

5.6 Auxiliary circuits

The characteristics of auxiliary circuits are the number and kind of contacts ("a" contact, "b" contact, etc.) in each of these circuits and their ratings according to IEC 60947-5-1.

The characteristics of auxiliary contacts and switches shall comply with the requirements of IEC 60947-5-1.

5.7 Co-ordination with short-circuit protective devices

Contactors are characterized by the type, ratings and characteristics of the short-circuit protective devices (SCPD) to be used to provide adequate protection of the contactor against short-circuit currents. Requirements are given in 8.2.5.

6 Product information

6.1 Nature of information

6.1.1 General

The information given in 6.1.2 to 6.1.3 shall be given by the manufacturer.

6.1.2 Identification

- a) the manufacturer's name or trade mark;
- b) type designation or serial number;
- c) number of this document, ~~if the manufacturer claims compliance.~~

6.1.3 Characteristics, basic rated values and utilization

- c) rated operational voltages (see 5.3.2.2);
- d) utilization category and rated operational currents (or rated powers), at the rated operational voltage (see 5.3.3.4 and 5.4);
- e) value of the rated frequency/frequencies, e.g.: 50 Hz or 50 Hz/60 Hz;
- f) rated duty with indication of the class of intermittent duty, if any (see 5.3.5).

Associated values:

- g) rated making and breaking capacities. These indications ~~may~~ can be replaced, where applicable, by the indication of the utilization category (see Table 7);

Safety and installation:

- h) rated insulation voltage (see 5.3.2.3);
- i) rated impulse withstand voltage (see 5.3.2.4), the marking of U_{imp} is not required if equal to 4 kV;
- j) IP code, in case of an enclosed contactor (see 8.1.11);
- k) pollution degree (see 7.1.4.2);
- l) rated conditional short-circuit current (see 5.3.7) and the type, current rating and characteristics of the associated SCPD;
- m) ~~vacant~~

For non-universal screwless terminals:

- "s" or "sol" for terminals declared for solid conductors;
- "r" for terminals declared for solid and stranded conductors;
- "f" for terminals declared for flexible conductors.

Control circuits (see 5.5):

The following information concerning control circuits shall be placed either on the coil or on the contactor:

- n) rated control circuit voltage (U_c), nature of current and rated frequency;
- o) if necessary, nature of current, rated frequency and rated control supply voltage (U_s);

For contactors, the control circuit of which is intended to be connected to a SELV supply:

- p) suitability of the control circuit to be connected to a SELV supply, the main circuit being supplied with a voltage having a value greater than that of the SELV circuit.

- q) In case the control circuit is supplied by another means than the main power supply (e.g., control circuit connected to a SELV supply), additional characteristics or the reference type should be provided for selection criteria of the power supply unit.

Auxiliary circuits:

- r) ratings of auxiliary circuits (see 5.6).

6.2 Marking

Markings shall be indelible and easily legible.

Marking of the manufacturer's name or trademark and type designation or serial number is mandatory on the contactor, preferably on the nameplate if any, to enable complete data to be obtained from the manufacturer.

NOTE 1 In the USA and Canada, the rated operational voltage U_e ~~may~~ can be marked as follows:

- on equipment for use on three-phase – four-wire systems, by both the value of phase-to-earth voltage and that of phase-to-phase voltage, e.g. 277/480 V;
- on equipment for use on three-phase – three-wire systems, by the value of phase-to-phase voltage, e.g. 480 V.

The following information shall be marked and visible after mounting:

- direction of movement of the actuator (see 8.1.5.3), if applicable;
- indication of the position of the actuator (see also 8.1.6.1 and 8.1.6.2);
- ~~– reference to this standard, if the manufacturer claims compliance.~~

The following information shall be marked and visible after wiring, before installation of covers or lids:

- for miniaturized contactors, symbol, colour code or letter code;
- terminal identification and marking (see 8.1.7.4);
- IP code and class of protection against electric shock, when applicable (marked preferably on the contactor as far as possible).

Markings shall not be placed on screws, removable washers or other removable parts.

Data under k) shall be indicated on the enclosure, if any.

Data under c) shall be ~~indicated~~ marked on the ~~nameplate~~ product.

Data under n), if relevant, shall be indicated on the nameplate, or marked on the contactor or, if the space available is not sufficient, on the smallest package unit or in technical information provided with the product or in the manufacturer's published literature. In the case of a group of terminals located together, a single marking on the device is acceptable. An appropriate marking indicating the length of insulation to be removed before insertion of the conductor into the terminal shall be shown on the contactor.

Data under d) to j), l), m) and o) to s) shall be included on the nameplate, or on the contactor, or in the manufacturer's published literature.

The manufacturer's published literature can be provided digitally for example using an electronically readable identifier on the equipment or its packaging (see IEC 63365).

The marking of terminals shall be in accordance with Annex A of this document.

NOTE 2 Additional utilization categories according to IEC 60947-4-1 ~~may~~ can also be marked (see footnote a to Table 1).

6.3 Instructions for installation, operation and maintenance

~~The manufacturer shall specify in his documents or catalogues the conditions, if any, for installation, operation and maintenance of the contactor during operation and after a fault.~~

~~If necessary, the instructions for the transport, installation and operation of the contactor shall indicate the measures that are of particular importance for the proper and correct installation, commissioning and operation of the contactor.~~

~~These documents shall indicate the recommended extent and frequency of maintenance, if any.~~

The contactor shall be installed in accordance with all specifications given in 6.1, considering its intended use.

Information shall be provided if the control circuit is to be protected by a short circuit protective device.

Maintenance is unusual for contactors intended for household applications.

7 Normal service, mounting and transport conditions

7.1 Normal service conditions

7.1.1 General

Contactors complying with this document shall be capable of operating under the following standard conditions.

7.1.2 Ambient air temperature

The ambient air temperature does not exceed +40 °C and its average over a period of 24 h does not exceed +35 °C.

The lower limit of the ambient air temperature is –5 °C.

Ambient air temperature is that existing in the vicinity of the contactor if supplied without enclosure, or in the vicinity of the enclosure if supplied with an enclosure.

Contactors intended to be used in ambient air temperatures above +40 °C (particularly in tropical countries) or below –5 °C shall either be specially designed or be used according to the information given in the manufacturer's catalogue.

7.1.3 Altitude

The altitude of the site of installation does not exceed 2 000 m.

For installations at higher altitudes than 2000 m, ~~it is necessary to take into account the reduction of the dielectric strength and the cooling effects of the air~~ instruction shall be provided in the contactor documentation.

~~Contactors intended to be so used shall be designed especially or used according to an agreement between manufacturer and user.~~

~~Information in the manufacturer's catalogue may take the place of such an agreement.~~

7.1.4 Atmospheric conditions

7.1.4.1 Humidity

The relative humidity of the air does not exceed 50 % at a maximum temperature of +40 °C. Higher relative humidity ~~may~~ can be permitted at lower temperatures, e.g. 90 % at +20 °C. ~~Special measures may be necessary in cases of occasional condensation due to variation in temperature.~~

NOTE The pollution degrees given in 7.1.4.2 define the environmental conditions more precisely.

7.1.4.2 Pollution degree

The pollution degree (see 3.5.26) refers to the environmental conditions for which the contactor is intended.

NOTE The micro-environment of the creepage distance or clearance and not the environment of the contactor determines the effect on the insulation. The micro-environment ~~may~~ can be better or worse than the environment of the contactor. It includes all the factors influencing the insulation, such as climatic and electromagnetic conditions, generation of pollution, etc.

For contactors intended for use within an enclosure or provided with an integral enclosure, the pollution degree of the environment in the enclosure is applicable.

For the purposes of evaluating clearances and creepage distances, the following four degrees of pollution of the micro-environment are established (the clearances and creepage distances being according to the different pollution degrees given in Table 17 and Table 18)

Pollution degree 1:

No pollution or only dry, non-conductive pollution occurs.

Pollution degree 2:

Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation ~~may~~ can be expected.

Pollution degree 3:

Conductive pollution occurs, or dry, non-conductive pollution occurs which becomes conductive due to condensation.

Pollution degree 4:

The pollution generates persistent conductivity caused, for instance, by conductive dust or by rain or snow.

Standard pollution degree of household and similar applications:

Contactors for household and similar applications are generally for use in a pollution degree 2 environment.

7.1.5 Normal electromagnetic environmental conditions

The normal electromagnetic environmental conditions are those which relate to low-voltage public networks such as residential, commercial and light industrial locations/installations.

7.2 Conditions during transport and storage

The conditions during transport and storage, e.g. temperature and humidity, are those defined in 7.1, except that, unless otherwise specified, the following temperature range applies during transport and storage: between $-25\text{ }^{\circ}\text{C}$ and $+55\text{ }^{\circ}\text{C}$ and, for short periods not exceeding 24 h, up to $+70\text{ }^{\circ}\text{C}$.

7.3 Mounting

The contactor shall be mounted in accordance with the manufacturer's instructions.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

The contactor with its enclosure, if any, whether integral or not, shall be designed and constructed to withstand the stresses occurring during installation and normal use and, in addition, shall provide a specified degree of resistance to abnormal heat and fire.

NOTE An enclosed contactor is a contactor mounted in an enclosure, designed and dimensioned to contain one contactor only.

Protection against hazards caused by the electronic circuits shall be maintained under normal and single fault conditions, as specified in this document.

8.1.2 Materials

8.1.2.1 General

The suitability of materials used is verified by making the following tests on the contactor and/or, if not practicable, on parts taken from it.

- resistance to ageing (see 8.1.2.2)
- resistance to humidity (see 8.1.2.3)
- resistance to heat (see 8.1.2.4)
- resistance to abnormal heat and fire (see 8.1.2.5)
- resistance to rusting (see 8.1.2.6)

As far as resistance to heat, abnormal heat and fire hazard are concerned, priority shall be given to tests made on the contactor or on a suitable part taken from the contactor.

However, in certain cases, tests on materials ~~may~~ can be used, for practical reasons, as an alternative to tests on the contactor.

8.1.2.2 Resistance to ageing

Contactors shall be resistant to ageing.

In general, it is only necessary to test contactors having (or supplied with) enclosures or parts of p.v.c. or similar thermoplastic material and parts of rubber such as sealing rings and gaskets.

Compliance is checked by inspection and, if necessary, by a test according to 9.2.2.1.

8.1.2.3 Resistance to humidity

The contactor shall be protected against the effects of humidity which ~~may~~ can occur in normal service.

Compliance shall be verified by the test specified in 9.2.2.2.

8.1.2.4 Resistance to heat

All parts of enclosed, partially enclosed and unenclosed contactors intended to prevent access to live parts shall not be adversely affected by the highest temperature likely to be reached during normal service.

Compliance shall be verified by the tests specified in 9.2.2.3.1 and 9.2.2.3.2.

8.1.2.5 Resistance to abnormal heat and fire

Parts of insulating material which might be exposed to thermal stresses due to electrical effects, the deterioration of which might impair the safety of the contactor, shall not be adversely affected by abnormal heat or fire.

Compliance shall be verified by the test specified in 9.2.2.4.

If a test has to be made at more than one place on the same sample, care shall be taken to ensure that any deterioration caused by previous tests does not affect the test to be made. Small parts with surface dimensions not exceeding 14 mm × 14 mm are not subjected to the test.

8.1.2.6 Resistance to rusting

Ferrous parts of the contactor including enclosures and covers, but excluding pole faces of electromagnets, shall be protected against rusting.

Compliance shall be verified by the test specified in 9.2.2.5.

8.1.3 Strength of screws or nuts other than those on terminals which are intended to be operated during installation or maintenance

Screws or nuts intended to be operated during installation or maintenance, as recommended by the manufacturer, shall withstand the mechanical stresses occurring in normal service.

Thread-forming tapping screws and thread-cutting tapping screws intended only for mechanical assembly ~~may~~ can be used provided they are supplied together with the piece in which they are intended to be inserted.

An example of a thread-forming tapping screw is shown in Figure 1. An example of a thread-cutting tapping screw is shown in Figure 2. In addition, thread-cutting tapping screws intended to be operated by the installer shall be captive with the relevant part of the accessory.

Screws or nuts which transmit contact pressure shall be in engagement with metal threads.

For electrical connections, no contact pressure shall be transmitted through insulating material other than ceramic or other material with characteristics not less suitable and compensated for any possible shrinkage or yielding.

Compliance shall be verified by inspection and by the test of 9.2.3.

8.1.4 Vacant

8.1.5 Actuator

8.1.5.1 General

The requirements of 8.1.5.2 and 8.1.5.3 apply to contactors provided with a manually operated actuator.

8.1.5.2 Insulation

The actuator of the contactor shall be insulated from the live parts for the rated insulation voltage and, if applicable, the rated impulse withstand voltage.

Moreover:

- if the activator is made of metal, it shall be capable of being satisfactorily connected to a protective conductor unless it is provided with additional reliable insulation;
- if it is made of or covered by insulating material, any internal metal part which might become accessible in the event of insulation failure shall also be insulated from live parts for the rated insulation voltage.

8.1.5.3 Direction of movement

The direction of operation for actuators of devices shall normally ~~conform to~~ comply with IEC 60447. Where devices cannot ~~conform to~~ comply with these requirements, e.g. due to special applications or alternative mounting positions, they shall be clearly marked such that there is no doubt as to the "I" and "O" positions and the direction of the operation.

8.1.5.4 Mounting

Actuators mounted on removable panels or opening doors shall be so designed that when the panels are replaced or the doors closed, the actuator will engage correctly with the associated mechanism.

8.1.6 Indication of the OFF and ON positions

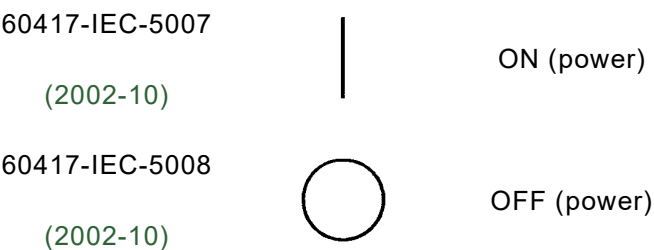
8.1.6.1 Indicating means

When a contactor is provided with means for indicating the closed and open positions, these positions shall be unambiguous and clearly indicated.

NOTE In the case of enclosed contactors, the indication ~~may or may not~~ can be visible from the outside.

This is done by means of a position indicating device (see 3.3.15).

If symbols are used, they shall indicate the closed and open positions respectively, in accordance with IEC 60417:



For contactors operated by means of two push-buttons, only the push-button designated for the opening operation shall be red or marked with the symbol "O".

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

The colours of other push-buttons, illuminated push-buttons and indicator lights shall be in accordance with IEC 60073.

8.1.6.2 Indication by the actuator

When the actuator is used to indicate the position of the contacts, it shall automatically take up or stay in, when released, the position corresponding to that of the moving contacts; in this case, the actuator shall have two distinct rest positions corresponding to those of the moving contacts, but for automatic opening, a third distinct position of the actuator ~~may~~ can be provided.

8.1.7 Terminals

8.1.7.1 Constructional requirements

All parts of terminals which maintain contact and carry current shall be of metal having adequate mechanical strength.

Terminal connections shall be such that the force to connect the conductors ~~may~~ can be ~~connected~~ applied by ~~means of~~ screws, ~~springs~~ screwless-type or other equivalent means to ensure that the necessary contact pressure is maintained.

Terminals shall be so constructed that the conductors can be clamped between suitable surfaces without any significant damage either to conductors or terminals.

Terminals shall not allow the conductors to be displaced or be displaced themselves in a manner detrimental to the operation of the contactor and the insulation voltage shall not be reduced below the rated values.

Screwless terminals shall be so designed and constructed that each conductor is clamped individually.

Screwless-type clamping units, unless otherwise specified by the manufacturer, shall accept solid, stranded and flexible conductors.

On screwless-type clamping unit, the connection or disconnection of conductors shall be made as follows:

- on universal clamping units by the use of a general-purpose tool or a convenient device, integral with the clamping unit to open it for the insertion or withdrawal of the conductors;
- on push-wire clamping units by simple insertion. For the disconnection of the conductors an operation other than a pull only on the conductor shall be necessary. The use of a general-purpose tool or of a convenient device, integral with the clamping unit is allowed in order to "open" it and to assist the insertion or the withdrawal of the conductor.

Examples of screwless terminals are given in Figure 23.

The requirements of this subclause shall be verified by the tests of 9.2.5.3, 9.2.5.4, 9.2.5.5, 9.2.5.7 and 9.2.5.8 as applicable.

NOTE North American countries have particular requirements for terminals suitable for aluminium conductors and marking to identify the use of aluminium conductors.

8.1.7.2 Connecting capacity

The manufacturer shall state the type (rigid – solid or stranded – or flexible), the minimum and the maximum cross-sections of conductors for which the terminal is suitable and, if applicable, the number of conductors simultaneously connectable to the terminal. However, the maximum cross-section shall not be smaller than that stated in 9.3.3.3 for the temperature-rise test and the terminal shall be suitable for conductors of the same type (rigid – solid or stranded – or flexible) at least two sizes smaller, as given in the appropriate column of Table 2.

Standard values of cross-sections of round copper conductors (both metric and AWG/MCM sizes) are shown in Table 2 which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

Table 2 – Standard cross-sections of round copper conductors

ISO cross-sections mm ²	AWG/MCM	
	Sizes	Equivalent cross-sections mm ²
0,2	24	0,205
–	22	0,324
0,5	20	0,519
0,75	18	0,82
1	–	–
1,5	16	1,3
2,5	14	2,1
4	12	3,3
6	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6

NOTE The dash, when it appears, counts as a size when considering connecting capacity.

8.1.7.3 Connection

Terminals for connection to external conductors shall be readily accessible during installation.

Clamping screws and nuts shall not serve to fix any other component although they ~~may~~ can hold the terminals in place or prevent them from turning.

8.1.7.4 Terminal identification and marking

Terminals shall be clearly and permanently identified in accordance with IEC 60445.

Terminals intended exclusively for the neutral conductor shall be identified by the letter "N", in accordance with IEC 60445.

The protective earth terminal shall be identified in accordance with 8.1.9.3.

Additional requirements for terminal identification and marking are given in Annex A.

8.1.8 Additional requirements for contactors provided with a neutral pole

When a contactor is provided with a pole intended only for connecting the neutral, this pole shall be clearly identified to that effect by the letter "N" (see 8.1.7.4).

A switched neutral pole shall not break before and shall not make after the other poles.

The value of the conventional thermal current shall be identical for all poles.

8.1.9 Provisions for earthing

8.1.9.1 Constructional requirements

The exposed conductive parts (e.g. chassis, framework and fixed parts of metal enclosures) other than those which cannot constitute a danger shall be electrically interconnected and connected to a protective earth terminal for connection to an earth electrode or to an external protective conductor.

This requirement can be met by the normal structural parts providing adequate electrical continuity and applies whether the contactor is used on its own or incorporated in an assembly.

Exposed conductive parts are not considered to constitute a danger if they cannot be touched on large areas or grasped with the hand or if they are of small size (approximately 50 mm × 50 mm) or are so located as to exclude any contact with live parts.

Examples of these are screws, rivets, nameplates, transformer cores, electromagnets and certain parts of releases, irrespective of their size.

8.1.9.2 Protective earth terminal

The protective earth terminal shall be readily accessible and so placed that the connection of the contactor to the earth electrode or to the protective conductor is maintained when the cover or any other removable part is removed.

The protective earth terminal shall be suitably protected against corrosion.

In the case of contactors with conductive structures, enclosures, etc., means shall be provided if necessary, to ensure electrical continuity between the exposed conductive parts of the contactors and the metal sheathing of connecting conductors.

The protective earth terminal shall have no other function, except when it is intended to be connected to a PEN conductor. In that case, it shall also have the function of a neutral terminal in addition to meeting the requirements applicable to the protective earth terminal.

8.1.9.3 Protective earth terminal marking and identification

The protective earth terminal shall be clearly and permanently identified by its marking.

The identification shall be achieved by colour (green-yellow mark) or by the notation PE, or PEN as applicable, in accordance with Clause 7 of IEC 60445:2006/2021, or, in the case of PEN, by a graphical symbol for use on contactors.

The graphical symbol to be used is symbol:

60417-IEC-5019 (2006-08)  Protective earth (ground) of IEC 60417.

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

8.1.10 Enclosures

8.1.10.1 General

The requirements of 8.1.10.2 and 8.1.10.3 are applicable only to enclosures supplied or intended to be used with the contactor.

8.1.10.2 Design

The enclosure shall be so designed that when it is opened and other protective means, if any, have been removed, all parts requiring access for installation and maintenance, as prescribed by the manufacturer, are readily accessible.

Sufficient space shall be provided inside the enclosure for the accommodation of external conductors from their point of entry into the enclosure to the terminals to ensure adequate connection.

The fixed parts of a metal enclosure shall be electrically connected to the other exposed conductive parts of the contactor and connected to a terminal which enables them to be earthed or connected to a protective conductor.

Under no circumstances shall a removable metal part of the enclosure be insulated from the part carrying the earth terminal when the removable part is in place.

The removable parts of the enclosure shall be firmly secured to the fixed parts by a device such that they cannot be accidentally loosened or detached owing to the effects of operation of the contactor or its vibrations.

For enclosures having a degree of protection IP1X up to and including IP4X, sufficient space shall be provided for establishing a drain-hole; ~~such a drain hole shall meet the requirements of IEC 60947-1.~~ Subclause 11.3 of IEC 60529:1989 applies with the following addition:

Drain and ventilating holes are treated as normal openings.

Enclosures shall have adequate mechanical strength (see 8.1.12).

Furthermore, it shall not be possible to remove any cover of the enclosure without the use of a tool.

An integral enclosure is considered to be a non-removable part.

If the enclosure is used for mounting push-buttons, it shall not be possible to remove the buttons from the outside of the enclosure.

8.1.10.3 Insulation

If, in order to prevent accidental contact between a metallic enclosure and live parts, the enclosure is partly or completely lined with insulating material, this lining shall be securely fixed to the enclosure.

Compliance shall be verified by inspection.

8.1.11 Degrees of protection of enclosed contactors

IEC 60529 defines degrees of protection for enclosed equipment and guidance for the application of that standard to contactors is under consideration.

8.1.12 Resistance to impact

The external parts of enclosed, partially enclosed, and parts of unenclosed contactors, shall withstand impacts which might be expected in normal service.

Compliance shall be verified by the test specified in 9.2.6.

8.1.13 Durability of markings

The contactor shall be provided with a nameplate marked in a durable manner.

Compliance shall be verified by the test specified in 9.2.7.

8.1.14 Fault and abnormal conditions

This clause applies to contactors incorporating electronic circuits only. For the purpose of this document, "electronic circuit" excludes circuits in which all components are passive (including diodes, resistors, varistors, capacitors, surge suppressors, inductors).

The product shall be designed to avoid operating modes or sequences that can cause a fault condition or component failure leading to a hazard, unless other measures to prevent the hazard are provided by the installation and are described in the installation information provided with the product. The requirements in this clause also apply to abnormal operating conditions as applicable.

Circuit analysis or testing shall be performed to determine whether or not failure of a particular component (including insulation systems) would result in hazard.

This analysis shall include situations where a failure of the component or the insulation (basic and supplementary) would result in:

- an impact on the risk of electric shock
- a risk of degradation resulting in emission of flame, burning particles or molten metal.

The analysis or testing shall include the effect of short-circuit and open-circuit conditions of the component. Testing is necessary unless analysis can conclusively show that, in short-circuit and open circuit conditions, no shock and fire hazard will result from failure of the component.

Compliance shall be checked by test of 9.2.8.

Contactors already tested according to Clauses 101 and 102 of IEC 60669-2-1:2021 are deemed to fulfil the requirements of 8.1.14 and therefore, 9.2.8 is covered.

Components evaluated for their reliability according to relevant product standards are considered to meet these requirements and do not need any further investigation, if tested under conditions that fulfil the conditions for which the product is designed.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

The contactor shall be operated in accordance with the manufacturer's instructions.

The moving contacts of multipole contactors intended to make and break together shall be so mechanically coupled that all poles make and break substantially together (however, for switched neutral pole, see 8.1.8) whether operated manually or automatically.

8.2.1.2 Limits of operation

Contactors shall close satisfactorily at any value between 85 % and 110 % of their rated control supply voltage U_s . Where a range is declared, 85 % shall apply to the lower value and 110 % to the higher.

The limits between which contactors shall drop out and open fully are 75 % to 20 % of their rated control supply voltage U_s . Where a range is declared, 20 % shall apply to the higher value and 75 % to the lower.

The limits between which a contactor with an electronically controlled electromagnet shall drop out and open fully are 75 % to 20 % of their rated control supply voltage U_s , or 75 % to 10 % of their rated control supply voltage U_s if specified by the manufacturer. In that case, the contactor shall, in addition, be submitted to the capacitive drop out test as follows.

A capacitor C shall be inserted in series in the supply circuit U_s , the total length of the connecting conductors being ≤ 3 m.

The capacitor is short-circuited by a switch of negligible impedance. The supply voltage shall then be adjusted to 110 % U_s .

It shall be verified that the equipment drops out when the switch is operated to the open position.

The value of the capacitor shall be

$$C = 30 + 200\,000 / (f \times U)$$

where C is expressed in nF; f is the minimum rated frequency expressed in Hz; U is the maximum value of U_s expressed in V.

For example, for a coil rated 12...24 V – 50 Hz, the capacitor value is 196 nF (calculation made with U_s max). The test voltage is the highest value of the declared rated supply voltage range U_s .

NOTE The value of the capacitor simulates a typical control wiring of 100 m long cable of 1,5 mm² (0,3 nF/m that is 30 nF for 100 m) connected to a static output having a 1,3 mA leakage current (200 000 in the formula $\approx \frac{10^9 \times 1,3 \times 10^{-3}}{2 \times \pi}$).

Limits for closing are applicable after the coils have reached a stable temperature corresponding to indefinite application of 100 % U_s in an ambient temperature of +40 °C.

Limits for drop-out are applicable with the coil circuit resistance at –5 °C. This can be verified by calculation using values obtained at normal ambient temperature.

The limits apply at declared frequency, if any.

8.2.2 Temperature-rise

8.2.2.1 General

~~The requirements of 8.2.2, 8.2.2.2, 8.2.2.3 and 8.2.2.4 apply to contactors in clean, new condition.~~

The temperature-rises of the several parts of the contactor measured during a test carried out under the conditions specified in 9.3.3.3 shall not exceed the limiting values stated in Table 3 and in 8.2.2.2 and 8.2.2.3.

In the case of an electronically controlled electromagnet, coil temperature measuring by variation of resistance can be impracticable; in such a case, other methods are permitted, e.g. thermocouples, calculation or other suitable methods.

NOTE 1 Temperature-rises in normal service ~~may~~ can differ from the test values, depending on the installation conditions and the size of connected conductors.

Table 3 – Temperature-rise limits for insulated coils in air

Classes of insulating materials	Temperature-rise limits (measured by resistance variation)
	K
	Coils in air
A	85
E	100
B	110
F	135
H	160
NOTE The insulation classification is that given in IEC 60085.	

NOTE 2 The temperature-rise limits given in Table 3 and in Table 5 are applicable only if the ambient air temperature remains within the limits -5°C , $+40^{\circ}\text{C}$.

8.2.2.2 Terminals

The temperature-rise of terminals shall not exceed the values stated in Table 4.

Table 4 – Temperature-rise limits of terminals

Terminal materials	Temperature-rise limits
	K ^a
Bare copper	60
Bare brass	65
Tin-plated copper or brass	65
Silver- or nickel-plated copper or brass	70 ^a
Other metals	^b
^a The terminal temperature-rise limit of 70 K is based on the connection of PVC cables. The use in service of connected conductors significantly smaller than those listed in Table 15 could result in higher terminal and internal part temperatures and such conductors should not be used without the manufacturer's consent since higher temperatures could lead to contactor failure. ^b Temperature-rise limits to be based on service experience or life tests but not to exceed 65 K.	

8.2.2.3 Accessible parts

The temperature-rise of accessible parts shall not exceed the values stated in Table 5.

Table 5 – Temperature-rise limits of accessible parts

Accessible parts	Temperature-rise limits ^a
	K
Manual operating means:	
Metallic	15
Non-metallic	25
Parts intended to be touched but not hand-held:	
Metallic	30
Non-metallic	40
Parts which need not be touched for normal operation:	
Metallic	40
Non-metallic	50
Parts not intended to be touched during normal operation	
Exteriors of enclosures adjacent to cable entries:	
Metallic	40
Non-metallic	50
^a Different values ~~may~~ can be prescribed for different test conditions and for devices of small dimensions but not exceeding by more than 10 K the values of this table.	

8.2.2.4 Ambient air temperature

The temperature-rise limits given in Table 4 and Table 5 are applicable only if the ambient air temperature remains within the limits given in 7.1.2.

8.2.2.5 Main circuit

The main circuit of a contactor shall be capable of carrying without the temperature-rises exceeding the limits specified in 8.2.2.2 when tested in accordance with 9.3.3.3.4:

- for a contactor intended for continuous duty: its conventional thermal current (see 5.3.3.2 and/or 5.3.3.3);
- for a contactor intended for intermittent or temporary duty: the relevant rated operational current (see 5.3.3.4).

8.2.2.6 Control circuits

The control circuits of a contactor shall permit the rated duty according to 5.3.5 and also the temperature-rise tests specified in 9.3.3.3.5 to be made without the temperature-rise exceeding the limits specified in Table 3, Table 4 and Table 5.

8.2.2.7 Windings of coils and electromagnets

8.2.2.7.1 Eight-hour duty (continuous duty) windings

With the maximum value of current according to 8.2.2.5 flowing through the main circuit, the windings of the coils shall withstand under continuous load and at the rated frequency their rated control supply voltage without the temperature-rise exceeding the limits specified in Table 3 and 8.2.2.3.

NOTE Depending on the technology, e.g. for some kinds of electronically controlled electromagnets, the control supply voltage cannot be directly applied on the coil winding when connected as in normal service.

8.2.2.7.2 Intermittent duty windings

With no current flowing through the main circuit, the windings of the coils shall withstand, at the rated frequency, their rated control supply voltage applied as detailed in Table 6, according to their intermittent duty class, without the temperature-rise exceeding the limits specified in Table 3 and 8.2.2.3.

NOTE Depending on the technology, e.g. for some kinds of electronically controlled electromagnets, the control supply voltage cannot be directly applied on the coil winding when connected as in normal service.

Table 6 – Intermittent duty test cycle data

Intermittent duty classes	One close-open operating cycle every	Interval of time during which the supply to the control coil is maintained
1	3 600 s	"ON" time shall normally correspond to the on-load factor specified by the manufacturer
3	1 200 s	
12	300 s	
30	120 s	
300	12 s	
1 200	3 s	

8.2.2.7.3 Specially rated (short-time and periodic duty) windings

Specially rated windings shall be tested under operating conditions corresponding to the most severe duty for which they are intended and their ratings shall be stated by the manufacturer.

8.2.2.8 Auxiliary circuits

Auxiliary circuits of a contactor including auxiliary switches shall be capable of carrying their conventional thermal current without the temperature-rise exceeding the limits specified in Table 4 and Table 5 when tested in accordance with 9.3.3.3.7.

NOTE If an auxiliary circuit forms an integral part of the contactor, it suffices to test it at the same time as the main circuit, but at its actual service current.

8.2.2.9 Other parts

The temperature-rises obtained during the test shall not cause damage to current-carrying parts of adjacent parts of the contactor. In particular, for insulating materials, the manufacturer shall demonstrate compliance either by reference to the insulation temperature index (determined for example by the methods of IEC 60216 (all parts) or by compliance with IEC 60085.

8.2.3 Dielectric properties

8.2.3.1 General

The dielectric properties are based on basic safety publications IEC 60664-1 and IEC 61140.

- a) The following requirements provide the means of achieving co-ordination of insulation of a contactor with the conditions within the installation.
- b) The contactor shall be capable of withstanding:
 - the rated impulse withstand voltage (see 5.3.2.4 in accordance with the overvoltage category given in Annex F;
 - the power-frequency withstand voltage.

NOTE The correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of the contactor is given in Annex F.

The rated impulse withstand voltage for a given rated operational voltage shall be not less than that corresponding in Annex F to the nominal voltage of the supply system of the circuit at the point where the contactor is to be used, and the appropriate overvoltage category.

- c) The requirements of this subclause shall be verified by the tests of 9.3.3.4.

8.2.3.2 Impulse withstand voltage

a) Main circuit

- 1) Clearances from live parts to parts intended to be earthed and between poles shall withstand the test voltage given in Table 16 appropriate to the rated impulse withstand voltage.
- 2) Solid insulation of contactor associated with clearances item a) 1) above shall be subjected to the impulse voltage specified in item a) 1).

b) Auxiliary and control circuits

- 1) For auxiliary and control circuits which operate directly from the main circuit at the rated operational voltage, clearances from live parts to parts intended to be earthed and between poles shall withstand the test voltage given in Table 16 appropriate to the impulse withstand voltage of the main circuit. See also 8.2.3.2, item a) 2).
- 2) Auxiliary and control circuits which do not operate directly from the main circuit ~~may~~ can have an overvoltage withstand capacity different from that of the main circuit. Clearances and associated solid insulation of such circuits, whether AC or DC, shall withstand the appropriate voltage in accordance with Annex F.

8.2.3.3 Power-frequency withstand voltage of the main, auxiliary and control circuits

a) Power-frequency dielectric tests are used in the following cases:

- dielectric tests as type tests for the verification of solid insulation;
- dielectric withstand verification, as a criterion of failure, after switching or short-circuit type tests;
- routine tests.

b) Type tests of dielectric properties

The tests of dielectric properties, as type tests, shall be made in accordance with 9.3.3.4.

c) Verification of dielectric withstand after switching or short-circuit tests

The verification of dielectric withstand after switching and short-circuit tests as a criterion of failure, is always made at power-frequency voltage in accordance with item d) of 9.3.3.4.1.

d) Verification of dielectric withstand during routine tests

Tests to detect faults in materials and workmanship are made at power-frequency voltage, in accordance with item b) of 9.3.3.4.2.

8.2.3.4 Clearances

Clearances shall be sufficient to enable the equipment to withstand the rated impulse withstand voltage, according to 8.2.3.2.

Clearances shall be higher than the values given in Table 17, for case B (homogeneous field) (see 3.5.30) and verified by a sampling test according to 9.3.3.4.3. This test is not required if the clearances, related to the rated impulse withstand voltage and pollution degree, are higher than the values given in Table 17 for case A (inhomogeneous field).

The method of measuring clearances is given in Annex E.

8.2.3.5 Creepage distances

a) Dimensioning

For pollution degrees 1 and 2, creepage distances shall be not less than the associated clearances selected according to 8.2.3.4. For pollution degree 3, the creepage distances shall be not less than the case A clearances (Table 17) to reduce the risk of disruptive discharge due to overvoltages, even if the clearances are smaller than the values of case A as permitted in 8.2.3.4.

The method of measuring creepage distances is given in Annex E.

Creepage distances shall correspond to a pollution degree as specified in 7.1.4.2 and to the corresponding material group at the rated insulation or working voltage given in Table 18.

Material groups are classified as follows, according to the range of values of the comparative tracking index (CTI) (see 3.5.33):

- Material group I $600 \leq \text{CTI}$
- Material group II $400 \leq \text{CTI} < 600$
- Material group IIIa $175 \leq \text{CTI} < 400$
- Material group IIIb $100 \leq \text{CTI} < 175$

NOTE The CTI values refer to the values obtained in accordance with IEC 60112, method with Solution A, for the insulating material used.

b) Use of ribs

A creepage distance can be reduced to 0,8 of the relevant value of Table 18 by using ribs of 2 mm minimum height, irrespective of the number of ribs. The minimum base of the rib is determined by mechanical requirements (see E.2).

8.2.3.6 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with item c) of 9.3.3.4.1, or DC tests if AC tests cannot be applied.

Dimensioning rules for solid insulation and DC test voltages are under consideration.

8.2.3.7 Spacing between separate circuits

For dimensioning clearances, creepage distances and solid insulation between separate circuits, the highest voltage ratings shall be used (rated impulse withstand voltage for clearances and associated solid insulation and rated insulation voltage or working voltage for creepage distances).

8.2.3.8 Requirements for contactor with protective separation

Requirements for contactor with protective separation are given in Annex I.

8.2.4 Normal load and overload performance requirements**8.2.4.1 General**

Requirements concerning normal load and overload characteristics according to 5.3.6 are given in 8.2.4.2, 8.2.4.3 and 8.2.4.4 below.

8.2.4.2 Making and breaking capacities

Contactors shall be capable of making and breaking currents without failure under the conditions stated in Table 7 for the required utilization categories and the number of operations indicated as specified in 9.3.3.5.

The values of off-time and on-time given in Table 7 and Table 8 shall not be exceeded.

Table 7 – Making and breaking capacities. Making and breaking conditions corresponding to the utilization categories

Categories	Making and breaking conditions						
	I_c/I_e	P_t/P	U_r/U_e	$\cos \varphi$	On-time ^a s	Off-time s	Number of operating cycles
AC-7a	1,5		1,05	0,80	0,05	b	50
AC-7b	8,0		1,05	0,45	0,05	b	50
AC-7c ^c	1,5		1,05	0,90 ^c	0,05	b	50
AC-7d ^d		1,5 ^e	1,05	d	0,05	10 s	50
I_c is the current made and broken, expressed in RMS symmetrical values, but it is understood that the actual peak value in the making operation ~~may~~ can assume a higher value than the symmetrical peak value; I_e is the rated operational current; P_t is the power corresponding to I_{peak} and I^2t test values (See Table 20) P is the rated power; U_r is the power frequency recovery voltage; U_e is the rated operational voltage; $\cos \varphi$ is the power factor of the test circuit. ^a Time ~~may~~ can be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening. ^b See Table 8. ^c The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 2)). ^d The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 3)). ^e P_t shall be calculated with a ratio 1,5 (with a tolerance of $\pm 0,2$) to correspond to a value of Table 20.							

Table 8 – Relationship between current broken I_c and off-time for the verification of rated making and breaking capacities

Current broken I_c A	Off-time s
$I_c \leq 100$	10
$100 < I_c \leq 200$	20
$200 < I_c \leq 300$	30

The values of off-time ~~may~~ can be reduced if agreed by the manufacturer.

8.2.4.3 Conventional operational performance

Tests concerning the operational performance of a contactor are intended to verify that the contactor is capable of making, carrying and breaking without failure the currents flowing in its main circuit under conditions corresponding to the specified utilization category, where relevant.

Contactors shall be capable of making and breaking currents without failure under the conventional conditions stated in Table 9 for the required utilization categories and the number of operations indicated as specified in 9.3.3.6.

Table 9 – Conventional operational performance. Making and breaking conditions corresponding to the utilization categories

Categories	Making and breaking conditions						
	I_c/I_e	P_t/P	U_r/U_e	$\cos \varphi$	On-time ^a s	Off-time s	Number of operating cycles
AC-7 ^a	1,0		1,05	0,80	0,05	b	30 000
AC-7 ^b	d		c	0,45	0,05	b	30 000
AC-7c ^e	1,0		1,05	0,90 ^e	0,05	b	30 000
AC-7d ^f		1	1,05	f	0,05	10 s	30 000
I_c is the current made and broken, expressed in RMS symmetrical values, but it is understood that the actual peak value in the making operation ~~may~~ can assume a higher value than the symmetrical peak value; I_e is the rated operational current; P_t is the power corresponding to I_{peak} and I^2t test values (See Table 20) P is the rated power; U_r is the power frequency recovery voltage; U_e is the rated operational voltage; $\cos \varphi$ is the power factor of the test circuit. ^a Time ~~may~~ can be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening. ^b These OFF times shall be not greater than the values specified in Table 8. ^c $U_r/U_e = 1,0$ for making and $U_r/U_e = 0,17$ for breaking. ^d $I_c/I_e = 6,0$ for making and $I_c/I_e = 1,0$ for breaking. ^e The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 2)). ^f The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 3)).							

8.2.4.4 Ability to withstand overload currents

Contactors with utilization category AC-7b shall withstand the overload currents given in Table 10 as specified in 9.3.5.

Table 10 – Overload current withstand requirements

Test current	Duration of test
$8 \times I_e \text{ max/AC-7b}$	10 s

8.2.5 Co-ordination with short-circuit protective devices

~~Performance under short-circuit conditions~~
~~(rated conditional short-circuit current)~~

The rated conditional short-circuit current of contactors backed up by short-circuit protective device(s) (SCPDs) shall be verified by short-circuit tests as specified in 9.3.4. These tests shall be made:

- at the appropriate value of prospective current shown in Table 24 (test current I_r) and
- at the rated conditional short-circuit current I_Q , if higher than test current I_r .

The rating of the SCPD shall be adequate for any given rated operational current, rated operational voltage and the corresponding utilization category.

Test conditions are given in 9.3.4.3.

Co-ordination requires that, under short-circuit conditions, the contactor shall cause no danger to persons or installations. It is permissible that it is not suitable for further use.

NOTE Use of an SCPD not in compliance with the manufacturer's recommendations ~~may~~ can invalidate the co-ordination.

8.3 EMC Electromagnetic compatibility

8.3.1 General

Contactors not incorporating electronic circuits are not sensitive to electromagnetic disturbances and do not generate significant disturbances in normal service conditions, and therefore no EMC tests are required.

For the purpose of this document, "electronic circuit" excludes circuits in which all components are passive (including diodes, resistors, varistors, capacitors, surge suppressors, inductors).

8.3.2 Immunity

The behaviour of electromechanical contactors for household and similar purposes in case of voltage amplitude variations is specified in 8.2.1.2.

~~They are not sensitive to other electromagnetic disturbances in normal service conditions which occur in the environment described in 7.1.4. Therefore, no immunity tests are required.~~

Contactor incorporating electronic circuits shall have a satisfactory immunity to electromagnetic disturbances.

For the appropriate tests, to verify the compliance with these requirements, see 9.4.2.

8.3.3 Emission

~~Electromechanical contactors for household and similar purposes do not incorporate electronic circuits, or may incorporate only a simple rectifier circuit or components such as diodes, varistors, resistors or capacitors (for instance in the surge suppressors).~~

~~They can only generate electromagnetic disturbances during switching operations. The duration of the disturbances is of the order of milliseconds.~~

Contactors for household and similar purposes which do not incorporate electronic circuits can only generate electromagnetic disturbances during switching operations. The duration of the disturbances is of the order of milliseconds.

Provisionally, until further study is carried out, the frequency and the level of these emissions are considered as part of the normal electromagnetic environment of electromechanical contactors for household and similar purposes, and no electromagnetic emission tests are necessary.

Harmonic tests are not required for contactor incorporating electronically controlled electromagnet because no electronic are used on the main circuit.

The high-frequency (greater than 9 kHz) continuous emissions from equipment incorporating electronic switching circuits shall not exceed the limits specified in 9.4.3.

8.4 Embedded software

Guidance for the development of embedded software for switchgear and controlgear including secure coding is provided by IEC TR 63201, especially by establishing:

- a software management plan according to Clause 5 of IEC TR 63201:2019;
- a design lifecycle management according to Clause 7 of IEC TR 63201:2019.

9 Tests

9.1 Types of test

9.1.1 General

Tests shall be made to prove compliance with the requirements laid down in this document. If relevant, tests ~~may~~ can be carried out in sequences, see test sequences in Annex B.

9.1.2 Type tests

Type tests are intended to verify compliance of the contactor's design with this document. They comprise the verification of:

- a) temperature-rise limits (see 9.3.3.3);
- b) dielectric properties (see 9.3.3.4);
- c) rated making and breaking capacities (see 9.3.3.5);
- d) conventional operational performance (see 9.3.3.6);
- e) operation and operating limits (see 9.3.3.1 and 9.3.3.2);
- f) overload current withstand capability (see 9.3.5);
- g) performance under short-circuit conditions (see 9.3.4);
- h) mechanical properties of terminals (see 9.2.5);
- i) degrees of protection of enclosed contactors (see 9.2.4);
- j) resistance to ageing (see 9.2.2.1);
- k) resistance to humidity (see 9.2.2.2);
- l) resistance to heat (see 9.2.2.3);
- m) resistance to abnormal heat and fire (see 9.2.2.4);
- n) resistance to rusting (see 9.2.2.5);
- o) resistance to tracking (see 9.2.2.6);
- p) screws or nuts other than those on terminals which are intended to be operated during installation or maintenance (see 9.2.3);
- q) resistance to impact (see 9.2.6);
- r) durability of marking (see 9.2.7);
- s) Breakdown of components (see 9.2.8);
- t) Tests for EMC (see 9.4).

If relevant, type tests are grouped in test sequences.

Test sequences, number of samples and results to be obtained are indicated in Annex B.

Unless otherwise specified, each test (or test sequence) is performed on a new sample in clean condition.

Unless otherwise specified, the contactors are tested at an ambient air temperature of $25\text{ °C} \pm 10\text{ °C}$.

9.1.3 Routine tests

Routine tests are intended to detect faults in materials and workmanship and to ascertain proper functioning of the contactor. They shall be made on each individual contactor under the same or equivalent conditions as those specified for type tests (see 9.3.6.1).

Routine tests for contactors comprise:

- operation and operating limits (see 9.3.6.2);
- dielectric tests (see 9.3.6.3).

9.1.4 Sampling tests for clearance verification

Sampling tests for clearance verification are made according to 9.3.3.4.3. Sampling plans and test procedures are under consideration.

9.2 Compliance with constructional requirements

9.2.1 General

Verification of compliance with the constructional requirements stated in 8.1 concerns, for example:

- the materials;
- the contactor;
- the degree of protection of enclosed contactors;
- the mechanical properties of terminals;
- the actuator;
- the position indicating device (see 3.3.15).

9.2.2 Materials

9.2.2.1 Test of resistance to ageing

Contactors incorporating separate gaskets, screwed glands, membranes and parts manufactured from rubber, p.v.c. or similar thermoplastic materials are subjected to a test in a heating cabinet with an atmosphere having the composition and pressure of the ambient air and ventilated by natural circulation, gaskets, glands and membranes being suspended freely.

The temperature in the cabinet is $70\text{ °C} \pm 2\text{ °C}$.

The samples shall be kept in the cabinet for seven days (168 h). The use of an electrically heated cabinet is recommended. Natural air circulation ~~may~~ can be provided by holes in the walls of the cabinet.

After treatment, the samples shall be removed from the cabinet and kept at room temperature and relative humidity between 45 % and 55 % for at least four days (96 h).

The samples shall show, with normal or corrected vision without further magnification, neither surface crack nor shrinkage impairing their further use, nor shall the material have become sticky or greasy, this being judged as follows:

- with the forefinger wrapped in a dry piece of rough cloth the sample shall be pressed with a force of 5 N.

The force of 5 N can be obtained in the following way:

- the sample is placed on one of the pans of a balance and the other pan is loaded with a mass equal to the mass of the sample plus 500 g. Equilibrium is then restored by pressing the sample with the forefinger wrapped in a dry piece of rough cloth.

No trace of the cloth shall remain on the sample and the material of the sample shall not stick to the cloth.

9.2.2.2 Test of resistance to humidity

The contactor resistance to humidity shall be verified by test Ca: damp heat, steady state of IEC 60068-2-78 under the following test conditions:

Inlet openings, if any, shall be left open; if knock-outs are provided, one of them shall be opened. Parts which can be removed without the aid of a tool shall be removed and subjected to the humidity treatment with the main parts: spring lids shall be open during this treatment.

Before being placed in the test chamber, the samples shall be stored at room temperature for at least 4 h before the test. The test duration shall be four days.

After this period, the contactor is removed from the test chamber, the removed parts are reinstalled and the lid closed. The contactor is then submitted to a dielectric test as specified in 9.3.3.4.1, item c).

9.2.2.3 Test of resistance to heat

9.2.2.3.1 Tests on contactor

- a) Parts of insulating material, if any, necessary to retain in position current-carrying parts and parts of the earthing circuit shall be subjected to a ball pressure test at $125\text{ °C} \pm 2\text{ °C}$, except that insulating parts of an enclosure necessary to retain in position the earthing terminal, if any, shall be tested as specified in item b) hereafter.

The ball-pressure apparatus is shown in Figure 3.

The surface of the part to be tested shall be placed in a horizontal position and supported by a steel plate of at least 5 mm thickness and a steel ball of 5 mm diameter shall be pressed against this surface with a force of 20 N.

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

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

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

When it is not possible to make the test on the complete sample, the test shall be carried out on a suitable part of it of at least 2 mm thickness.

NOTE The thickness of 2 mm can be obtained by using several layers.

- b) External parts of insulating material not necessary to retain in position current-carrying parts and parts of the earthing circuit even though they ~~may~~ can be in contact with them, shall be subjected to a ball-pressure test in accordance with item a) above, except that the test is made at a temperature of $70\text{ °C} \pm 2\text{ °C}$ or $40\text{ °C} \pm 2\text{ °C}$ plus the highest temperature-rise determined for the relevant part during the temperature-rise test, whichever is the higher.
- c) Before being placed in the heating cabinet, the contactor under test shall be stored at room temperature for at least 4 h before the test.

The contactor shall be kept for the time sufficient to reach thermal equilibrium, but not less than 1 hour in the heating cabinet at a temperature of $100\text{ °C} \pm 2\text{ °C}$.

The sample shall then be allowed to cool to approximately room temperature.

The standard test finger (see Figure 10) shall be applied to the external surfaces which are accessible during normal service with a force not exceeding 5 N, and there shall be no

access to live parts when the contactor is mounted as in normal use. After the test, markings shall still be legible.

9.2.2.3.2 Tests on materials

A sample of the material, of at least 2 mm thickness, is subjected to the test(s) of 9.2.2.3.1, a) and/or b).

NOTE The manufacturer ~~may~~ can provide data from the insulating material manufacturer (or other reliable source) to demonstrate compliance with these requirements.

9.2.2.4 Tests of resistance to abnormal heat and fire

9.2.2.4.1 Tests on parts of the contactor

The test to be performed for the verification of resistance to abnormal heat and fire is the glow-wire test, which simulates the thermal stresses produced by sources of heat or ignition in order to simulate fire hazard.

The glow-wire test shall be made according to IEC 60695-2-10 and IEC 60695-2-11 under the following conditions:

- for parts of insulating material, necessary to retain in position current-carrying parts by the test made at a temperature of 850 °C, for the purpose of this test a protective conductor, if any, is not considered as a current-carrying part,
- for parts of insulating material not necessary to retain in position current-carrying parts and parts of the earthing circuit, if any, even though they ~~may~~ can be in contact with them, by the test made at a temperature of 650 °C.

9.2.2.4.2 Tests on materials

Suitable specimens of the material shall be subjected to the following tests:

NOTE The manufacturer ~~may~~ can provide data from the insulating material manufacturer (or other reliable source) to demonstrate compliance with the requirements of 8.1.2.5.

- a) Flammability classification test, in accordance with IEC 60695-11-10.
- b) Hot wire ignition (HWI) test, as described in Annex G.

9.2.2.5 Test of resistance to rusting

All grease shall be removed from the parts to be tested, by immersion and agitation for 10 min in a cold chemical degreaser such as refined petrol.

The parts shall then be immersed for 10 min in a 10 % solution of ammonium chloride in water at a temperature of 20 °C ± 5 °C.

Without drying, but after shaking off any drops, the parts shall then be placed for 10 min in a box containing air saturated with moisture at a temperature of 20 °C ± 5 °C.

After the parts have been dried for 10 min in a heating cabinet at a temperature of 100 °C ± 5 °C, their surface shall show no signs of rust.

Traces of rust on sharp edges and any yellowish film removable by rubbing shall be ignored.

For small springs and the like, and for inaccessible parts exposed to abrasion, a layer of grease ~~may~~ can provide sufficient protection against rusting.

Such parts shall only be subjected to the test if there is doubt about the effectiveness of the grease film, the test shall then be made without previous removal of the grease.

NOTE A revision of this test is under consideration.

9.2.2.6 Test of resistance to tracking

This test shall be made on a suitable part taken from the contactor or, if agreed for practical reasons, on a suitable specimen of the insulating material, according to IEC 60112, Solution A.

9.2.3 Test on screws or nuts other than those on terminals which are intended to be operated during installation or maintenance

The screws or nuts shall be tightened and loosened:

- 10 times when 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 shall be completely removed and reinserted each time.

The test shall be made with a suitable screwdriver or spanner, applying a torque as given in Table 11 or as specified by the manufacturer.

The screws or nuts shall be tightened without jerks.

When a screw has a hexagonal head with a slot for tightening with a screwdriver and when Table 11 is used and the values in columns II and III are different, the test shall be made twice:

- first applying to the hexagonal head, the torque specified in column III by means of the spanner,
- then, on a new sample, applying the torque specified in column II by means of the screwdriver.

If the values in columns II and III are the same, only the test with the screwdriver shall be made.

During the test, the screwed connections 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, or damage to enclosures and covers, that will impair the further use of the contactor.

9.2.4 Verification of the degrees of protection of enclosed contactors

See Annex H.

9.2.5 Mechanical properties of terminals

9.2.5.1 General

This subclause does not apply to aluminium terminals or to terminals for the connection of aluminium conductors.

9.2.5.2 General conditions for tests

Unless otherwise stated by the manufacturer, each test shall be made on terminals in a clean and new condition.

When tests are made with round copper conductors, the copper shall be according to IEC 60028.

9.2.5.3 Tests of mechanical strength of terminals

Tests shall be made with the appropriate type of conductor having the maximum cross-sectional area.

The conductor shall be connected and disconnected five times.

For screw-type terminals, the tightening torque shall be in accordance with Table 11 or 110 % of the torque specified by the manufacturer, whichever is the greater.

The test shall be conducted on two separate clamping units.

When a screw has a hexagonal head with means 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 set of samples, 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.

Each time the clamping screw or nut is loosened, a new conductor shall be used for each tightening test.

During the test, clamping units and 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 screwed connections.

Table 11 – Tightening torques for the verification of the mechanical strength of screw-type terminals

Diameter of thread mm		Tightening torque Nm.		
Metric standard values	Range of diameter	I	II	III
2,5	≤2,8	0,2	0,4	0,4
3,0	>2,8 up to and including 3,0	0,25	0,5	0,5
–	>3,0 up to and including 3,2	0,3	0,6	0,6
3,5	>3,2 up to and including 3,6	0,4	0,8	0,8
4	>3,6 up to and including 4,1	0,7	1,2	1,2
4,5	>4,1 up to and including 4,7	0,8	1,8	1,8
5	>4,7 up to and including 5,3	0,8	2,0	2,0
6	>5,3 up to and including 6,0	1,2	2,5	3,0
8	>6,0 up to and including 8,0	2,5	3,5	6,0
10	>8,0 up to and including 10,0	–	4,0	10,0
Column I	applies to screws without heads which, when tightened, do not protrude from the hole, and to other screws which cannot be tightened by means of a screwdriver with a blade wider than the root diameter of the screw.			
Column II	applies to nuts and screws which are tightened by means of a screwdriver.			
Column III	applies to nuts and screws which can be tightened by means other than a screwdriver.			

9.2.5.4 Tests for damage to and accidental loosening of conductors (flexion test)

The test applies to terminals for the connection of unprepared round copper conductors, of number, cross-section and type (flexible and/or rigid [stranded and/or solid]), specified by the manufacturer.

The following tests shall be carried out using two new samples with:

- a) the maximum number of conductors of the smallest cross-section connected to the terminal;
- b) the maximum number of conductors of the largest cross-section connected to the terminal;
- c) the maximum number of conductors of the smallest and largest cross-sections connected to the terminal.

Terminals intended for connection of either flexible or rigid (solid and/or stranded) conductors shall be tested with each type of conductor with different sets of samples.

Terminals intended for connection of both flexible and rigid (solid and/or stranded) conductors simultaneously shall be tested as stated in c) above.

For screwless terminal of several clamping-units, each clamping-unit shall be equipped with one conductor according to a), b) and c) if applicable.

The test should be carried out with suitable test equipment. The specified number of conductors shall be connected to the terminal. The length of the test conductors should be 75 mm longer than the height H specified in Table 12. The clamping screws shall be tightened with a torque in accordance with Table 11 or with the torque specified by the manufacturer. The device tested shall be secured as shown in Figure 4.

Table 12 – Test values for flexion and pull-out tests for round copper conductors

Conductor cross-section		Diameter of bushing hole ^a	Height $H \pm 13$ mm	Mass	Pulling force
mm ²	AWG/MCM	mm	mm	kg	N
0,2	24	6,4	260	0,3	10
–	22	6,4	260	0,3	20
0,5	20	6,4	260	0,3	30
0,75	18	6,4	260	0,4	30
1,0	–	6,4	260	0,4	35
1,5	16	6,4	260	0,4	40
2,5	14	9,5	279	0,7	50
4,0	12	9,5	279	0,9	60
6,0	10	9,5	279	1,4	80
10	8	9,5	279	2,0	90
16	4	12,7	298	2,9	100
25	6	12,7	298	4,5	135
–	3	14,3	318	5,9	156
35	2	14,3	318	6,8	190
^a If a bushing with the hole diameter given is not adequate to accommodate the conductor without binding, a bushing having the next larger hole ~~may~~ can be used.					

Each conductor is subjected to circular motions according to the following procedure:

The end of the conductor under test shall be passed through an appropriate size bushing in a platen positioned at a height H below the contactor terminal, as given in Table 12. The other conductors shall be bent in order not to influence the result of the test. The bushing shall be positioned in the horizontal platen concentric with the conductor. The bushing shall be moved so that its centre-line describes a circle of 75 mm diameter about its centre in the horizontal plane at 10 r.p.m. $\pm$ 2 r.p.m. The distance between the mouth of the terminal and the upper surface of the bushing shall be within 13 mm of the height H in Table 12. The bushing ~~is to~~ shall be lubricated to prevent binding, twisting or rotation of the insulated conductor. A mass as specified in Table 12 is to be suspended from the end of the conductor. The test shall consist of 135 continuous revolutions.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

Immediately after the flexion test, each conductor under test shall be submitted in the test equipment to the test of 9.2.5.5 (pull-out test).

9.2.5.5 Pull-out test for round copper conductors

Following the test of 9.2.5.4, the pulling force given in Table 12 shall be applied to the conductor tested in accordance with 9.2.5.4.

The clamping screws shall not be tightened again for this test.

The force shall be applied without jerks for 1 min, in the direction of the axis of the conductor.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

9.2.5.6 Test for insertability of unprepared round copper conductors having the maximum specified cross-section

9.2.5.6.1 Test procedure

The test shall be carried out with the gauges specified in Table 13. The measuring section of the gauge shall be able to penetrate into the terminal aperture under the weight of the gauge to the full depth of the terminal (see also Note to Table 13).

Table 13 – Maximum conductor cross-sections and corresponding gauges

Conductor cross-sections		Gauges (see Figure 5)			
Flexible conductors mm ²	Rigid conductors (solid or stranded) mm ²	Form and marking	Diameter <i>a</i> mm	Width <i>b</i> mm	Permissible deviations for <i>a</i> and <i>b</i> mm
1,5	1,5	A1	2,4	1,5	0 –0,05
2,5	2,5	A2	2,8	2,0	
2,5	4	A3	2,8	2,4	
4	6	A4	3,6	3,1	0 –0,06
6	10	A5	4,3	4,0	
10	16	B6	5,3	–	
16	25	B7	6,9	–	0 –0,07
25	35	B8	8,7	–	
35	50	B9	10,0	–	

NOTE For conductor cross-sections other than those given in the table, an unprepared conductor of appropriate cross-section ~~may~~ can be used as the gauge, the force of insertion being not greater than 5 N.

Alternatively, the test can be carried out by inserting the largest conductor of type and rated cross-section among those recommended by the manufacturer. The stripped end of the conductor shall be able to enter completely within the clamping unit aperture, without use of undue force.

NOTE The manufacturer can specify the test method.

9.2.5.6.2 Construction of gauges

The construction of the gauges is shown in Figure 5.

Details of dimensions *a* and *b* and their permissible deviations are shown in Table 13. The measuring section of the gauge shall be made from gauge steel.

9.2.5.7 Electrical performance of screwless-type clamping units

The electrical performance of screwless-type clamping units is verified by the following test, which is made on at least 6 new samples of each design which have not been used for any other test.

NOTE A sample can include either one pole or two clamping units.

The insertion and disconnection of the conductors shall be made in accordance with the manufacturer's instructions.

A suitable test arrangement is shown in Figure 24. If the measurement points cannot be positioned within the 10 mm to the point of contact, the voltage difference between the ideal and the actual measuring points shall be deducted from the voltage drop measured. This voltage difference within the part of the conductor shall be determined with a suitable measurement method on one sample at a stabilised temperature. The measurement methods and the results shall be documented in the test report.

The device sample can be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal.

The test is made with new copper conductors having the minimum and the maximum cross-section area:

- universal clamping units shall be tested with rigid (solid or stranded) and flexible conductor;
- non universal clamping units for solid only shall be tested with solid conductor;
- non universal clamping units for rigid shall be tested with both solid and stranded conductor;
- non universal clamping units for flexible only shall be tested with flexible conductor.

A conductor having the minimum cross-section area is connected, as in normal use, to each of 3 samples and a conductor having the maximum cross-section area is connected, as in normal use, to each of the 3 other samples. This for each type of conductors, as applicable.

The clamping units are loaded for 1 h with the rated operational current.

The control circuit is loaded at U_s .

When screwless terminals are used for the control circuit, they can be tested during the test on the load circuit, if applicable.

Immediately after this period and with the same current flowing, the voltage drop across each clamping unit is measured as near as possible to the area of contact on the clamping unit.

In no case shall the voltage drop exceed 15 mV.

9.2.5.8 Ageing test for screwless-type clamping units

The screwless-type clamping units already subjected to the determination of the voltage drops specified in 9.2.5.7, are placed in a heating cabinet, which is initially kept at a temperature of $20\text{ °C} \pm 2\text{ °C}$.

During the test, a current equal to the rated operational current passes through terminals, except during the cooling period.

The control circuit is loaded at U_s .

The conductor of 1 m is connected in series between two terminals to be tested as shown in Figure 25.

The device sample can be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal.

The whole test arrangement, including the conductors, shall not be moved until all the following voltage drop tests have been completed.

The clamping units are then subjected to 192 temperature cycles, each cycle having a duration of approximately 1 h, as follows:

The air temperature in the cabinet is raised in approximately 20 min to 40 °C .

It is maintained within $\pm 5\text{ °C}$ of this value for approximately 10 min. The clamping units are then allowed to cool down, during approximately 20 min to a temperature of approximately 30 °C , forced cooling being allowed.

They are kept at this temperature for approximately 10 min and, if necessary, for measuring the voltage drop, allowed to cool down further, to a temperature of $20\text{ °C} \pm 2\text{ °C}$.

The voltage drop is measured using the current and, test arrangement previously specified in 9.2.5.7 after the 24th temperature cycle and after the 192 temperature cycles are completed.

The allowable voltage drop shall not exceed the smaller of the two following values:

- either 22,5 mV,
- or 1,5 times the value measured after the 24th cycle.

The temperature in the heating cabinet is measured at a distance of at least 50 mm from the specimens.

After this test an inspection by the naked eye, with normal or corrected vision and without additional magnification, shall show no changes obviously preventing further use, such as cracks, deformations or the like.

9.2.6 Test of resistance to impact

9.2.6.1 Test procedure

Unenclosed contactors, exposed parts of partially enclosed contactors, covers and cover plates of contactors shall be tested with the pendulum hammer test apparatus (see 9.2.6.2.1) with a shock energy of 0,5 J.

Enclosures designed and dimensioned to contain a contactor shall be tested with the sphere test apparatus (see 9.2.6.2.2) with a shock energy of 2 J.

The ambient air temperature shall be $25\text{ °C} \pm 10\text{ °C}$.

The sample with cover, or the enclosure, if any, shall be fixed as in normal use or placed against a rigid support.

Cable entries which are not provided with knock-outs shall be left open. If they are provided with knock-outs, two of them shall be opened.

Before applying the blows, fixing screws of bases, covers and the like shall be tightened with a torque equal to two thirds of that specified in Table 11.

The samples are subjected to ten blows, which are evenly distributed over the sample. The blows are not applied to knock-outs, fragile parts such as windows, pilot lights, etc.

In general, five of the blows are applied as follows:

- for flush-type contactors, one blow in the centre, one at each extremity of the area over the recess in the block, and the other two approximatively midway between the previous blows, preferably on the ridge, if any, the sample being moved horizontally;
- for other contactors and for mounting boxes, one blow in the centre, one at each side of the sample after it has been turned as far as possible, but not through more than 60° , about a vertical axis, and the other two approximatively midway between the previous blows, preferably on the ridge, if any.

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.

After the test, the sample shall show no damage within the meaning of this document.

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

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

Damage to the appearance, for example surface cracks, small dents which do not reduce the clearances or creepage distances below the values specified in 8.2.3.4 and 8.2.3.5, and small chips which do not adversely affect the protection against electric shock shall be neglected.

9.2.6.2 Test apparatus

9.2.6.2.1 Pendulum hammer test apparatus (0,5 J test)

The test apparatus shown in Figure 6, Figure 7 and Figure 8 shall be used.

The design of the test apparatus shall be 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 striking element, having a mass of 0,25 kg, shall be allowed to fall from a height of 0,20 m on to surfaces which are exposed when the contactor is mounted as in normal conditions of use so that the point of impact lies in the vertical plane through the axis of the pivot of the pendulum.

The height of fall shall be 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 shall be 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.

The head of the striking element shall have a hemispherical face of radius 10 mm and shall be of polyamide having a Rockwell hardness of $R\ 100$. The striking element 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 shall be pivoted at its upper end in such a way that it swings only in a vertical plane.

The axis of the pivot shall be $1\ 000\ \text{mm} \pm 1\ \text{mm}$, above the axis of the striking element.

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

- diameter of the ball: $12,7\ \text{mm} \pm 0,002\ 5\ \text{mm}$,
- initial load: $100\ \text{N} \pm 2\ \text{N}$,
- overload: $500\ \text{N} \pm 2,5\ \text{N}$.

Additional information concerning the determination of the Rockwell hardness of plastics is given in ISO 2039-2. Surface-mounting contactors shall be mounted on a sheet of plywood, 8 mm thick and 175 mm square, secured at its top and bottom edges to a rigid bracket, which shall be part of the mounting support as shown in Figure 7.

The mounting support shall have a mass of $10\ \text{kg} \pm 1\ \text{kg}$ and shall be mounted on a rigid frame by means of pivots.

9.2.6.2.2 Sphere test apparatus (2 J test) (see Figure 9)

The impact shall be produced by dropping or swinging a steel sphere 50 mm in diameter and weighing 0,5 kg from a height of 0,4 m as shown in Figure 9.

H indicates the vertical distance the sphere ~~must~~ shall travel to produce the desired impact. The sphere is to contact the test sample when the wire is in the vertical position.

The wire shall have a negligible mass in comparison with the sphere.

The supporting surface shall consist of a layer of tongue-and-groove oak flooring mounted on two layers of 19 mm plywood.

The oak flooring shall be nominally 19 mm thick. The assembly shall rest on a concrete floor. An equivalent non-resilient supporting surface ~~may~~ can be used.

The backing support shall consist of 19 mm plywood over a rigid surface of concrete.

An equivalent non-resilient backing support ~~may~~ can be used.

9.2.7 Test of durability of marking

Compliance with the requirements of 8.1.13 is checked by inspection, also by lightly rubbing the marking by hand for 15 s with a piece of cloth soaked with water and again for 15 s with a piece of cloth soaked with petroleum spirit.

Petroleum spirit used in the test should consist of aliphatic solvent hexane with a content of aromatics of maximum 0,1 % by volume, a kauri butanol value of 29, an initial boiling point of approximately 65 °C, a dry-point of approximately 69 °C and a density of approximately 0,68 g/cm³.

After this test the marking shall be easily legible. It shall not be easily possible to remove labels and these shall show no curling.

The marking shall also remain easily legible after all the tests of this document.

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

9.2.8 Breakdown of components

9.2.8.1 General

The breakdown of a component, identified as a result of the circuit analysis of 8.1.14, shall be tested with the product operating with the load creating the more severe condition.

NOTE A possible loss of main function can be applied.

The test is not required:

- when circuit analysis indicates that no other component or portion of the circuit will be overloaded as a result of open- or short-circuit failure mode of another component;
- for components in circuits supplied by limited energy sources in compliance with IEC 60947-4-1:2018, 8.1.14;
- on power semiconductor devices when equivalent testing is accomplished during short-circuit tests;
- for components that have previously been positively evaluated considering their failure modes and the circuit conditions in which the component is used within the device.

9.2.8.2 Breakdown of components test

Each identified component shall be subjected to a breakdown of components test in open- and or short-circuit failure modes, whichever is most severe.

NOTE 1 The breakdown of components test can be done only with those circuits of the device that can affect the result of the test being fully energized and in operation.

During this test, there shall be no emission of flame or molten metal, nor ignition of cotton. The fusible element shall not open.

Components, such as capacitors or diodes, are short- or open-circuited. For device without a dedicated enclosure, an outer metal enclosure or a wire mesh cage (with surrounded cotton on the cage) that is 1,5 times the size of the device (or different, according to manufacturer declarations) shall be provided to simulate the potential grounded parts around the device. In case of dedicated enclosure, the cotton shall be placed over all openings. The outer dedicated enclosure or wire mesh cage (when provided) and any grounded or exposed dead metal part shall be connected through a fusible element F, according to subclause 9.3.3.5.2 g), to the supply circuit.

NOTE 2 Explanations about enclosed equipment are given in 5.3.3.2 NOTE 2 (unenclosed contactor) and 5.3.3.3 NOTE 2 (enclosed contactor).

9.3 Compliance with performance requirements

9.3.1 Test sequences

The sequence of tests and the corresponding samples are indicated in Annex B.

9.3.2 General test conditions

9.3.2.1 General requirements

The contactors to be tested shall agree in all their essential details with the design of the type which they represent.

Unless otherwise stated in the relevant test clauses, the tests shall be made with the same kind of current (and, at the rated frequency and with the same number of phases) as in the intended service.

If, for convenience of testing, it appears desirable to increase the severity of a test (e.g. to adopt a higher rate of operation in order to reduce the duration of the test), this ~~may~~ can be done only with the consent of the manufacturer.

The contactor under test shall be mounted complete on its own support or an equivalent support and connected as in normal service, in accordance with the manufacturer's instructions and under the ambient conditions stated in 7.1.

Enclosed contactors shall be mounted complete and any opening normally closed in service shall be closed for tests. Contactors intended for use in an individual enclosure shall be tested in the smallest of such enclosures stated by the manufacturer.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one contactor only.

Contactors not intended to be used in an individual enclosure shall be tested in free air. In this case, unless otherwise specified in the relevant test clauses of this document, for tests concerning making and breaking capacities and performance under short-circuit conditions, a wire mesh shall be placed at all points of the contactor likely to be a source of external phenomena capable of producing a breakdown, in accordance with the arrangements and distances specified by the manufacturer. Details, including distances from the contactor under test to the wire-mesh, shall be stated in the test report.

Maintenance or replacement of parts is not permitted, unless otherwise specified in this document.

The contactor ~~may~~ can be operated without load prior to beginning a test.

For the tests, the actuating system, if any, shall be operated as for the intended use in service stated by the manufacturer and at the rated values of control quantities (such as voltage), unless otherwise specified in this document.

9.3.2.2 Test quantities

9.3.2.2.1 Values of test quantities

All the tests shall be made with the values of test quantities corresponding to the ratings assigned by the manufacturer, in accordance with the relevant tables and data of this document.

9.3.2.2.2 Tolerances on test quantities

The test recorded in the test report shall be within the tolerances given in Table 14, unless otherwise specified in the relevant subclauses. However, with the agreement of the manufacturer, the tests ~~may~~ can be made under more severe conditions than those specified.

Table 14 – Tolerances on test quantities

All tests	Tests under no load, normal load and overload conditions	Tests under short-circuit conditions
– current: $\begin{smallmatrix} +5 \\ 0 \end{smallmatrix}$ %	– power factor: $\pm 0,5$	– power factor: $\begin{smallmatrix} 0 \\ -0,05 \end{smallmatrix}$
– voltage: $\begin{smallmatrix} +5 \\ 0 \end{smallmatrix}$ %		
(including power frequency recovery voltage)	– frequency: ± 5 %	– frequency ± 5 %
NOTE 1 Where maximum and/or minimum operating limits are stated in this document, the above tolerances do not apply.		
NOTE 2 ~~By agreement between manufacturer and user,~~ Tests made at 50 Hz ~~may be accepted~~ are valid for operation at 60 Hz and vice-versa.		

9.3.2.2.3 Recovery voltage

a) Power-frequency recovery voltage

For all breaking capacity and short-circuit breaking capacity tests, the value of the power-frequency recovery voltage shall be 1,05 times the value of the rated operational voltage.

NOTE 1 The value of 1,05 times the rated operational voltage for the power-frequency recovery voltage is deemed to cover the effects of the variations of the system voltage under normal service conditions.

NOTE 2 ~~This may require that~~ The applied voltage can possibly be increased but the prospective peak-making current ~~should~~ is not preferably be exceeded without the consent of the manufacturer.

NOTE 3 The upper limit of the power-frequency recovery voltage ~~may~~ can be increased with the approval of the manufacturer (see 9.3.2.2.2).

b) Transient recovery voltage

Transient recovery voltages, where required in this document, are determined according to 9.3.3.5.3.

9.3.2.3 Evaluation of test results

The behaviour of the contactor during the tests and its condition after the tests are specified in the relevant test clauses of this document.

9.3.2.4 Test reports

Written reports on type tests proving compliance with this document shall be made available by the manufacturer. The details of test arrangements such as type and size of the enclosure, if any, size of conductors, distance from the live parts to the enclosure or to parts normally earthed in service, method of operation of the actuating system, etc., shall be given in the test report.

Test values and parameters shall form part of the test report.

9.3.3 Performance under no load, normal load and overload conditions

9.3.3.1 Operation

It shall be verified that contactors operate according to the requirements of 8.2.1.1.

9.3.3.2 Operating limits

Contactors shall be tested to verify the performance according to the requirements given in 8.2.1.2.

9.3.3.3 Temperature-rise

9.3.3.3.1 Ambient air temperature

The ambient air temperature shall be recorded during the last quarter of the test period by at least two temperature sensing means, e.g. thermometers or thermocouples, equally distributed around the contactor at about half its height and at a distance of about 1 m from the contactor. The temperature sensing means shall be protected against air currents, heat radiation and indicating errors due to rapid temperature changes.

During the tests, the ambient air temperature shall be between +10 °C and +40 °C and not vary by more than 10 K.

9.3.3.3.2 Measurement of the temperature of parts

For parts other than coils, the temperature of the different parts shall be measured by suitable temperature sensing means at those points most likely to attain the maximum temperature; these points shall be stated in the test report.

The temperature sensing means shall not significantly affect the temperature-rise.

Good thermal conductivity between the temperature sensing means and the surface of the part under test shall be ensured.

For electromagnet coils, the method of measuring the temperature by variation of resistance shall generally be used. Other methods are permitted only if it is impracticable to use the resistance method.

The temperature of the coils before beginning the test shall not differ from that of the surrounding medium by more than 3 K.

For copper conductors, the value of the hot temperature T_2 may can be obtained from the value of the cold temperature T_1 as a function of the ratio of the hot resistance R_2 to the cold resistance R_1 by the following formula:

$$T_2 = \frac{R_2}{R_1} (T_1 + 234,5) - 234,5$$

where

T_1 and T_2 are expressed in degrees Celsius.

The test shall be made for a time sufficient for the temperature-rise to reach a steady-state value, but not exceeding 8 h. It is assumed that a steady-state is reached when the variation does not exceed 1 K per hour.

9.3.3.3.3 Temperature-rise of a part

The temperature-rise of a part is the difference between the temperature of that part measured in accordance with 9.3.3.3.2 and the ambient air temperature measured in accordance with 9.3.3.3.1.

9.3.3.3.4 Temperature-rise of the main circuit

The contactor shall be mounted as specified in 9.3.2.1 and shall be protected against abnormal external heating or cooling.

The main circuit shall be loaded as stated in 8.2.2.5.

All auxiliary circuits which normally carry current shall be loaded at their maximum rated operational current (see 5.6) and the control circuits shall be energized at their rated voltage.

Contactors having an integral enclosure and contactors only intended for use with a specified type of enclosure shall be tested in their enclosure for the conventional thermal current test. No opening giving false ventilation shall be allowed.

Contactors intended for use with more than one type of enclosure shall be tested either in the smallest enclosure stated by the manufacturer to be suitable or tested without an enclosure. If tested without an enclosure the manufacturer shall be prepared to state a value of conventional enclosed thermal current (see 5.3.3.3).

For tests with multiphase currents, the current shall be balanced in each phase within $\pm 5\%$, and the average of these currents shall be not less than the appropriate test current.

Unless otherwise specified in this document, the temperature-rise test of the main circuit is made at one or both of the conventional thermal currents, as defined in 5.3.3.2 and 5.3.3.3 and ~~may~~ can be made at any convenient voltage.

When the heat exchange between the main circuit, the control circuit and the auxiliary circuits ~~may~~ can be of significance, the temperature-rise tests stated in 9.3.3.3.4, 9.3.3.3.5, 9.3.3.3.6 and 9.3.3.3.7 shall be made simultaneously.

In the case of multipole contactors, the test ~~may~~ can be carried out but, subject to the manufacturer's agreement, with single-phase current with all poles connected in series.

At the end of the test, the temperature-rise of the different parts of the main circuit shall not exceed the values given in Table 4 and Table 5.

The following test connection arrangements shall be used:

- a) The connections shall be single-core, p.v.c.-insulated, copper conductors with cross-sections as given in Table 15.
- b) The connections shall be in free air and spaced at approximately the distance existing between the terminals.
- c) For single-phase or multi-phase tests, the minimum length of any temporary connection from a terminal to another terminal or to the test supply or to a star point shall be 1 m.

Table 15 – Test copper conductors

Range of test current ^a		Conductor size ^{b, c}	
		mm ²	AWG/MCM
0	8	1,0	18
8	12	1,5	16
12	15	2,5	14
15	20	2,5	12
20	25	4,0	10
25	32	6,0	10
32	50	10	8
50	65	16	6
65	85	25	4

^a The value of the test current shall be greater than the first value in the first column and less than or equal to the second value in that column.

^b For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current ~~may~~ can be used.

^c The table gives alternative sizes for conductors in the metric and AWG/MCM systems.

9.3.3.3.5 Temperature-rise of control circuits

The temperature-rise of control circuits shall be measured during the test of 9.3.3.3.4.

The temperature-rise tests of control circuits shall be made with the specified current and at the rated frequency. Control circuits shall be tested at their rated voltage.

Circuits intended for continuous operation shall be tested for a sufficient time for the temperature-rise to reach a steady-state value.

At the end of these tests the temperature-rise of the different parts of the control circuits shall not exceed the values specified in 8.2.2.6.

9.3.3.3.6 Temperature-rise of coils of electromagnets

Coils and electromagnets shall be tested according to the conditions given in 8.2.2.7.

They shall be tested for a sufficient time for the temperature-rise to reach a steady-state value.

The temperature shall be measured when thermal equilibrium is reached in both the main circuit and the coil of the electromagnet.

Coils and electromagnets of contactors shall be tested as follows:

- Electromagnets of contactors intended for a duty period of 8 h (continuous duty) shall be subjected only to the test prescribed in 8.2.2.7.1, with the corresponding rated current flowing through the main circuit for the duration of the test. The temperature-rise shall be measured during the test of 9.3.3.3.4.
- Electromagnets of contactors intended for intermittent duty shall be subjected to the test as stated above, and also to the test prescribed in 8.2.2.7.2 dealing with their duty class, with no current flowing through the main circuit.
- Specially rated (short-time and periodic duty) windings shall be tested as stated in 8.2.2.7.3 without current in the main circuit.

At the end of these tests the temperature-rise of the different parts shall not exceed the values specified in 8.2.2.7.

9.3.3.3.7 Temperature-rise of auxiliary circuits

The temperature-rise tests of auxiliary circuits shall be made during the test of 9.3.3.3.4 under the same conditions as those specified in 9.3.3.3.5 but ~~may~~ can be carried out at any convenient voltage.

At the end of these tests the temperature-rise of the auxiliary circuits shall not exceed the values specified in 8.2.2.8.

9.3.3.4 Dielectric properties

9.3.3.4.1 Type tests

a) General conditions for withstand voltage tests

The contactor to be tested shall comply with the general requirements of 9.3.2.1.

If the contactor is to be used without an enclosure, it shall be mounted on a metal plate and all exposed conductive parts (frame, etc.) intended to be connected to the protective earth in normal service shall be connected to that plate.

When the base of the contactor is of insulating material, metallic parts shall be placed at all of the fixing points in accordance with the conditions of normal installation of the contactor and these parts shall be considered as part of the frame of the contactor.

Any actuator of insulating material and any integral non-metallic enclosure of contactor intended to be used without an additional enclosure shall be covered by a metal foil and connected to the frame or the mounting plate. The foil shall only be applied to those parts of surface which can be touched with the standard test finger (see Figure 10) during operation or adjustment of the contactor. If the insulation part of an integral enclosure cannot be touched by the standard test finger due to the presence of an additional enclosure, no foil shall be required.

For the dielectric test between phases, all circuits between these phases can be disconnected for the test.

NOTE 1 The purpose of this tests is to check the functional insulation only.

Where the control circuit normally connected to the main circuit is disconnected, the method used to maintain the main contacts closed shall be indicated in the test report.

b) Verification of impulse withstand voltage

1) General

The contactor shall comply with the requirements stated in 8.2.3.2.

The verification of the insulation is made by a test at the rated impulse withstand voltage.

Clearances equal to or larger than the values of case A of Table 17 ~~may~~ can be verified by measurement, according to the method described in Annex E.

2) Test voltage

The test voltage shall be that specified in 8.2.3.2.

For contactor incorporating overvoltage suppressing means, the energy content of the test current shall not exceed the energy rating of the overvoltage suppressing means. The latter shall be suitable for the application.

NOTE 2 Such ratings are under consideration.

The test equipment shall be calibrated to produce a 1,2/50 μ s waveform as defined in IEC 61180. The output is then connected to the contactor to be tested and the impulse applied five times for each polarity at intervals of 1 s minimum. The influence of the contactor under test on the waveshape, if any, is ignored.

3) Application of test voltage

With the contactor mounted and prepared as specified in item 1) above, the test voltage is applied as follows:

- i) between all the terminals of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and the enclosure or mounting plate, with the contacts in all normal positions of operation;
- ii) between each pole of the main circuit and the other poles connected together and to the enclosure or mounting plate, with the contacts in all normal positions of operation;
- iii) between each control and auxiliary circuit not normally connected to the main circuit and:
 - the main circuit,
 - the other circuits,
 - the exposed conductive parts,
 - the enclosure or mounting plate,
 which, wherever appropriate, ~~may~~ can be connected together.

4) Acceptance criteria

There shall be no unintentional disruptive discharge during the tests.

NOTE 3 An exception is an intentional disruptive discharge, for example by transient overvoltage suppressing means.

NOTE 4 The term "disruptive discharge" related to phenomena associated with the failure of insulation under electrical stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero.

NOTE 5 The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric.

NOTE 6 The term "flashover" is used when a disruptive discharge occurs over the surface of a dielectric in a gaseous or liquid medium.

NOTE 7 The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

NOTE 8 A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric, the loss ~~may~~ can be only temporary.

c) Power-frequency withstand verification of solid insulation

1) General

This test applies to the verification of solid insulation and the ability to withstand temporary overvoltages.

The values of Table 19 are deemed to cover the ability to withstand temporary overvoltages (see Footnote a of Table 19).

2) Test voltage

The test voltage shall have a practically sinusoidal waveform and a frequency between 45 Hz and 65 Hz. The high-voltage transformer used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current shall be at least 200 mA.

The overcurrent relay shall not trip when the output current is less than 100 mA.

The value of the test voltage shall be as follows:

- i) for the main circuit, and for the control and auxiliary circuits, in accordance with Table 19. The uncertainty of measurement of the test voltage shall not exceed ± 3 %.
- ii) if an alternating test voltage cannot be applied, for example due to EMC filter components, a direct test voltage ~~may~~ can be used having the value of Table 19, third column. The uncertainty of measurement of the test voltage shall not exceed ± 3 %.

The test voltage applied shall be within ± 3 %.

3) Application of test voltage

For the dielectric test between phases, all circuits between these phases ~~may~~ can be disconnected for the test.

NOTE 9 The purpose of this test is to check the basic and supplementary insulation only.

For the dielectric test between phase and earth, all circuits shall be connected.

NOTE 10 The purpose of this test is to check both basic and supplementary insulation, and the ability to withstand temporary overvoltages.

The test voltage shall be applied to for 5 s in accordance with items b) 3) i), b) 3) ii) and b) 3) iii) above.

4) Acceptance criteria

During the test, no flashover, breakdown of insulation either internally (puncture) or externally (tracking) or any other manifestation of disruptive discharge shall occur. Any glow discharge shall be ignored. Components connected between phase and earth ~~may~~ can be damaged during the tests but such failure shall not result in a condition that would lead to a hazardous situation.

NOTE 11 The voltage levels to earth are based on IEC 60664-1 under worst case conditions which generally do not occur in practice.

d) Power-frequency withstand verification after switching tests

1) General

The test should be performed on the contactor whilst it remains mounted for the switching tests. If this is not practicable, it ~~may~~ can be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

2) Test voltage

The requirements of item c) 2) above shall apply except that the value of the test voltage shall be $2 U_e$ with a minimum of 1 000 V RMS or 1 415 V DC if an AC voltage test cannot be applied. The value of U_e referred to is that at which switching tests have been performed.

3) Application of test voltage

The requirements of item c) 3) above shall apply. The application of the metal foil, according to 9.3.3.4.1, item a), is not required.

4) Acceptance criteria

The requirements of item c) 4) above shall apply.

e) Verification of DC withstand voltage

Under consideration.

f) Verification of creepage distances

The shortest creepage distances between phases, between circuit conductors at different voltages and live and exposed conductive parts shall be measured. The measured creepage distance with respect to material group and pollution degree shall comply with the requirements of 8.2.3.5.

9.3.3.4.2 Routine tests

a) Impulse withstand voltage

The tests shall be performed in accordance with item b) of 9.3.3.4.1. The test voltage shall be not less than 30 % of the rated impulse withstand voltage (without altitude correction factor) or $2 U_i$ whichever is the higher.

b) Power-frequency withstand voltage

1) Test voltage

The test apparatus shall be the same as that stated in item c) 2) of 9.3.3.4.1 except that the overcurrent trip should be set at 25 mA.

However, at the discretion of the manufacturer for safety reasons, test apparatus of a lower power or trip setting ~~may~~ can be used, but the short-circuit current of the test apparatus shall be at least eight times the nominal trip setting of the overcurrent relay, for example for a transformer with a short-circuit current of 40 mA, the maximum trip setting of the overcurrent relay shall be 5 mA ± 1 mA.

NOTE 1 The capacitance of the contactor ~~may~~ can be taken into account.

The RMS value of the test voltage shall be $2 U_e$ with a minimum of 1 000 V RMS.

NOTE 2 In the case of multiple values, U_e refers to the highest value marked on the contactor or given in the manufacturer's documentation.

2) Application of test voltage

The requirements of item c) 3) of 9.3.3.4.1 shall apply, except that the duration of the test voltage shall be 1 s only.

However, as an alternative, a simplified test procedure ~~may~~ can be used if it is considered to subject the insulation to an equivalent dielectric stress.

3) Acceptance criteria

The overcurrent relay shall not trip.

c) Combined impulse voltage and power-frequency withstand voltage

The tests of items a) and b) above ~~may~~ can be replaced by a single power-frequency withstand test where the peak value of the sinusoidal wave corresponds to the value stated in items a) or b), whichever is the higher.

d) In no case the application of the metal foil according to 9.3.3.4.1, item a) is required.

9.3.3.4.3 Sampling tests for verification of clearances

a) General

These tests are intended to verify the maintaining of the design conformity regarding clearances and are only applicable to contactor with clearances smaller than those corresponding to Table 17, case A.

b) Test voltage

The test voltage shall be that corresponding to the rated impulse withstand voltage.

c) Application of test voltage

The requirements of item b) 3) of 9.3.3.4.1 shall apply, except that the metal foil ~~need~~ shall not be applied to the actuator or the enclosure.

d) Acceptance criteria

No disruptive discharge shall occur.

9.3.3.4.4 Tests for contactor with protective separation

Tests for contactor with protective separation are given in Annex I.

Table 16 – Impulse test voltages and corresponding altitudes

Rated impulse withstand voltage U_{imp} kV	$U_{1,2/50}$ impulse kV				
	Sea level	200 m	500 m	1 000 m	2 000 m
0,33	0,36	0,36	0,35	0,34	0,33
0,5	0,54	0,54	0,53	0,52	0,5
0,8	0,95	0,9	0,9	0,85	0,8
1,5	1,8	1,7	1,7	1,6	1,5
2,5	2,9	2,8	2,8	2,7	2,5
4	4,9	4,8	4,7	4,4	4
6	7,4	7,2	7	6,7	6
8	9,8	9,6	9,3	9	8

Table 17 – Minimum clearances in air

Rated impulse withstand voltage U_{imp} kV	Minimum clearances mm							
	Case A Inhomogeneous-field conditions (see 3.5.31)				Case B Homogeneous-field ideal conditions (see 3.5.30)			
	Pollution degree				Pollution degree			
	1	2	3	4	1	2	3	4
0,33	0,01				0,01			
0,5	0,04	0,2			0,04	0,2		
0,8	0,1		0,8		0,1		0,8	1,6
1,5	0,5	0,5		1,6	0,3	0,3		
2,5	1,5	1,5	1,5		0,6	0,6		
4	3	3	3	3	1,2	1,2	1,2	
6	5,5	5,5	5,5	5,5	2	2	2	2
8	8	8	8	8	3	3	3	3

Table 18 – Minimum creepage distances

Rated insulation voltage of equipment or working voltage AC, RMS or DC V^e	Creepage distances for equipment subject to long-term stress														
	mm														
	Pollution degree			Pollution degree				Pollution degree				Pollution degree			
	1 ^f	2 ^f	1	2				3				4			
	Material group			Material group				Material group				Material group			
	b	c	b	I ^a	II	IIIa	IIIb	I	II	IIIa	IIIb	I	II	IIIa	IIIb
10	0,025	0,04	0,08	0,4	0,4	0,4		1	1	1		1,6	1,6	1,6	
12,5	0,025	0,04	0,09	0,42	0,42	0,42		1,05	1,05	1,05		1,6	1,6	1,6	
16	0,025	0,04	0,1	0,45	0,45	0,45		1,1	1,1	1,1		1,6	1,6	1,6	
20	0,025	0,04	0,11	0,48	0,48	0,48		1,2	1,2	1,2		1,6	1,6	1,6	
25	0,025	0,04	0,125	0,5	0,5	0,5		1,25	1,25	1,25		1,7	1,7	1,7	
32	0,025	0,04	0,14	0,53	0,53	0,53		1,3	1,3	1,3		1,8	1,8	1,8	
40	0,025	0,04	0,16	0,56	0,8	1,1		1,4	1,6	1,8		1,9	2,4	3	
50	0,025	0,04	0,18	0,6	0,85	1,2		1,5	1,7	1,9		2	2,5	3,2	
63	0,04	0,063	0,2	0,63	0,9	1,25		1,6	1,8	2		2,1	2,6	3,4	d
80	0,063	0,1	0,22	0,67	0,95	1,3		1,7	1,9	2,1		2,2	2,8	3,6	
100	0,1	0,16	0,25	0,71	1	1,4		1,8	2	2,2		2,4	3,0	3,8	
125	0,16	0,25	0,28	0,75	1,05	1,5		1,9	2,1	2,4		2,5	3,2	4	
160	0,25	0,4	0,32	0,8	1,1	1,6		2	2,2	2,5		3,2	4	5	
200	0,4	0,63	0,42	1	1,4	2		2,5	2,8	3,2		4	5	6,3	
250	0,56	1	0,56	1,25	1,8	2,5		3,2	3,6	4		5	6,3	8	
320	0,75	1,6	0,75	1,6	2,2	3,2		4	4,5	5		6,3	8	10	
400	1	2	1	2	2,8	4		5	5,6	6,3		8	10	12,5	

^a Material group I or material groups II, IIIa, IIIb where likelihood to track is reduced due to the conditions of IEC 60664-1.

^b Material groups I, II, IIIa, IIIb.

^c Material groups I, II, IIIa.

^d Values of creepage distances in this area have not been established. Material group IIIb is in general not recommended for application in pollution degree 4.

^e As an exception, for rated insulation voltages 127, 208, 415 and 440 V, creepage distances corresponding to the lower values 125 V, 200 V, 400 V respectively may be used.

^f The values given in these two columns apply to creepage distances of printed wiring materials.

Table 19 – Dielectric test voltage corresponding to the rated insulation voltage

Rated insulation voltage U_i V	AC test voltage RMS V	DC test voltage ^{a, b} V
$U_i \leq 60$	1 000	1 415
$60 < U_i \leq 300$	1 500	2 120
$300 < U_i \leq 440$	1 640	2 320

^a Test voltages based on 6.4.5, 5th paragraph of IEC 60664-1:2007/2020.

^b A direct current test voltage may be used only if an alternating test voltage cannot be applied. See also item c) 2) ii) of 9.3.3.4.1.

9.3.3.5 Making and breaking capacities

9.3.3.5.1 General test conditions

Tests for verification of making and breaking capacities shall be made according to the general test conditions stated in 9.3.2.1.

Four-pole contactors shall be tested as three-pole contactors with the unused pole, which in the case of contactors provided with a neutral pole is the neutral pole, connected to the frame. One test on three adjacent poles is sufficient.

The tests shall be made under the operating conditions stated in Table 7 without failure (see 9.3.3.5.4, item b)).

The control supply voltage shall be 100 % of U_s for the test of utilization categories AC-7a, AC-7c and AC-7d. For the test of utilization category AC-7b, it shall be 110 % of U_s for half the number of operating cycles and 85 % of U_s for the other half.

Connections to the main circuit shall be similar to those intended to be used when the contactor is in service. If necessary, or for convenience, the control and auxiliary circuits, and in particular the coil of the contactor, ~~may~~ can be supplied by an independent source. Such a source shall deliver the same kind of current and the same voltage as specified for service conditions.

9.3.3.5.2 Test circuit

a) Figure 11, Figure 12, Figure 13 and Figure 14 give diagrams of the circuits to be used for the tests concerning:

- single-pole contactors on single-phase AC (Figure 11);
- two-pole contactors on single-phase AC (Figure 12);
- three-pole contactors or three single-phase contactors on three-phase AC (Figure 13);
- four-pole contactors on three-phase four wire AC (Figure 14).

A detailed diagram of the circuit used for the test shall be given in the test report.

b) The prospective current at the supply terminals of the contactor shall be not less than 10 times the test current.

c) The test circuit comprises the supply source, the contactor D under test and the load circuit.

d) 1) Utilization categories AC-7a and AC-7b:

The load circuit shall consist of resistors and air-cored reactors in series. Air-cored reactors in any phase shall be shunted by resistors taking approximately 0,6 % of the current through the reactor.

However, where a transient recovery voltage is specified, instead of the 0,6 % shunt resistors, parallel resistors and capacitors shall be included across the load, the complete, load circuit being as shown in Figure 16.

2) Utilization category AC-7c:

The diagram of the circuit is given under

Figure 22. The prospective short-circuit current of the supply shall be between 3 kA and 4 kA at $\cos \varphi = 0,90 \pm 0,05$.

The load circuit shall consist of resistors and air-cored reactors in series and capacitors in parallel.

The line resistor R_1 consists in a twin-core cable of $2 \times 12,5$ m in length with wires cross-section appropriate to the rated current.

The load circuit consists of:

- a compensated capacitor value C_p of 10 μF ($-0 \mu\text{F}$; $+2 \mu\text{F}$) per A.

Ex: for 10 A, $C_p = 100 \mu\text{F}$; for 20 A, $C_p = 200 \mu\text{F}$.

The capacitors shall be connected with 2,5 mm² conductors having the shortest possible length;

- an inductor, X, and a resistor, R, adjusted to give to the load circuit (comprising C_p , R and X) the power factor and the test current according to Table 7 and Table 9.

3) Utilization category AC-7d:

The diagram of the circuit is given under Figure 26.

The calculations are based on the following parameters in order to have the required values for inrush current and I^2t :

- a prospective short-circuit current (RMS) of the supply of 3 kA at $\cos \phi = 0,9$ (lagging);
- a resistance R3 equal to 0,25 Ω and an inductance L equal to 20 μH simulating the twin-core cable in the test

The load shall be in accordance with Figure 26. The values for the maximum peak value and the maximum I^2t of the inrush current are given in Table 20.

NOTE 1 R2 is the total series resistance in the lamp circuit including the ESR (equivalent series resistance) value of the capacitor.

The values of R2 and C in load B shall be chosen in order to reach the values ($\pm 5 \%$) for I_{peak} and I^2t as given in Table 20 when the switching contact closes at $90^\circ \pm 5^\circ$ phase-angle.

The value of R4 shall be chosen to reach the rated power as given in Table 7 and Table 20.

The values of R2 and C given in Table 21 are for information only. The circuit shall be adjusted to reach the I_{peak} and I^2t values of Table 20.

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Table 20 – Values for I_{peak} and I^2t depending on the type of distribution system

Rated power W	I_{peak} A Distribution system: 220/380, 230/400 240/415	I^2t A2s Distribution system: 220/380, 230/400 240/415	I_{peak} A Distribution system: 120/208 127/220	I^2t A2s Distribution system: 120/208 127/220
15	22	0,08	69	0,56
22 ^a	31	0,18	90	1
30	41	0,3	109	1,9
45 ^a	58	0,6	140	3,5
60	73	1,2	162	5,9
100	108	2,8	200	11,5
150	142	5,5	231	18,5
200	170	9	248	24,5
250	192	13	255	30
300	209	16,5	260	35
350	223	20,5	262	39
400	235	24,5	263	43
520 ^a	250	29	280	53
600 ^a	260	32	290	59

NOTE 1 For values not given in the Table, the test values are determined by interpolation.

NOTE 2 Above values are in-line with IEC 60669-2-1.

^a Intermediate values for making and breaking capacity test when other existing values can't be used. These values are based on Figure BB.4 of IEC 60669-2-1:2021.

Table 21 – Calculated circuit parameters

Rated Power W	R2(Ω) 230 V	C (μF) 230 V	R2 (Ω) 120 V	C (μF) 120 V
15	13	20	1,36	70
22	9	33	0,9	105
30	6,5	40	0,65	140
45	4,5	68	0,33	220
60	3,25	80	0,28	280
100	1,9	125	0,17	445
150	1,25	180	0,11	640
200	0,95	240	0,10	830
250	0,8	310	0,10	1000
300	0,7	355	0,11	1250
350	0,64	420	0,13	1500
400	0,59	480	0,135	1660
520	0,29	590	0,135	1900
600	0,22	680	0,135	2200
NOTE For values not given in the table, the values are recalculated.				

e) The loads shall be adjusted to obtain, at the specified voltage:

- the value of current, power-factor and power frequency recovery voltage specified in Table 7;
- when specified, the oscillatory frequency of the transient recovery voltage and the value of the factor γ .

The factor γ is the ratio of the value U_1 of the highest peak of the transient recovery voltage to the instantaneous value U_2 , at the instant of current zero, of the component of the recovery voltage at power frequency (see Figure 15).

- f) The test circuit shall be earthed at one unique point and the position of this point shall be stated in the test report.
- g) All parts of the contactor normally earthed in service, including the enclosure or the screens, shall be insulated from earth and connected as indicated in Figure 11, Figure 12, Figure 13 or Figure 14.

This connection shall comprise a fusible element F consisting of a copper wire 0,8 mm in diameter and at least 50 mm long, or an equivalent fusible element, for the detection of the fault current.

The prospective fault current in the fusible-element circuit shall be 1 500 A $\pm$ 10 %, except as stated in NOTE 3 and NOTE 4. If necessary, a resistor limiting the current to that value shall be used.

NOTE 2 A copper wire of 0,8 mm in diameter will melt at 1 500 A in approximately half a cycle at a frequency between 45 Hz to 67 Hz.

NOTE 3 The prospective fault current ~~may~~ can be less than 1 500 A, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in NOTE 2.

NOTE 4 In the case of a supply having an artificial neutral, a lower prospective fault current ~~may~~ can be accepted, subject to the agreement of the manufacturer, with a smaller diameter copper wire (see NOTE 5) corresponding to the same melting time as in NOTE 2.

NOTE 5 The relationship between the prospective fault current in the fusible element circuit and the diameter of the copper wire ~~should be~~ is in accordance with the Table 22 below:

Table 22 – relationship between the prospective fault current in the fusible element circuit and the diameter of the copper wire

Diameter of copper wire	Prospective fault current in the fusible element circuit
Mm	A
0,1	50
0,2	150
0,3	300
0,4	500
0,5	800
0,8	1 500

9.3.3.5.3 Characteristics of transient recovery voltage

The following requirements apply to contactors of utilization category AC-7b.

To simulate the conditions in circuits including individual motor loads (inductive loads), the oscillatory frequency of the transient recovery voltage of the load circuit shall be adjusted to the value:

$$f = 2\,000 \times I_c^{0,2} \times U_e^{-0,8} \pm 10\%$$

where

f is the oscillatory frequency, in kilohertz;

I_c is the breaking current, in amperes;

U_e is the rated operational voltage of the equipment, in volts.

The factor γ shall be adjusted to the value:

$$\gamma = 1,1 \pm 0,05.$$

The value of reactance necessary for the test ~~may~~ can be obtained by coupling several reactors in parallel on condition that the transient recovery voltage can still be considered as having only one oscillatory frequency. This is generally the case when the reactors have practically the same time-constant.

The load terminals of the contactor shall be connected as closely as possible to the terminals of the adjusted load circuit. The adjustment should be made with these connections in place.

Adjustment of the transient recovery voltage shall be made on the whole load circuit and, in particular, the earth point shall not be moved between the adjustment and the test.

A procedure for adjusting the load circuit is given in Annex C.

9.3.3.5.4 Rated making and breaking capacities

a) Rated making and breaking capacities of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 7.

b) Behaviour of the contactor during and condition after the making and breaking capacity tests.

During the tests within the limits of the specified making and breaking capacities of 9.3.3.5 and the verification of conventional operational performance of 9.3.3.6.2, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.3.5.2) and no welding of the contacts.

After the tests, the dielectric properties of the contactor shall be verified by a dielectric test as specified in 9.3.3.4.1, item d).

The contacts shall operate when the contactor is switched by the applicable method of control.

9.3.3.6 Operational performance capability

9.3.3.6.1 General

Tests concerning the verification of conventional operational performance are intended to verify that a contactor is capable of fulfilling the requirements given in Table 9.

Connections to the main circuit shall be similar to those intended to be used when the contactor is in service.

The test circuit given in 9.3.3.5.2 is applicable and the load is to be tuned according to 9.3.3.5.3.

The control voltage shall be 100 % of the rated control supply voltage.

9.3.3.6.2 Conventional operational performance of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 9.

9.3.3.6.3 Behaviour of the contactor during and condition after the conventional operational performance tests

The requirement of 9.3.3.5.4, item b), should be fulfilled and the dielectric properties of the contactor shall be verified by a dielectric test as specified in 9.3.3.4.1, item d).

9.3.4 Performance under short-circuit conditions

9.3.4.1 General

This subclause specifies test conditions for verification of compliance with the requirements of 8.2.5. Specific requirements regarding test procedure, test sequence, condition of contactor after the test are given in 9.3.4.2 and 9.3.4.3.

9.3.4.2 General conditions for short-circuit tests

9.3.4.2.1 General requirements for short-circuit tests

The general requirements of 9.3.2.1 apply. The contactor shall be operated under the conditions specified in 8.2.1. It shall be verified that the contactor operates correctly on no-load when it is operated under the above conditions.

9.3.4.2.2 Test circuit

- a) Figure 17, Figure 18, Figure 19 and Figure 20 give diagrams of the circuits to be used for the tests concerning:

- single-pole contactors on single-phase AC (Figure 17);
- two-pole contactors on single-phase AC (Figure 18);
- three-pole contactors on three-phase AC (Figure 19);
- four-pole contactors on three-phase four wire AC (Figure 20).

A detailed diagram of the circuit used for the test shall be given in the test report.

- b) The supply S feeds a circuit including resistors R_1 , reactors X and the contactor D under test.

In all cases the supply shall have sufficient power to permit the verification of the characteristics given by the manufacturer.

The resistance and reactance of the test circuit shall be adjustable to satisfy the specified test conditions. The reactors X shall be air-cored. They shall be connected in series with the resistors R_1 , 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 the test circuits including large air-cored reactors are not representative of usual service conditions, the air-cored reactor in each phase shall be shunted by a resistor taking approximately 0,6 % of the current through the reactor, ~~unless otherwise agreed between manufacturer and user.~~

- c) In each test circuit (Figure 17, Figure 18, Figure 19 and Figure 20), the resistors and reactances are inserted between the supply source S and the contactor D under test. The positions of the closing device A and the current sensing devices (I_1 , I_2 , I_3) ~~may~~ can be different. The connection of the contactor under test to the test circuit shall be stated in the test report.

When tests are made with current less than the rated value, the additional impedances required shall normally be inserted on the load side of the contactor between it and the short-circuit; they ~~may~~ can, however, be inserted on the line side, in which case this shall be stated in the test report.

~~Unless a special agreement has been drawn up between manufacturer and user and details noted in the test report, the diagram of The test circuit shall be in accordance with the figures.~~

The test circuit diagram shall conform to the figures, otherwise modifications shall be noted in the test report.

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

- d) All parts of the contactor normally earthed in service, including the enclosure or the screens, shall be insulated from earth and connected to a point, as indicated in Figure 17, Figure 18, Figure 19 and Figure 20.

This connection shall comprise a fusible element F consisting of a copper wire 0,8 mm in diameter and at least 50 mm long, or of an equivalent fusible element for the detection of the fault current.

The prospective fault current in the fusible-element circuit shall be 1 500 A $\pm$ 10 %, except as stated in Note 2 and Note 3. If necessary, a resistor limiting the current to that value shall be used.

NOTE 1 A copper wire of 0,8 mm in diameter will melt at 1 500 A in approximately half a cycle at a frequency between 45 Hz to 67 Hz.

NOTE 2 The prospective fault current ~~may~~ can be less than 1 500 A, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 3 In the case of a supply having an artificial neutral, a lower prospective fault current ~~may~~ can be accepted, subject to the agreement of the manufacturer, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 4 The relationship between the prospective fault current in the fusible element circuit and the diameter of the copper wire ~~should be~~ is in accordance with the Table 22.

9.3.4.2.3 Power-factor of the test circuit

The power-factor of each phase of the test circuit should be determined according to an established method which shall be stated in the test report.

Two examples are given in Annex D.

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

The power-factor shall be in accordance with Table 23.

The difference between the mean value and the maximum and minimum values of the power-factors in the different phases shall remain within $\pm 0,05$.

Table 23 – Values of power-factors corresponding to test currents and ratio n between peak and RMS values of current

Test current A	Power-factor	n
$I \leq 1\,500$	0,95	1,41
$1\,500 < I \leq 3\,000$	0,9	1,42
$3\,000 < I \leq 4\,500$	0,8	1,47
$4\,500 < I \leq 6\,000$	0,7	1,53

9.3.4.2.4 Calibration of the test circuit

The calibration of the test circuit is carried out by placing temporary connections B of negligible impedance as close as reasonably possible to the terminals provided for connecting the equipment under test.

Resistors R_1 and reactors X are adjusted so as to obtain, at the applied voltage, a current equal to the rated short-circuit breaking capacity as well as the power-factor indicated in 9.3.4.2.3.

In order to determine the short-circuit making capacity of the contactor under test from the calibration oscillogram, it is necessary to calibrate the circuit so as to ensure that the prospective making current is achieved in one of the phases.

NOTE The applied voltage is the open circuit voltage necessary to produce the specified power frequency recovery voltage (but see also Note 1 of 9.3.2.2.3).

The test circuit is energized simultaneously in all poles and the current curve is recorded for a duration of at least 0,1 s.

9.3.4.2.5 Test procedure

After calibration of the test circuit in accordance with 9.3.4.2.4, the temporary connections are replaced by the contactor under test, and its connecting cables, if any.

The contactor and its associated SCPD shall be mounted and connected as in normal use. They shall be connected to the circuit using a maximum of 2,4 m of cable (corresponding to the operational current) for each main circuit.

Three phase tests are considered to cover single-phase applications.

9.3.4.2.6 Interpretation of records

a) *Determination of the applied voltage and power-frequency recovery voltage*

The applied voltage and the power-frequency recovery voltage are determined from the record corresponding to the break test made with the contactor under test and evaluated as indicated in Figure 21.

The voltage on the supply side shall be measured during the first complete cycle after arc extinction in all poles and after high frequency phenomena have subsided (see Figure 21).

b) *Determination of the prospective breaking current*

This determination is made by comparing the current curves recorded during the calibration of the circuit with those recorded during the break test of the contactor (see Figure 21).

The AC component of the prospective breaking current is taken as being equal to the RMS value of the AC component of the calibration current at the instant which corresponds to the separation of the arcing contacts (value corresponding to $A_2/2\sqrt{2}$ of Figure 21, item a)). The prospective breaking current shall be the average of the prospective currents in all phases; the prospective current in any phase shall not vary from the average by more than 10 % of the average.

c) *Determination of the prospective peak making current*

The prospective peak making current is determined from the calibration record and its value shall be taken as being that corresponding to A_1 of Figure 21, item a). In the case of a three-phase test it shall be taken as the highest of the three A_1 values obtained from the record.

NOTE For tests on single-pole contactors, the prospective peak making current determined from the calibration record ~~may~~ can differ from the value of the actual making current corresponding to the test, depending on the instant of making.

9.3.4.3 Conditional short-circuit current

9.3.4.3.1 General

The contactor and the associated SCPD shall be subjected to the tests given in 9.3.4.3.2 and 9.3.4.3.3. The tests shall be so conducted that conditions of maximum I_e and of maximum U_e are covered.

For a magnetically operated contactor, the magnet shall be held closed by a separate electrical supply at the specified control voltage. The SCPD used shall be as stated in 8.2.5. If the SCPD is a circuit-breaker with an adjustable current setting, the test shall be made with the circuit-breaker adjusted to the maximum setting.

During the test, all openings of the enclosure shall be closed as in normal service and the door or cover secured by the means provided.

A new sample ~~may~~ can be used for each operation of the test sequences at prospective currents I_r and I_Q .

9.3.4.3.2 Test at the prospective current I_r

The circuit shall be adjusted to the prospective test current corresponding to the rated operational current I_e according to Table 24.

The contactor and the associated SCPD shall then be connected to the circuit. The following sequence of operations shall be performed:

- 1) One breaking operation of the SCPD shall be performed with SCPD and the contactor closed prior to the test.
- 2) One breaking operation of the SCPD shall be performed by closing the contactor on to the short-circuit.

Table 24 – Value of the prospective test current according to the rated operational current

Rated operational current I_e A	Prospective current I_r kA
$0 < I_e \leq 16$	1
$16 < I_e \leq 63$	3

The power factor shall be according to Table 23 of 9.3.4.2.3.

9.3.4.3.3 Test at the rated conditional short-circuit I_q

This test is done if the current I_q is higher than the current I_r .

The circuit shall be adjusted to the prospective short-circuit I_q equal to the rated conditional short-circuit current.

If the SCPD is a fuse and the test current is within the current-limiting range of the fuse then, if possible, the fuse shall be selected to permit the maximum let through peak current I_p and I^2t .

The contactor and the associated SCPD shall then be connected to the circuit.

The following sequence of operations shall be performed:

- 1) One breaking operation of the SCPD shall be performed with SCPD and the contactor closed prior to the test.
- 2) One breaking operation of the SCPD shall be performed by closing the contactor on to the short-circuit.

9.3.4.3.4 Results to be obtained

The contactor shall be considered to have passed the tests at the prospective current I_r and, where applicable, the prospective current I_q if the following conditions are met:

- A The fault current has been successfully interrupted by the SCPD and the fuse or fuse element or solid connection between the enclosure and supply shall not have melted.
- B The door or cover of the enclosure has not been blown open, and it is possible to open the door or cover. Deformation of enclosure is considered acceptable provided that the degree of protection by the enclosure is not less than IP2X.
- C There is no damage to the conductors or terminals and no conductor has been separated from the terminals.
- D There is no cracking or breaking of an insulating base to the extent that the integrity of mounting of a live part is impaired.

- E There has been no discharge of parts beyond the enclosure. Damage to the contactor is acceptable and the contactor ~~may~~ can be unsuitable for further use.

9.3.5 Overload current withstand capability

For the test, the contactor shall be mounted, wired and operated as specified in 9.3.2.

All poles of the contactor are simultaneously subjected to one test with the overload current and duration values stated in 8.2.4.4. The test is performed at any convenient voltage and it starts with the contactor at room temperature.

After the test, the contactor shall be substantially in the same condition as before the test. This is verified by visual inspection.

NOTE The $\int I^2 dt$ value (Joule integral) calculated from this test cannot be used to estimate the performance of the contactor under short-circuit conditions.

9.3.6 Routine tests

9.3.6.1 General

Routine tests are tests to which each individual contactor is subjected during or after manufacture to ascertain whether it complies with the stated requirements.

Routine tests shall be carried out under the same or equivalent conditions to those specified for type tests in the relevant parts of 9.1.2. However, the limits of operation in 9.3.3.2 ~~may~~ can be verified at the prevailing ambient air temperature ~~but a correction may be necessary to allow for the normal ambient conditions~~ with a correction if needed.

9.3.6.2 Operation and operating limits

Tests are carried out to verify operation within the limits specified in 8.2.1.2.

NOTE In these tests it is not necessary to reach thermal equilibrium.

9.3.6.3 Dielectric tests

Subclause 9.3.3.4.2 applies.

9.4 Tests for EMC

9.4.1 General

No tests are required for equipment not incorporating electronic circuits (see 8.3.1).

The test sample shall be in the open or closed position, whichever is the worse, and shall be supplied with the rated control circuit supply voltage.

9.4.2 Immunity

9.4.2.1 General

The tests of Table 25 are required.

If, during the EMC tests, conductors are to be connected to the test sample, the cross-section and the type of the conductors are optional but shall be in accordance with the manufacturer's literature.

Where a range of contactors comprise similar control electronics, within similar frame sizes, it is only necessary to test a single representative sample.

The product shall perform according to the performance criteria given in Table 26.

After the tests, the operating limits of 9.3.3.2 shall be verified at ambient temperature.

Table 25 – Tests for EMC – Immunity

Type of test	Reference test standard	Minimum test level required	Performance criterion
Electrostatic discharges	IEC 61000-4-2	Air discharge 8 kV Contact discharge 4 kV	B
Radio-frequency electromagnetic field	IEC 61000-4-3	80 Hz to 1 000 MHz – 3 V/m 1,4 GHz to 6 GHz – 3V/m 80 % AM (1 kHz)	A
Fast transient	IEC 61000-4-4	+1 kV Tr/Th 5/50 ns Repetition frequency 100 kHz	B
Surge	IEC 61000-4-5	1,2/50 (8/20) Tr/Td μ s 2 kV (line-to-earth) 1 kV (line-to-line)	B
Radio-frequency common mode	IEC 61000-4-6	0,15 MHz to 80 MHz 3 V 80 % AM (1 kHz)	A
Power-frequency magnetic field	IEC 61095	Covered by 9.3.4 Short-circuit test	/
Voltage dips ^a	for $I_e \leq 16$ A IEC 61000-4-11 for $I_e > 16$ A IEC 61000-4-34	0 % of the rated control supply voltage U_s during 0,5 cycle	B
		0 % of the rated control supply voltage U_s during 1 cycle	B
		70 % of the rated control supply voltage U_s during 25/30 cycles (50/60 Hz)	C
Voltage interruptions ^a		0 % of the rated control supply voltage U_s during 250/300 cycles (50/60 Hz)	C
^a This equipment is inherently sensitive to voltage dips and short time interruptions on the control supply; it shall react within the limits of 8.2.1.2 and this is verified by the operating limits tests given in 9.3.3.2.			

Table 26 – Specific acceptance criteria for immunity tests

Acceptance criteria			
Item	A	B	C
During the test referring to this criterion	the contactor shall remain in the expected position	contacts position can change self-recoverable	contacts position can change (not self-recoverable)

9.4.2.2 Electrostatic discharge

The point to which discharges shall be applied is selected by an exploration of the accessible surfaces of the contactor, when installed as for normal use.

9.4.2.3 Surge

Where three-phase equipment employs an identical circuit configuration for each phase then tests are required on only one phase.

9.4.3 Emission

9.4.3.1 Conducted radio-frequency emission tests

A description of the test, the test method and the test set-up are given in CISPR 14-1:2020, 5.1, 5.2 and 5.4.

The emission shall not exceed the levels given in Table 27.

Table 27 – Terminal disturbance voltage limits for conducted radio-frequency emission (for mains ports)

Frequency band MHz	Limits dB(μV)
0,15 to 0,5	66 to 56 quasi-peak 56 to 46 average
0,5 to 5,0	56 quasi-peak 46 average
5 to 30	60 quasi-peak 50 average
NOTE Limits are in accordance with CISPR 14-1 for mains ports Table 5.	

9.4.3.2 Radiated radio-frequency emission tests

A description of the test, the test method and the test set-up are given in CISPR 14-1:2020, 5.1, 5.2 and 5.4.

Tests are required where the control and auxiliary circuits contain components with fundamental switching frequencies greater than 9 kHz, for example switch-mode power supplies, etc.

The emission shall not exceed the levels given in Table 28.

Table 28 – Radiated emission test limits

Frequency range MHz	Limits ^a Quasi-peak dB (μV)	
	at 10 m	at 3 m
30 to 230	30	40
230 to 1 000	37	47
^a Tests can be carried out at 3 m distance only to small equipment (equipment, either positioned on a tabletop or standing on the floor which, including its cables fits in a cylindrical test volume of 1,2 m in diameter and 1,5 m above the ground plane).		

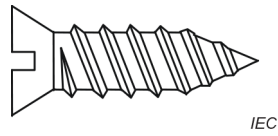


Figure 1 – Thread-forming tapping screw

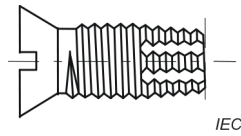


Figure 2 – Thread-cutting tapping screw

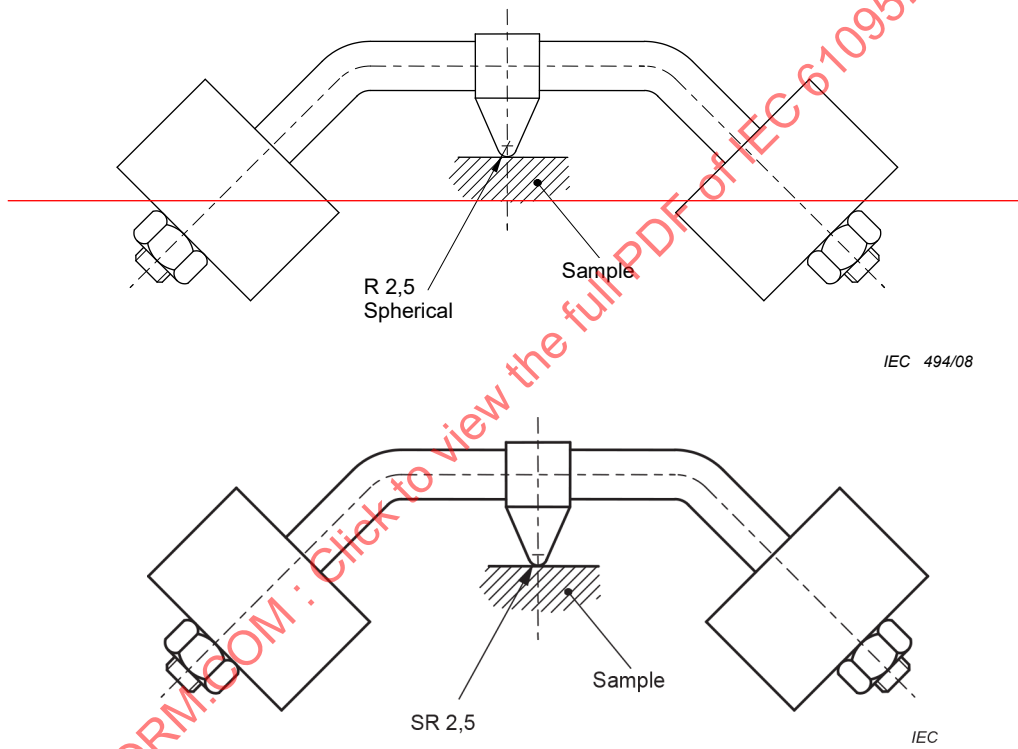


Figure 3 – Ball-pressure test apparatus (see 9.2.2.3.1)

Dimensions in millimetres

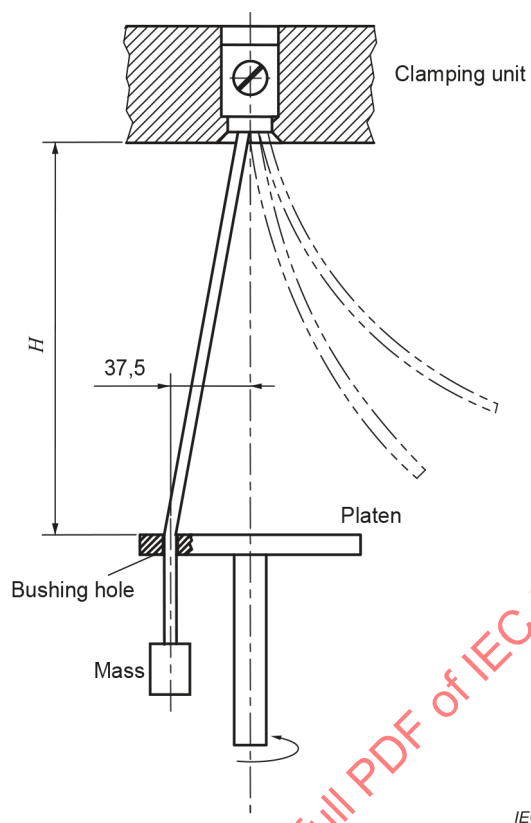


Figure 4 – Test equipment for flexion test (see 9.2.5.4)

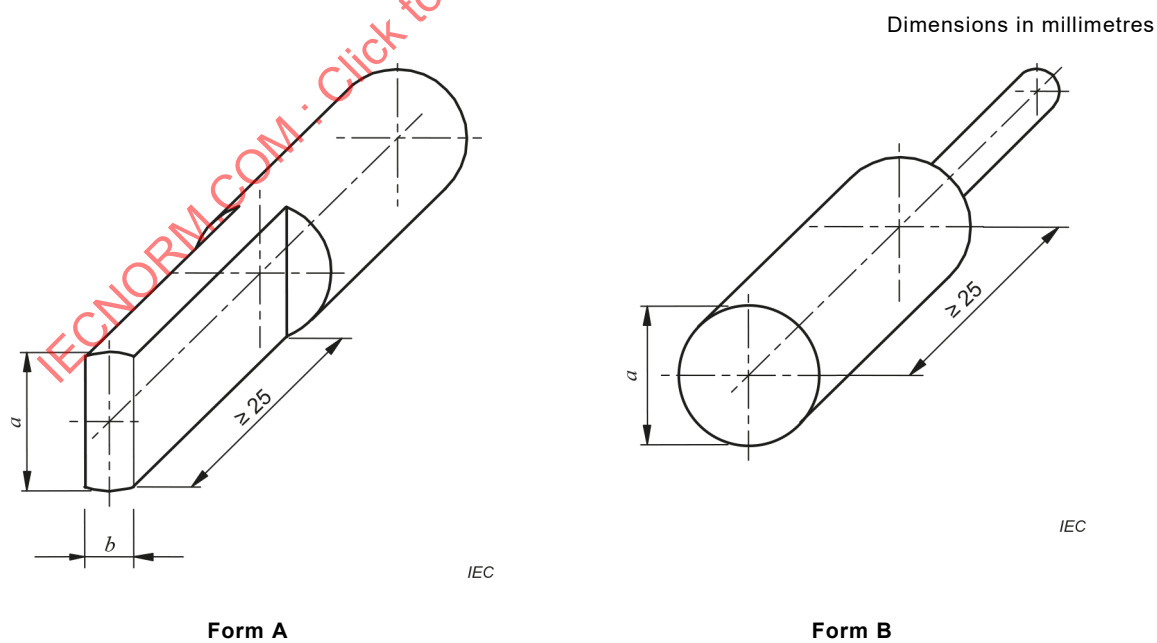
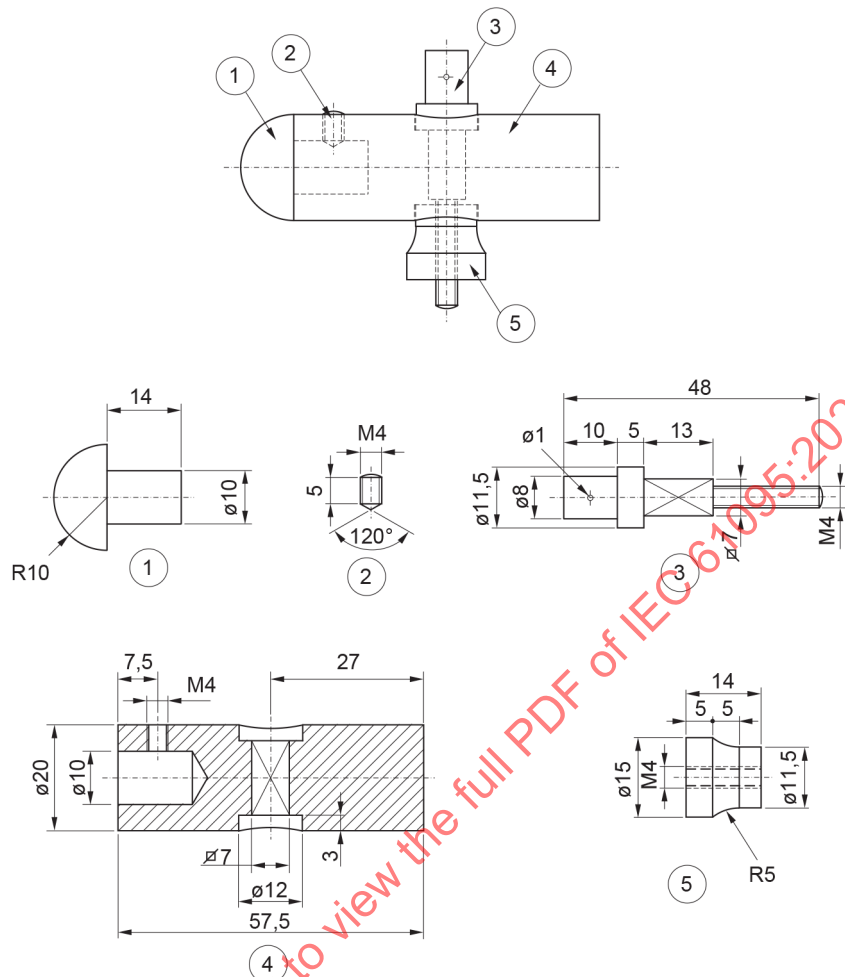


Figure 5 – Gauges of form A and form B (see 9.2.5.6)

Dimensions in millimetres



IEC

Key:

1 Polyamide

2, 3, 4, 5 Steel Fe 360

Figure 6 – Pendulum for mechanical impact test apparatus (striking element)
(see 9.2.6.2.1)

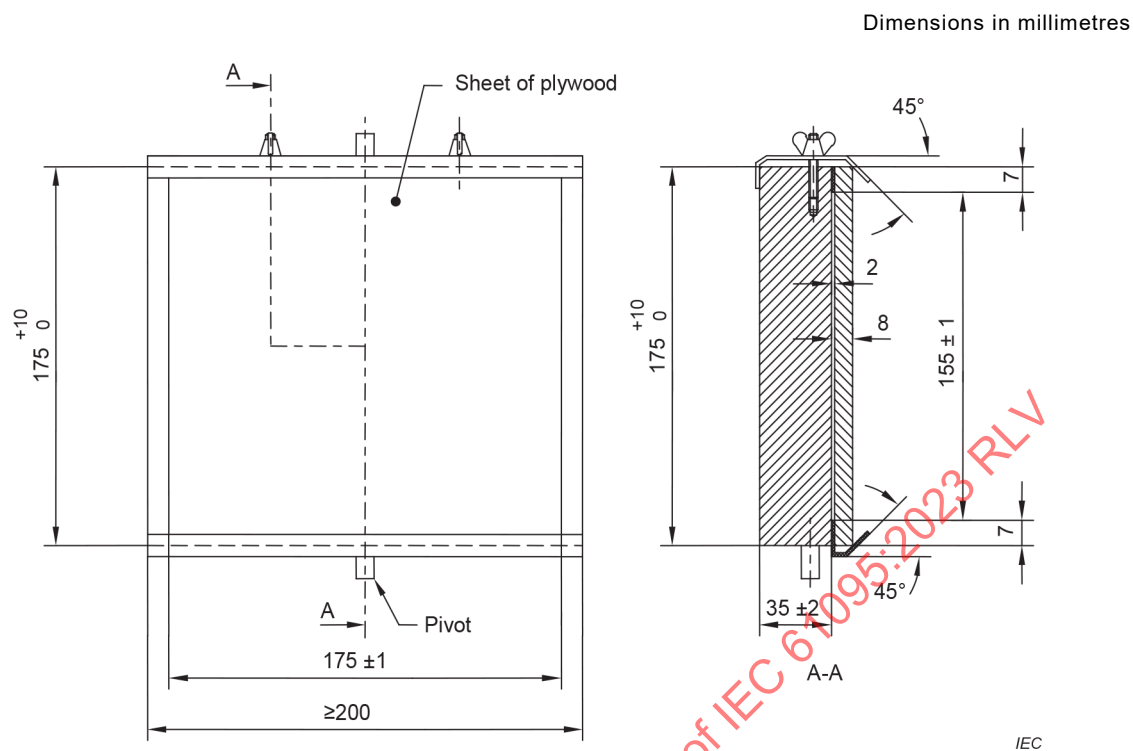


Figure 7 – Mounting support for sample, for mechanical impact test
(see 9.2.6.2.1)

Dimensions in millimetres

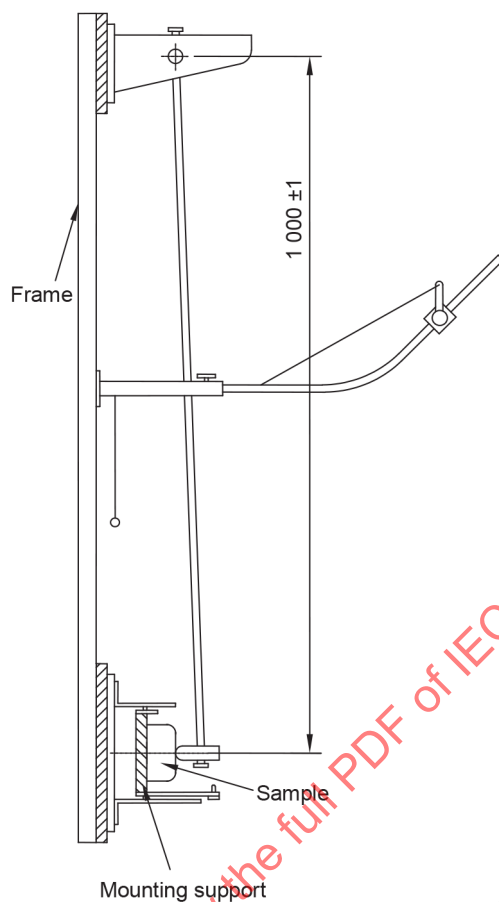
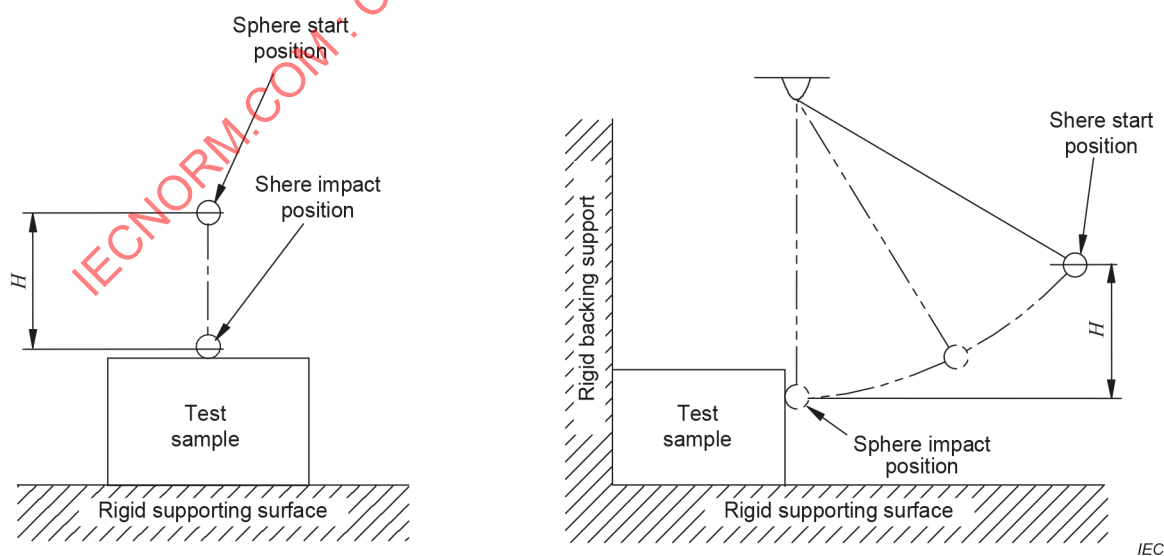


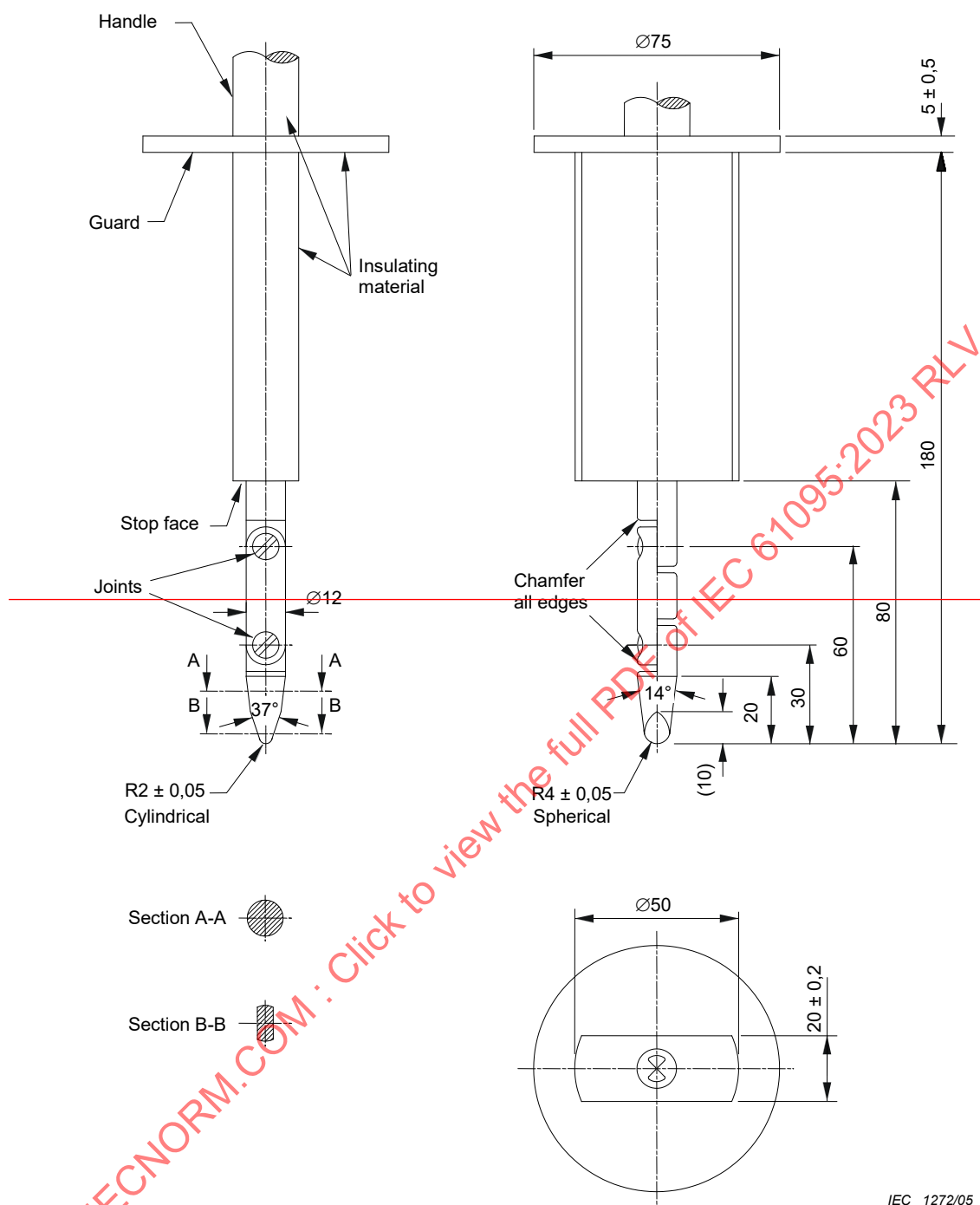
Figure 8 – Pendulum hammer test apparatus (see 9.2.6.2.1)



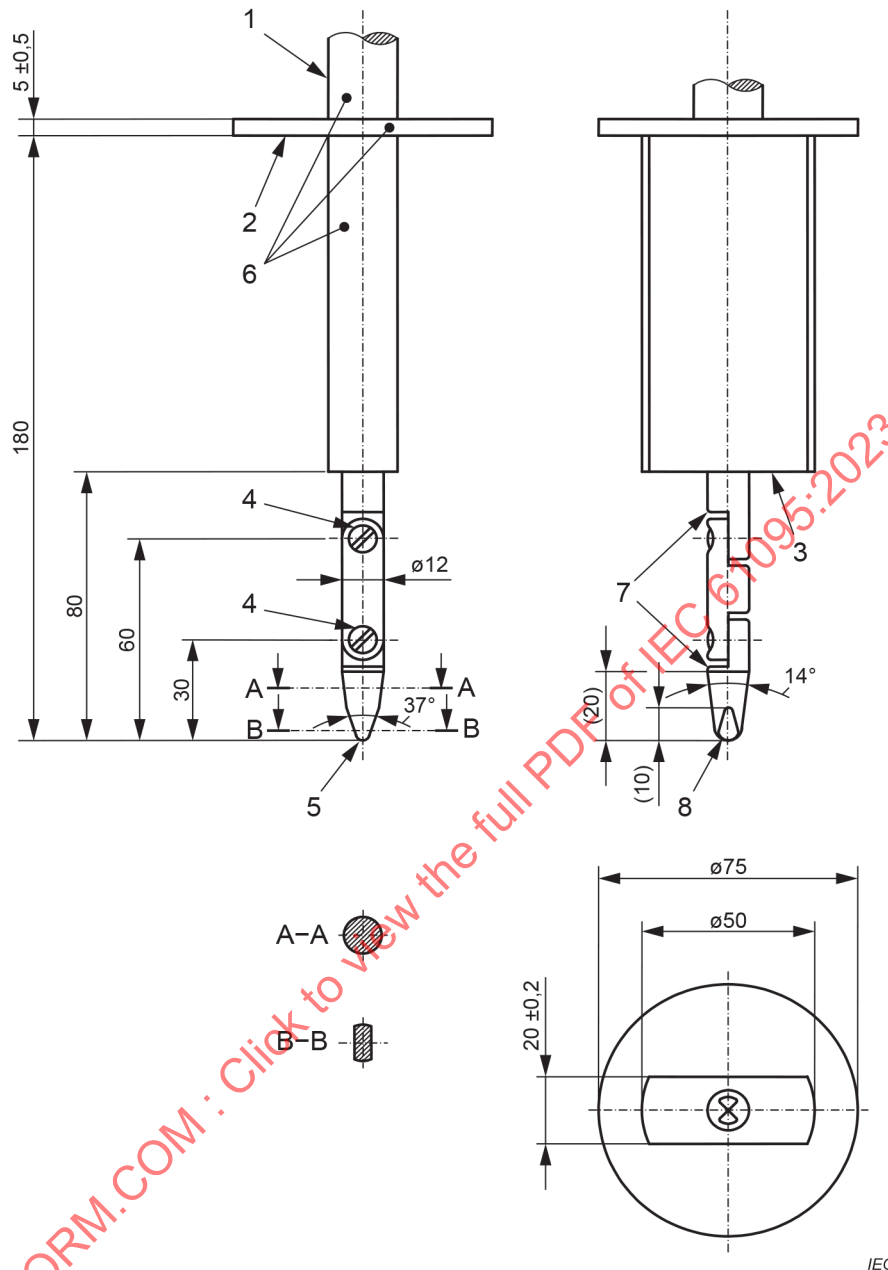
NOTE $H = 1\,300\text{ mm}$.

For the ball pendulum impact test, the sphere ~~must~~ shall contact the test sample when the cord is in the vertical position as shown.

Figure 9 – Sphere test apparatus (see 9.2.6.2.2)



Dimensions in millimetres



Key:

1 handle	2 guard	3 stop face
4 joints	5 R2 $\pm 0,05$ Cylindrica	6 insulating material
7 chamfer all edges	8 R4 $\pm 0,05$ Spherical	

Material: metal, except where otherwise specified

Linear dimensions in millimetres

Tolerances on dimensions without specific tolerance:

on angles: 0/-10'

on linear dimensions:

up to 25 mm: 0/-0,05

over 25 mm: $\pm 0,2$

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 10 – Jointed test finger (according to IEC 60529:1989, Figure 1)

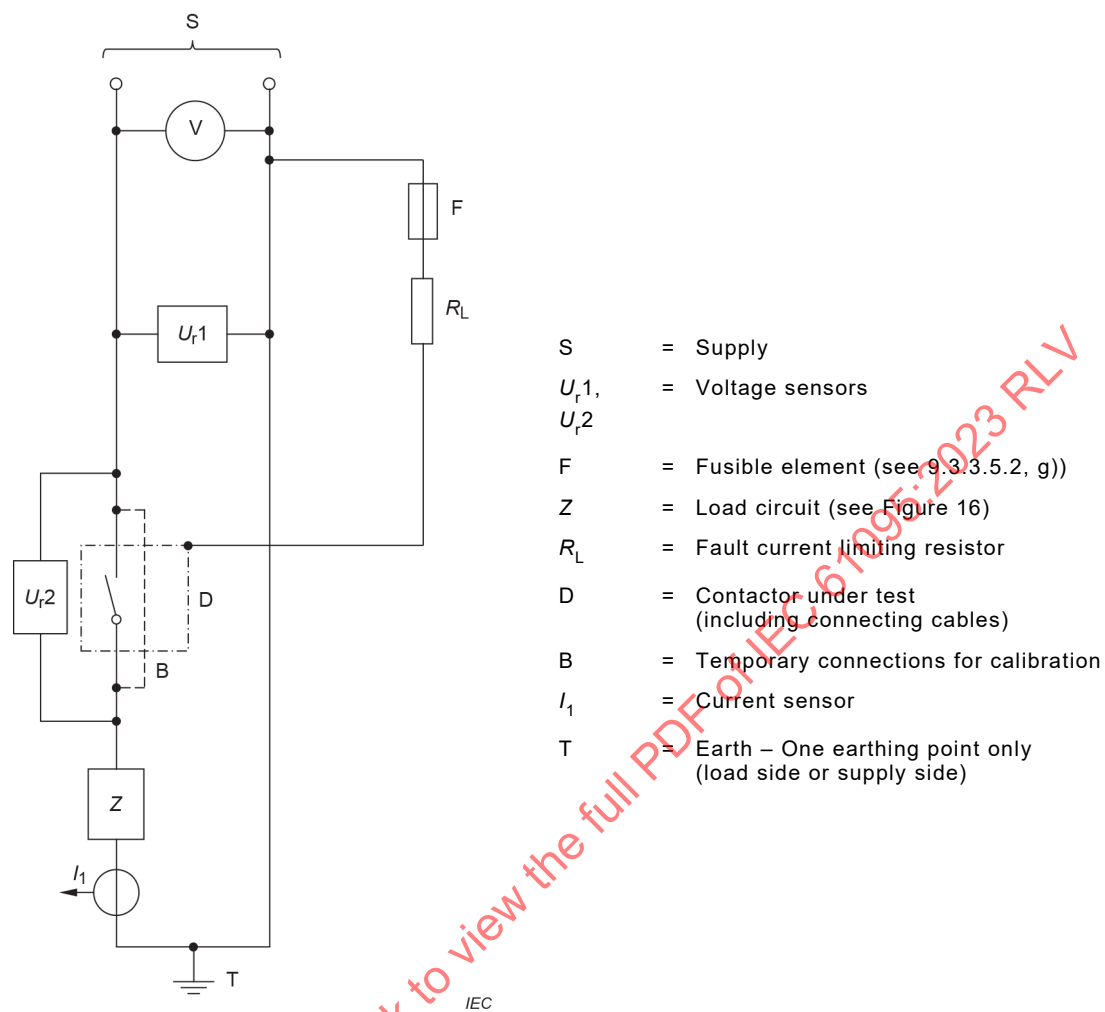
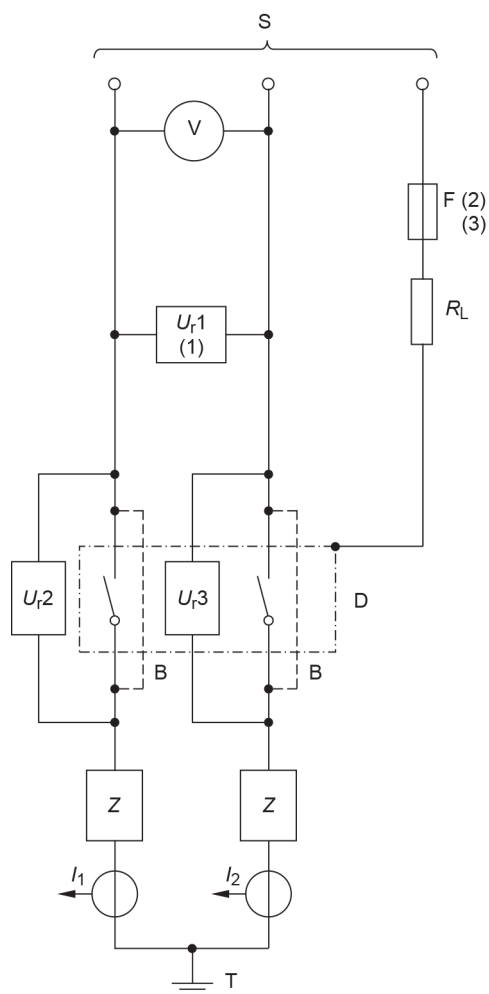


Figure 11 – Diagram of the test circuit for the verification of making and breaking capacities of a single-pole contactor on single-phase AC



S	= Supply
U_{r1}, U_{r2}, U_{r3}	= Voltage sensors
V	= Voltage measuring device
N	= Neutral of supply (or artificial neutral)
F	= Fusible element (see 9.3.3.5.2. g))
Z	= Load circuit (see Figure 16)
R_L	= Fault current limiting resistor
D	= Contactor under test (including connecting cables)
B	= Temporary connections for calibration
I_1, I_2	= Current sensors
T	= Earth – One earthing point only (load side or supply side)

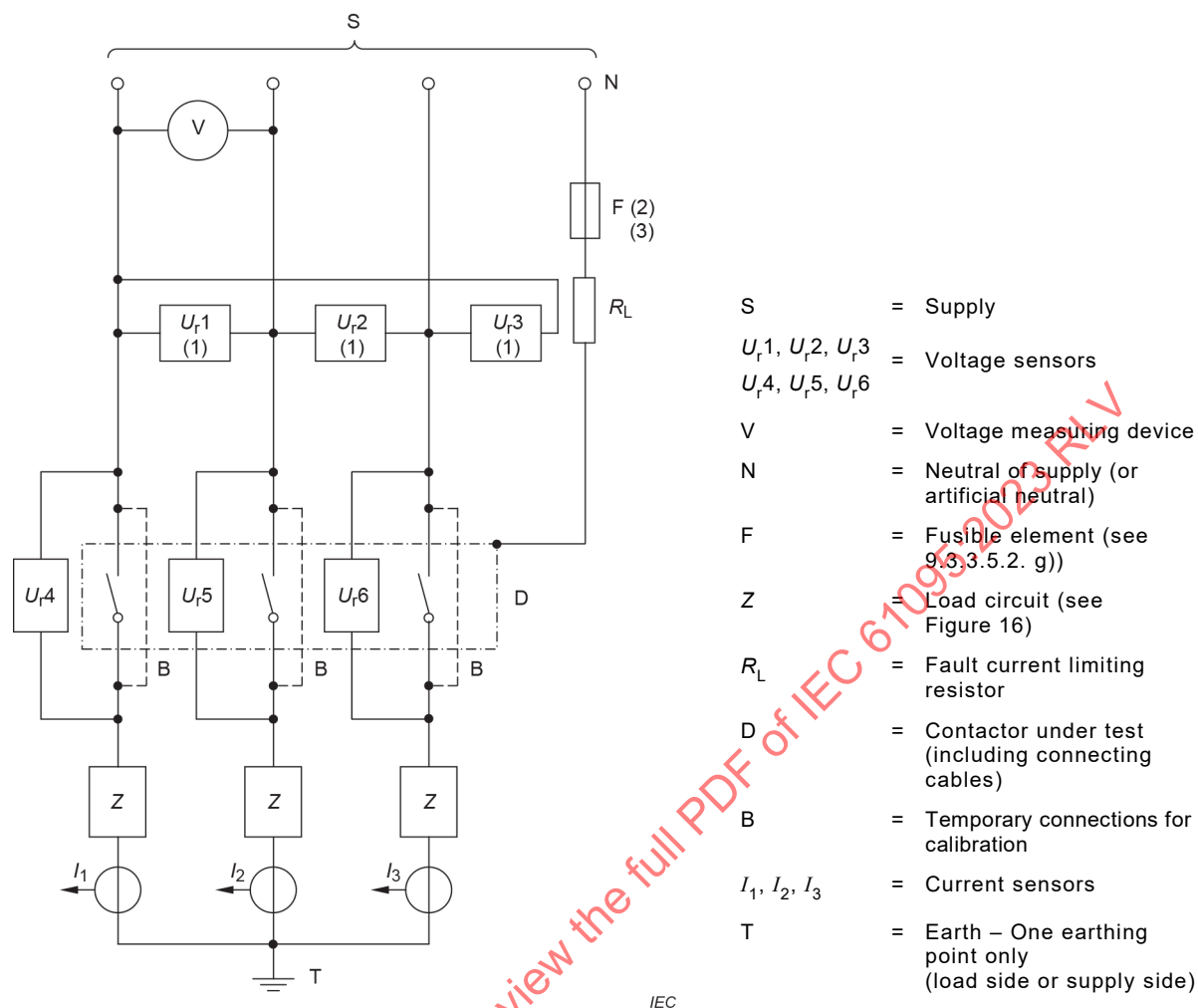
NOTE 1 U_{r1} may can, alternatively, be connected between phase and neutral.

NOTE 2 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 3 In the USA and Canada, F shall be connected:

- to one phase of the supply for equipment marked with a single value of U_e
- to the neutral for equipment marked with a twin voltage for U_e (see Note 1 of 6.2).

Figure 12 – Diagram of the test circuit for the verification of making and breaking capacities of a two-pole contactor on single-phase AC



NOTE 1 U_{r1}, U_{r2}, U_{r3} may can, alternatively, be connected between phase and neutral.

NOTE 2 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 32 In the USA and Canada, F shall be connected:

- to one phase of the supply for equipment marked with a single value of U_e .
- to the neutral for equipment marked with a twin voltage for U_e (see Note 1 of 6.2).

Figure 13 – Diagram of the test circuit for the verification of making and breaking capacities of a three-pole contactor

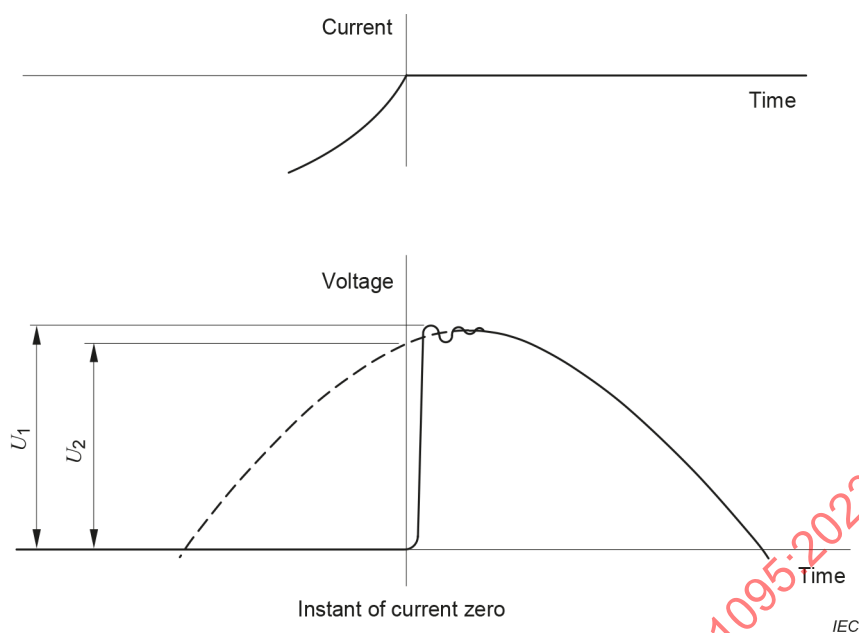
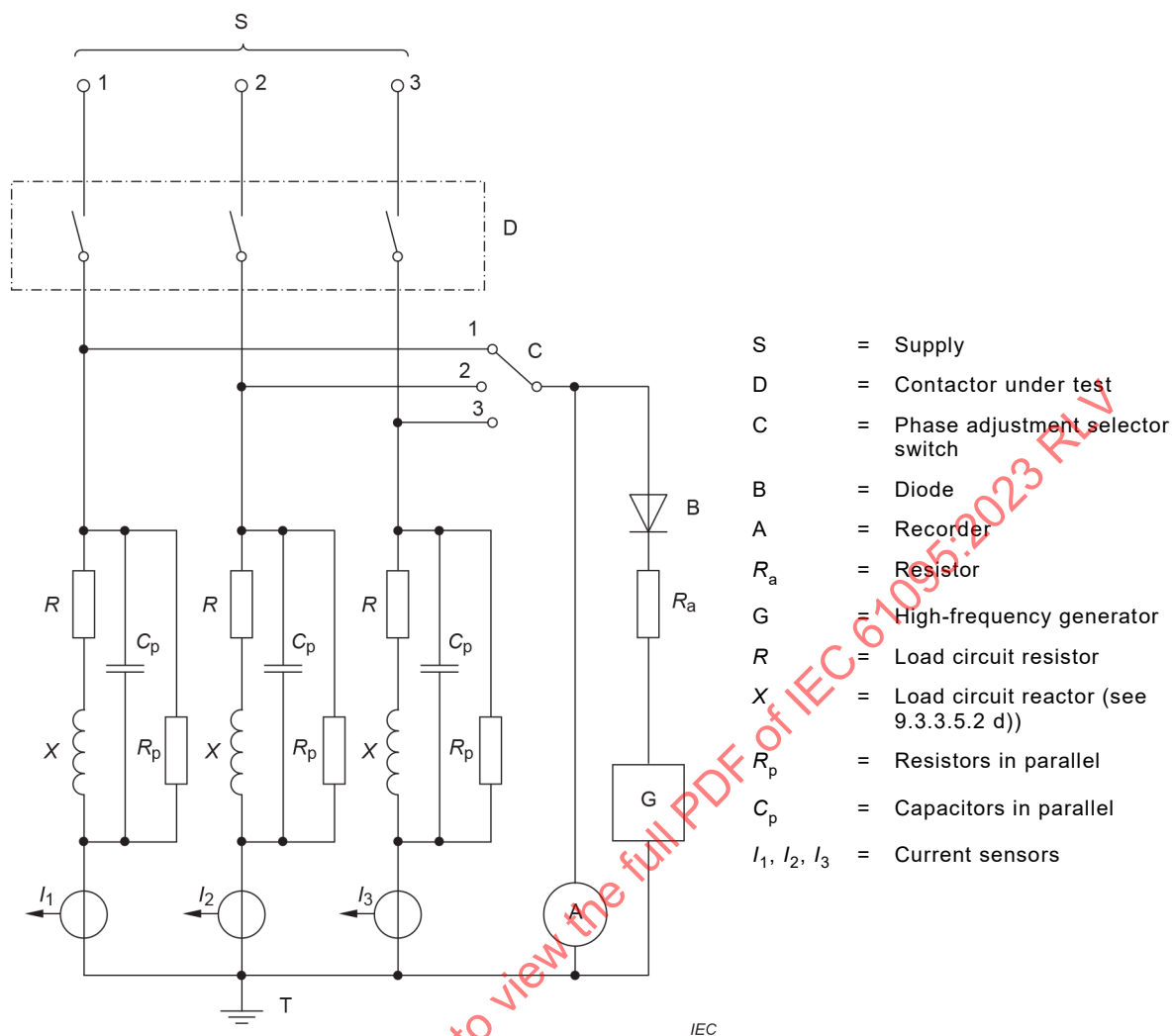
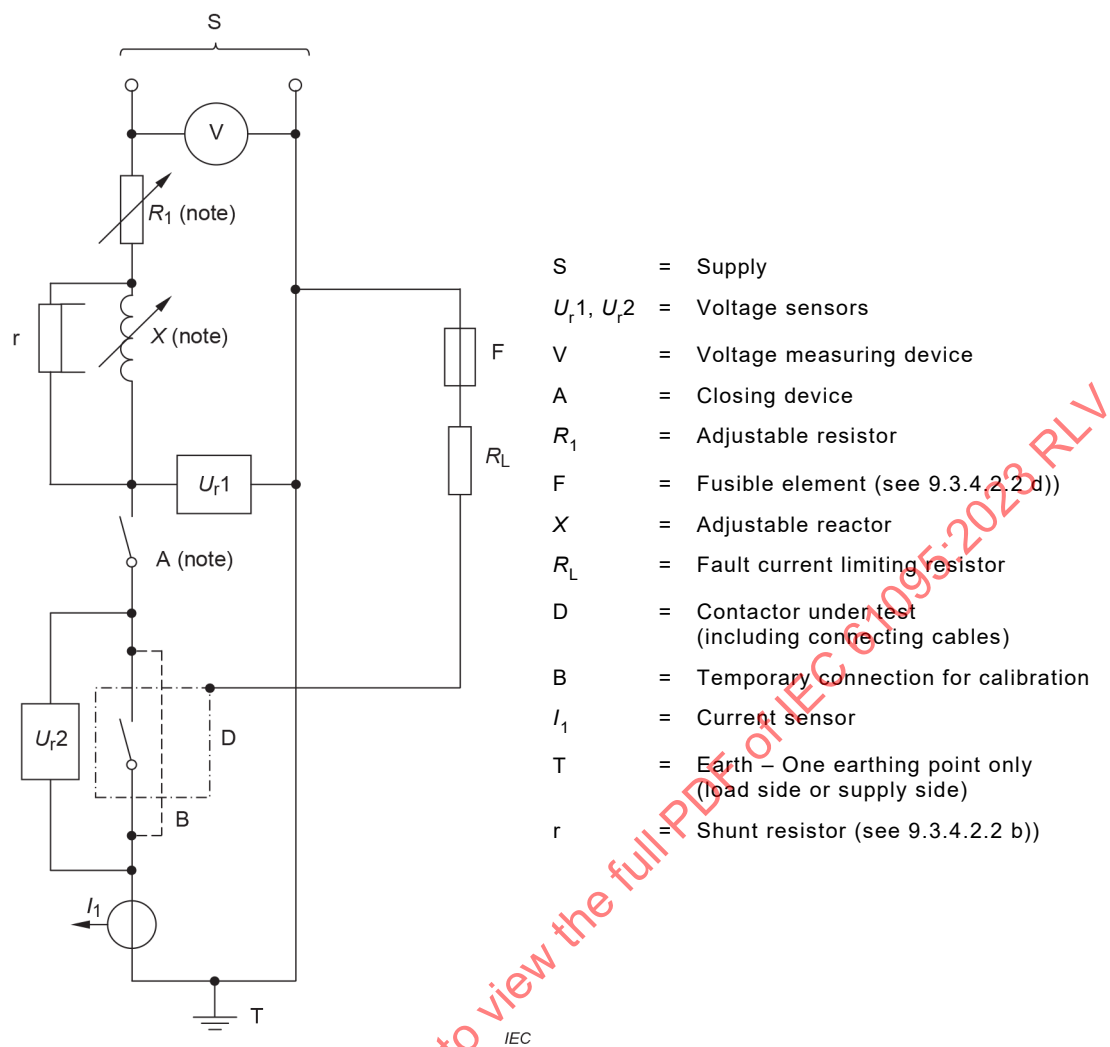


Figure 15 – Schematic illustration of the recovery voltage across contacts of the first phase to clear (see 9.3.3.5.2, e)) under ideal conditions



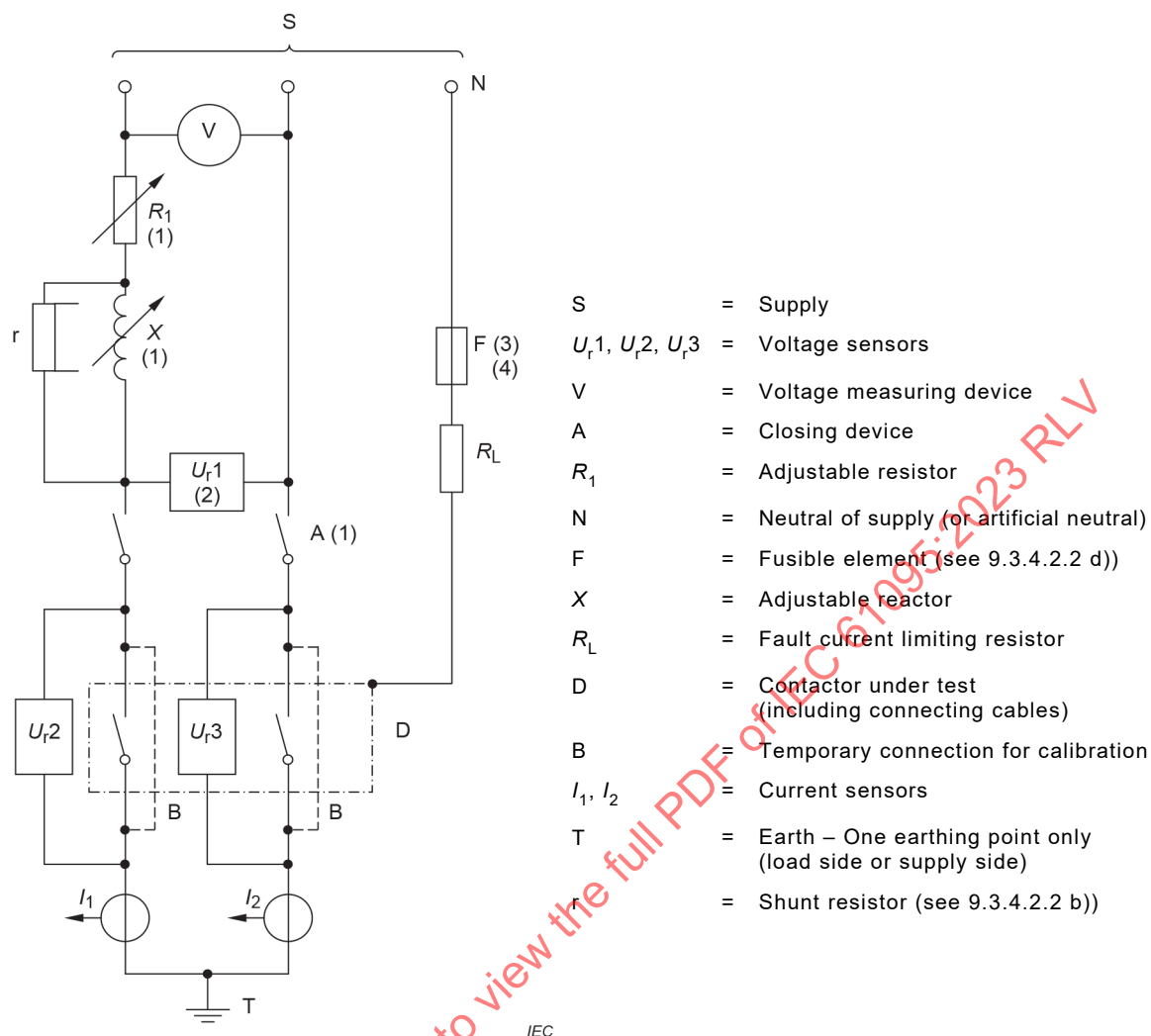
The relative positions of the high-frequency generator (G) and of the diode (B) shall be as shown.

Figure 16 – Diagram of a load circuit adjustment method



NOTE Adjustable loads X and R_1 may can be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

Figure 17 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a single-pole contactor on single-phase AC



NOTE 1 Adjustable loads X and R_1 may can be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

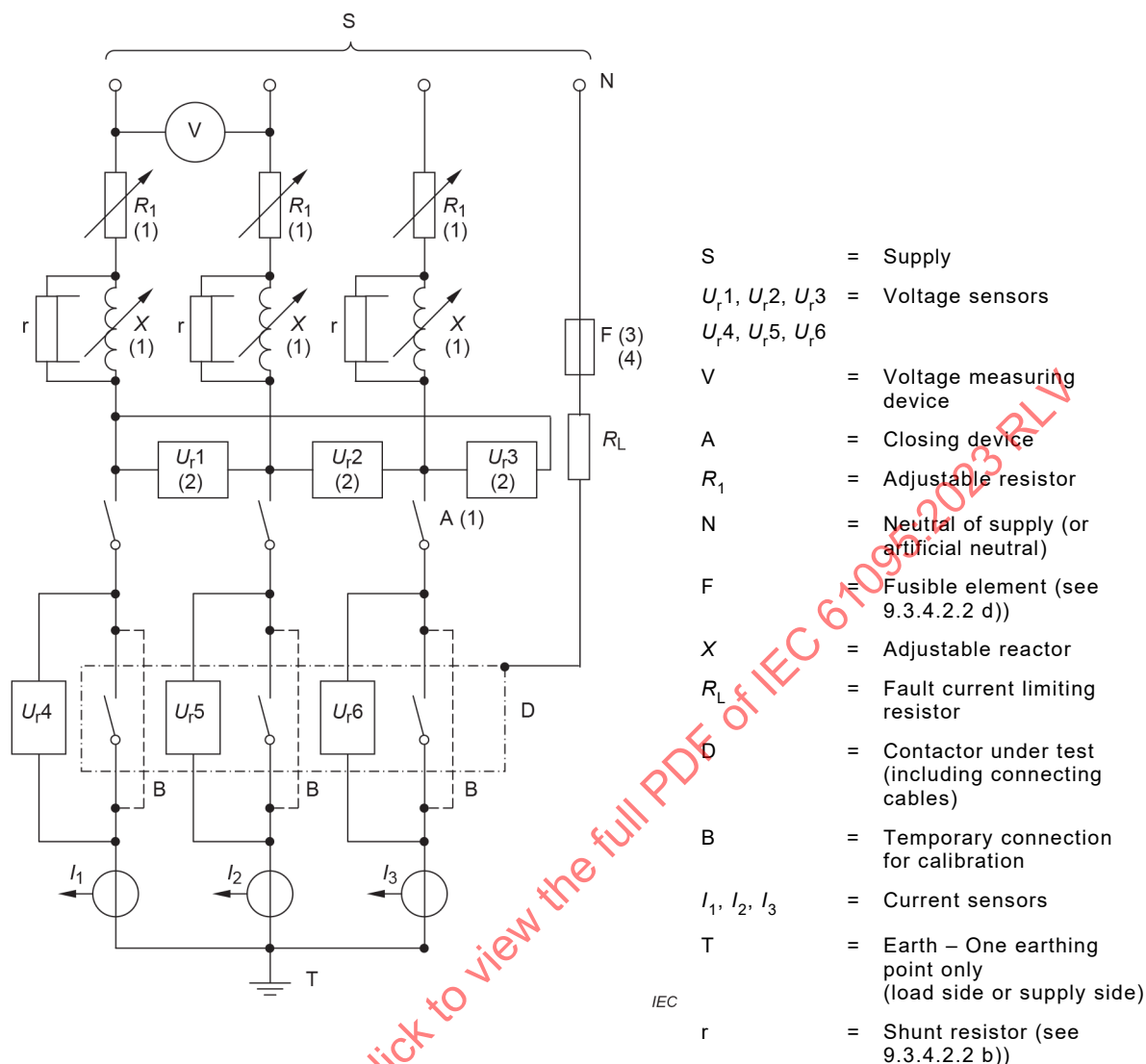
NOTE 2 U_{r1} may can, alternatively, be connected between phase and neutral.

NOTE 3 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 43 In the USA and Canada, F shall be connected:

- to one phase of the supply for equipment marked with a single value of U_e ,
- to the neutral for equipment marked with a twin voltage for U_e (see NOTE 1 to 6.2).

Figure 18 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a two-pole contactor on single-phase AC



NOTE 1 Adjustable loads X and R_1 may can be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

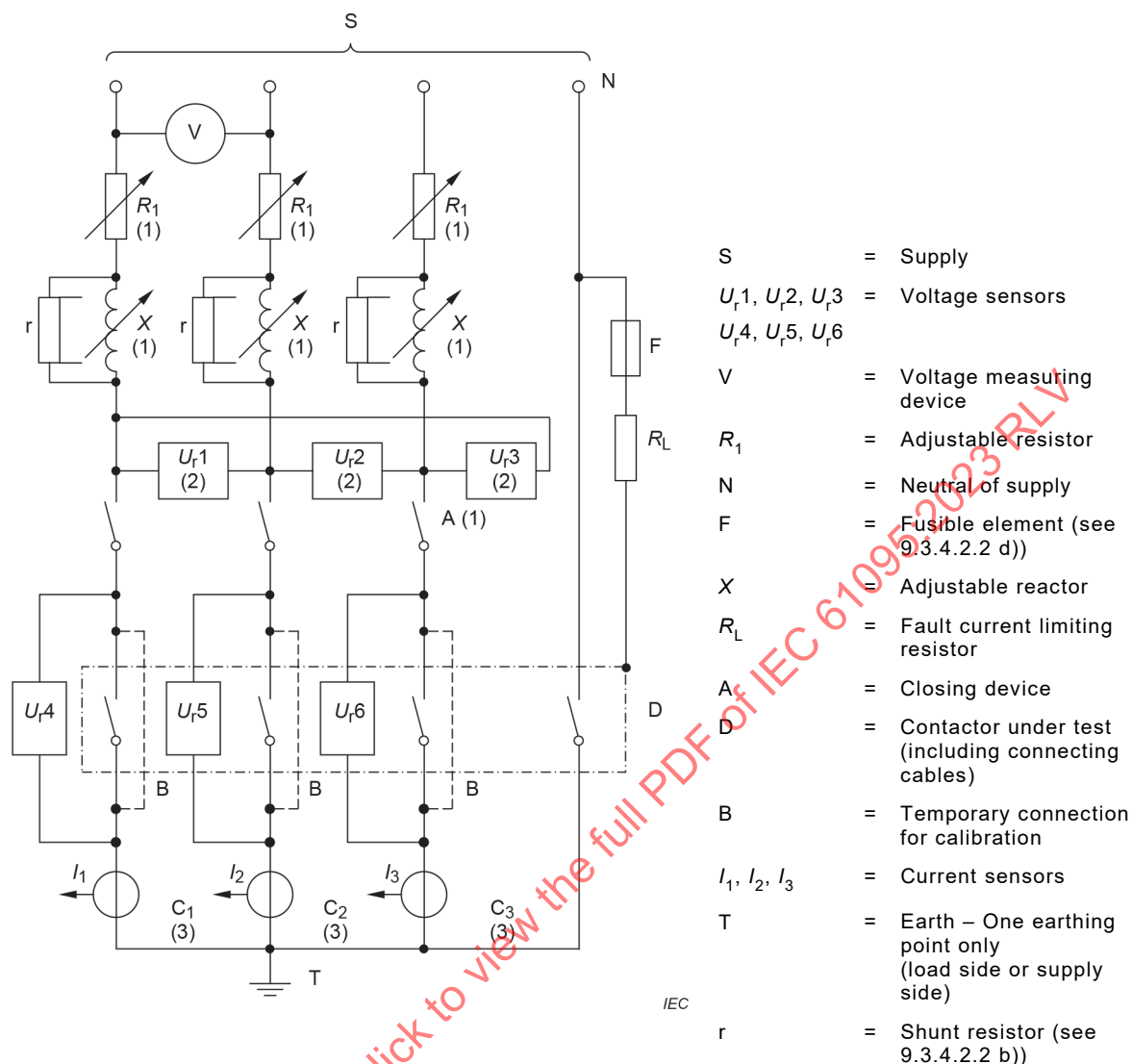
NOTE 2 U_{r1}, U_{r2}, U_{r3} may can, alternatively, be connected between phase and neutral.

NOTE 3 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 43 In the USA and Canada, F shall be connected:

- to one phase of the supply for equipment marked with a single value of U_e
- to the neutral for equipment marked with a twin voltage for U_e (see NOTE 1 to 6.2).

Figure 19 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a three-pole contactor

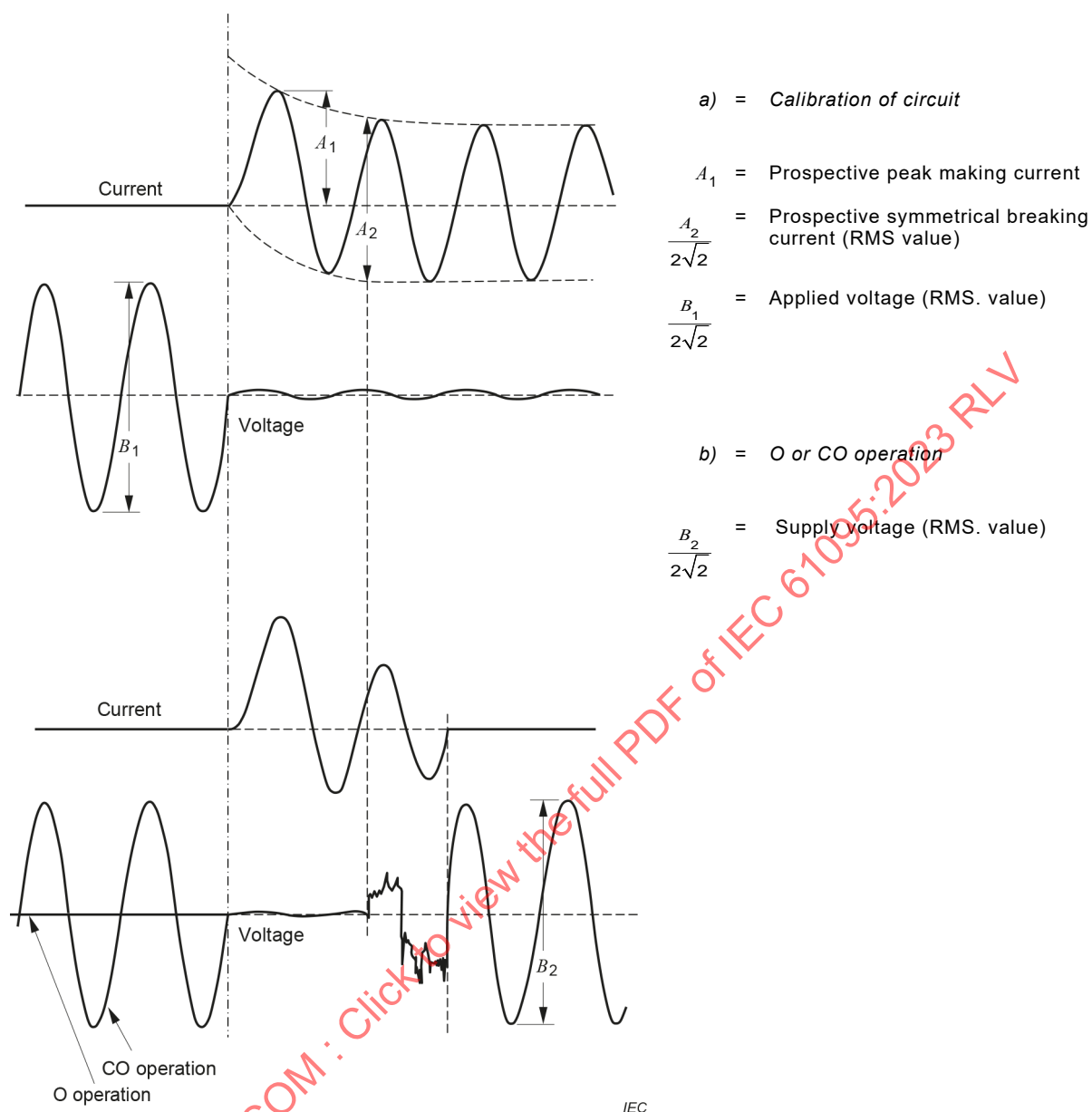


NOTE 1 Adjustable loads X and R_1 may can be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

NOTE 2 U_{r1}, U_{r2}, U_{r3} may can, alternatively, be connected between phase and neutral.

NOTE 3 If an additional test is required applicable between the neutral pole and the adjacent pole, the connections C_1 and C_2 are omitted.

Figure 20 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a four-pole contactor



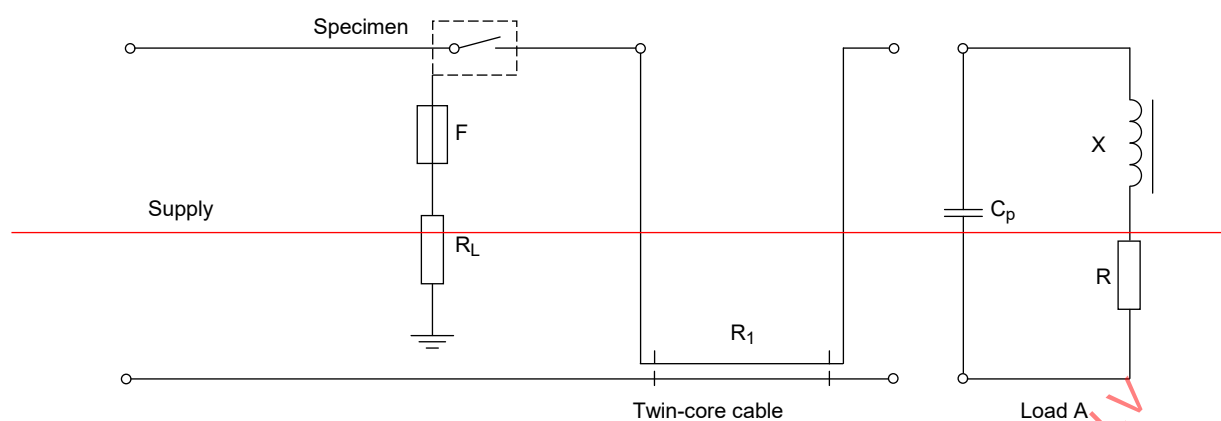
$$\text{Making capacity (peak value)} = A_1^* \quad \text{Breaking capacity (RMS value)} = \frac{A_2^*}{2\sqrt{2}}$$

NOTE 1 The amplitude of the voltage trace, after initiation of the test current, varies according to the relative positions of the closing device, the adjustable impedances, the voltage sensors and according to the test circuit diagram.

NOTE 2 It is assumed that the instant of making is the same for calibration and test.

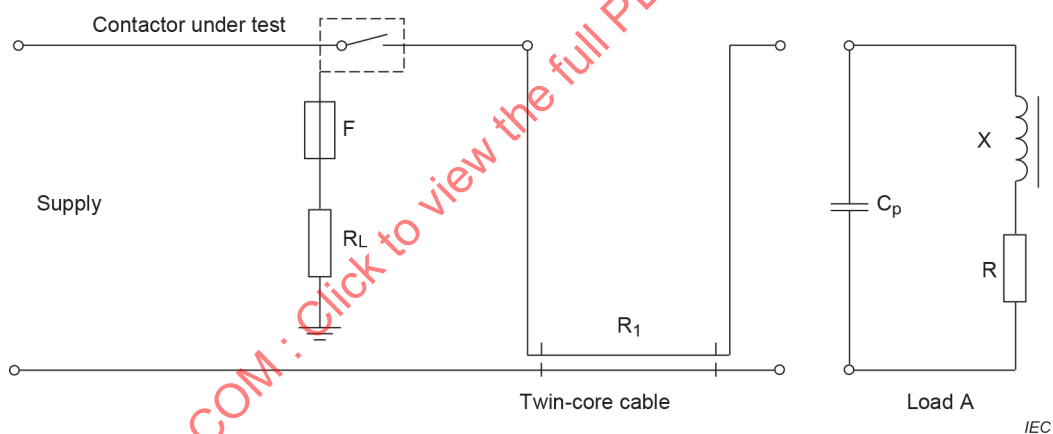
* See 9.3.4.2.6 b).

Figure 21 – Example of short-circuit making and breaking test record in the case of a single-pole contactor on single-phase AC



Key

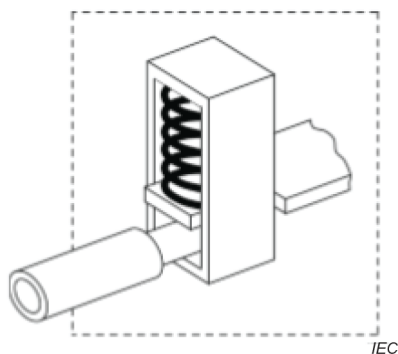
- F = Fuse
- R_L, R_1, R = Resistors
- X = Inductor
- C_p = Capacitor



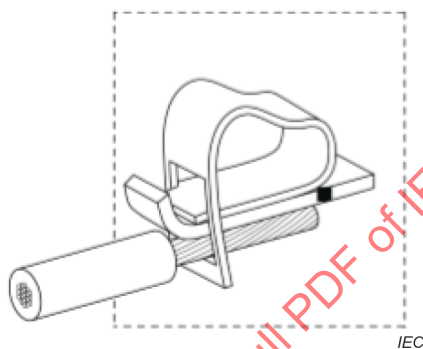
Key

- F = Fuse element (see 9.3.3.5.2 g)
- R_L = Fault current limiting resistor
- R_1 = Twin-core cable resistor
- R = Resistor of load circuit
- X = Inductor
- C_p = Capacitor

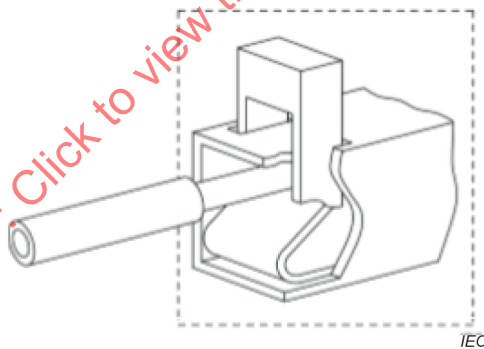
Figure 22 – Diagram of the test circuit for making and breaking verification for utilization category AC-7c



(a) Screwless-type terminal with indirect pressure



(b) Screwless-type terminal with direct pressure



(c) Screwless-type terminal with actuating element

Figure 23 – Example of screwless-type clamping units

Dimensions in millimetres

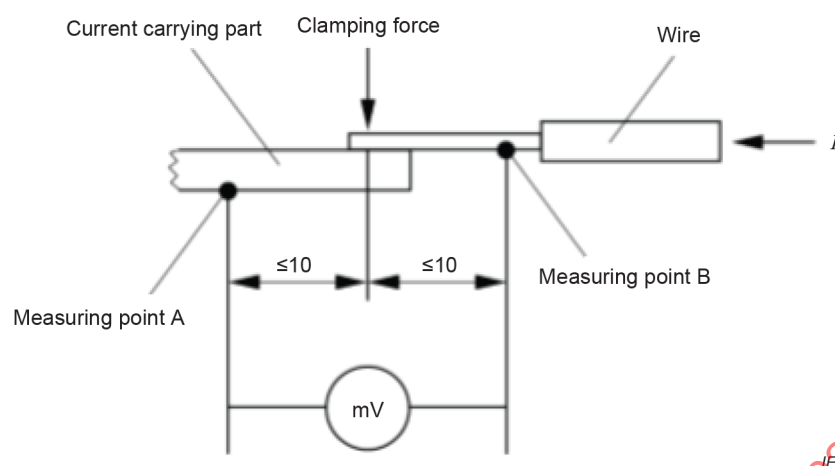


Figure 24 – Voltage drop measurement at contact point of the clamping terminal

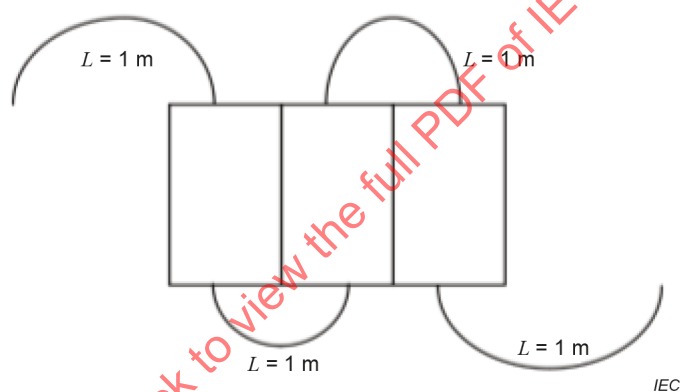
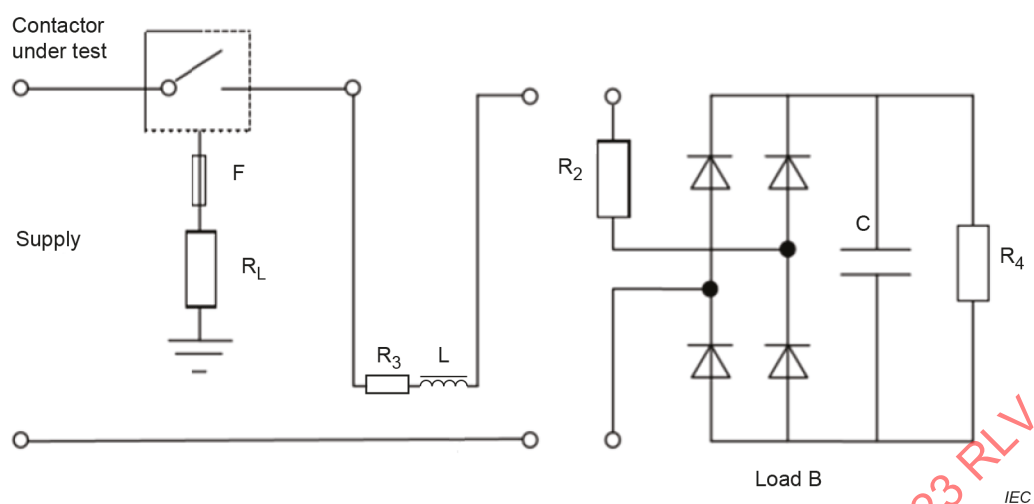


Figure 25 – Connecting samples for ageing test for screwless-type clamping units

**Key**

F = Fuse element (see 9.3.3.5.2 g)

R_L = Fault current limiting resistor

R₃ = Resistor simulating twin-core cable

L = Inductance simulating twin-core cable

R₂, R₄ = Resistors of load circuit

C = Capacitor

Figure 26 – Diagram of the test circuit for making and breaking verification for utilization category AC-7d

Annex A (normative)

Terminal marking and distinctive number

A.1 General

The purpose of identifying terminals of contactors is to provide information regarding the function of each terminal, or its location with respect to other terminals, or for other use.

A.2 Terminal marking of impedances (alphanumeric)

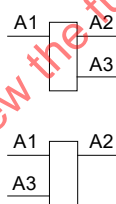
A.2.1 Coils

A.2.1.1 The two terminals of a coil for an electromagnetically operated drive shall be marked by A1 and A2.

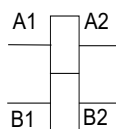


A.2.1.2 For a coil with tapplings, the terminals of the tapplings are marked in sequential order A3, A4, etc.

EXAMPLE



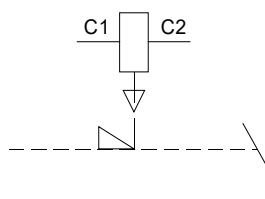
A.2.1.3 For a coil having two windings, the terminals of the first winding shall be marked A1, A2 and of the second winding B1, B2.



A.2.2 Electromagnetic releases

A.2.2.1 Shunt release

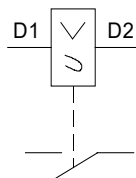
The two terminals of a shunt release shall be marked C1 and C2.



NOTE For a device with two shunt releases (for example with different ratings), the terminals of the second release ~~should be~~ are marked preferably C3 and C4.

A.2.2.2 Under-voltage release

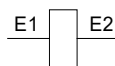
The two terminals of a coil intended to be used exclusively as an under-voltage release shall be marked D1 and D2.



NOTE For a device with two shunt releases (for example with different ratings), the terminals of the second release ~~should be~~ are marked preferably D3 and D4.

A.2.3 Interlocking electromagnets

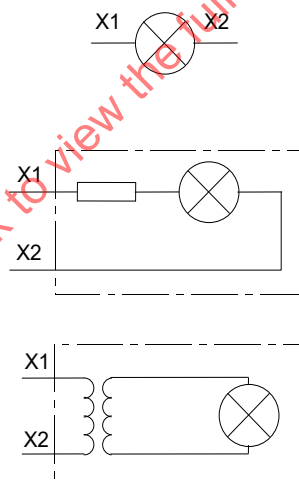
The two terminals of an interlocking electromagnet shall be marked E1 and E2.



A.2.4 Indicating light devices

The two terminals of an indicating light device shall be marked X1 and X2.

EXAMPLE



NOTE The term "indicating light devices" includes any incorporated resistor or transformer.

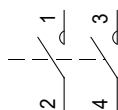
A.3 Terminal marking of contact elements for contactors with two positions (numerical)

A.3.1 Contact elements for main circuits (main contact elements)

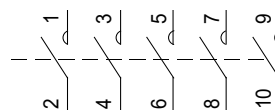
The terminals of main switching elements are identified by single figure numbers.

Each terminal marked by an odd number is associated with that terminal marked by the following even number.

EXAMPLES



Two main contact elements



Five main contact elements

When a contactor has more than five main contact elements, alphanumerical marking shall be chosen, according to IEC 60445.

A.3.2 Contact elements for auxiliary circuit (auxiliary contact elements)

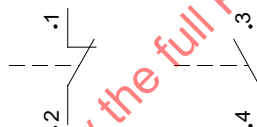
A.3.2.1 General

The terminals of auxiliary contact elements are identified by two-figure numbers:

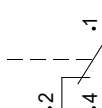
- the figure of the units is a function number;
- the figure of the tens is a sequence number.

A.3.2.2 Function number

A.3.2.2.1 Function numbers 1 and 2 are allocated to break-contact elements and functions 3 and 4 to make-contact elements.



The terminals of change-over contact elements are marked by the function numbers 1, 2 and 4.



NOTE The definitions of break-contact element and make-contact element are given in IEC 60050-441.

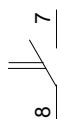
A.3.2.2.2 Auxiliary contact elements with special functions, such as time-delayed auxiliary contact elements, are identified by the function numbers 5 and 6, 7 and 8 for break-contact elements and make-contact elements respectively.

EXAMPLES

Break-contact delayed on closing



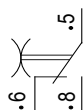
Make-contact delayed on closing



The terminals of change-over contact elements with special functions are marked by the function numbers 5, 6 and 8.

EXAMPLE

Change-over contact delayed in both directions

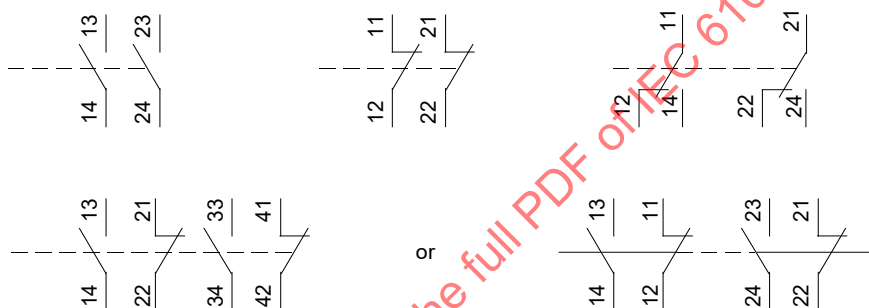


A.3.2.3 Sequence number

A.3.2.3.1 Terminals belonging to the same contact elements are marked with the same sequence numbers.

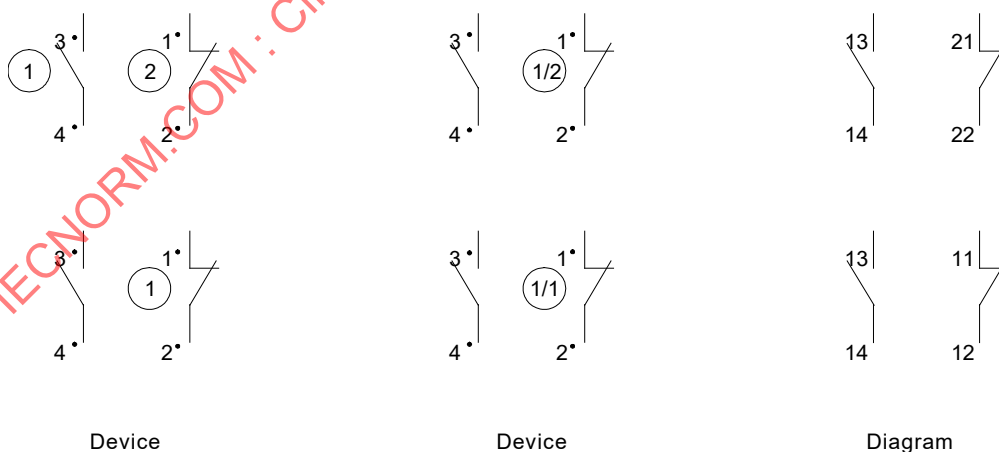
All contact elements having the same function shall have different sequence numbers.

EXAMPLES



A.3.2.3.2 The sequence number ~~may~~ can be omitted from the terminals only if additional information provided by the manufacturer or the user clearly gives such a number.

EXAMPLES



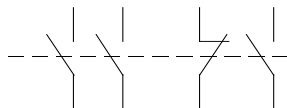
NOTE The dots shown in the examples of A.3.2 are merely used to show the relationship and ~~do~~ are not ~~need to~~ ~~be~~ necessarily used in practice.

A.4 Distinctive number

A device with a fixed number of make-contact elements and break-contact elements ~~may~~ can be allocated a two-figure distinctive number.

The first figure indicates the number of make-contact elements and the second figure the number of break-contact elements.

Distinctive number 31



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Annex B (normative)

Test sequences and number of samples

B.1 Test sequences

The tests are made according to Table B.1, where the tests in each sequence are carried out in the order indicated.

Table B.1 – Test sequences

Test sequences	Subclauses	Tests or inspections
A	9.3.3.3	Temperature-rise
	9.3.3.2	Operating limits
	9.3.3.5	~~Operation and operating limits~~ ~~Rated~~ Making and breaking capacities ^e
B	9.3.3.4	Dielectric properties ^{a, c}
	9.3.3.6	~~Conventional~~ Operational performance capability
C	9.2.2.2	Test of resistance to humidity
	9.3.5	Ability to withstand overload currents
	9.2.2.5	Test of resistance to rusting
D	9.2.7	Test of durability of marking
	9.2.6	Test of resistance to impact
	9.3.3.4	Verification of clearances when necessary and verification of creepage distances
E	9.2.5	Mechanical properties of terminals
	9.2.3	~~Screws, nuts, current-carrying parts~~
	9.2.2.3	Test on screws or nuts other than those on terminals which are intended to be operated during installation or maintenance
	9.2.2.4	Test of resistance to heat
	9.2.2.6	Tests of resistance to abnormal heat and fire ~~hazard~~ Test of resistance to tracking ^b
F	9.2.2.1	Test of resistance to ageing
	9.2.4	Verification of the degrees of protection of enclosed contactors
G	9.3.4	Performance under short-circuit conditions
H	9.2.8	Breakdown of components, if applicable
I	9.4	Tests for EMC, if applicable
^a Dielectric withstand test only, without measurement of clearances and creepage distances. ^b In case where no tests on specimen of insulating materials are available. ^c ~~Test 9.3.3.5 in test sequence A and test 9.3.3.4 in test sequence B may be inverted at the manufacturer's option.~~		

B.2 Number of samples

The number of samples to be submitted to the different test sequences are those indicated in the following Table B.2. Contactors in clean, new condition shall be used for each sequence, unless under specific agreement.

The samples required for a test sequence are submitted to all the tests of this test sequence and the requirements are met if all the tests are satisfied.

If only one of the samples does not satisfy a test in a given test sequence due to an assembly or manufacturing fault, which is not representative of the design, that test and any preceding ones which may have influenced the results of the test, shall be repeated on another full set of samples. Requirements are met if all the repeated tests are satisfied.

Table B.2 – Number of samples to be tested

Test sequences	Number of samples
A	3
B	3
C	1
D	1
E	1
F	1
G	4 ^a
H	/ ^b
I	3 ^c
^a One sample may be used for each operation if necessary (see 9.3.4.3). ^b Number of samples defined by the analysis ^c A set of three new samples may be used for each EMC test	

Annex C (normative)

Description of a method for adjusting the load circuit

To adjust the load circuit to obtain the characteristics prescribed in 9.3.3.5.3 several methods ~~may~~ can be applicable in practice. One of them is described below.

The principle is illustrated in Figure 16.

The oscillatory frequency f of the transient recovery voltage and the value of the factor γ are essentially determined by the natural frequency and the damping of the load circuit. Since these values are independent of the voltage and frequency applied to the circuit, the adjustment can be made by energizing the load circuit from an AC power supply, the voltage and frequency of which ~~may~~ can be different from those of the supply source utilized for the test of the contactor. The circuit is interrupted at a current zero by a diode, and the oscillations of the recovery voltage are observed on the screen of a cathode-ray oscilloscope, the sweep of which is synchronized with the frequency of the power supply (see Figure C.1).

To permit reliable measurements to be made, the load circuit is energized by means of a high-frequency generator G giving a voltage suitable for the diode. The frequency of the generator is chosen equal to:

- a) 2 kHz for test currents up to and including 1 000 A;
- b) 4 kHz for test currents higher than 1 000 A.

Connected in series with the generator are:

- a dropping resistor having a resistance value R_a high with respect to the load circuit impedance ($R_a \geq 10 Z$, where $Z = \sqrt{R^2 + (\omega L)^2}$ and where ω is $2\pi \times 2\,000\text{ s}^{-1}$ or $2\pi \times 4\,000\text{ s}^{-1}$ for cases a) and b) respectively;
- an instantaneously blocking switching diode B; switching diodes commonly used in computers such as diffused junction silicon switching diodes of not over 1 A forward rated current are suitable for this application.

Due to the value of frequency of the generator G, the load circuit is practically purely inductive and, at the instant of current zero, the applied voltage across the load circuit will be at its peak value. To ensure that the components of the load circuit are suitable, it ~~must~~ shall be checked on the screen that the curve of the transient voltage at its initiation (point A in Figure C.1) has a practically horizontal tangent.

The actual value of the factor γ is the ratio U_{11}/U_{12} ; U_{11} is read on the screen, U_{12} is read between the ordinate of point A and the ordinate of the trace when the load circuit is no longer energized by the generator (see Figure C.1).

When observing the transient voltage in the load circuit with no resistor R_p or capacitor C_p in parallel, one reads on the screen the natural oscillatory frequency of the load circuit. Care should be taken that the capacitance of the oscilloscope or of its connecting leads does not influence the resonant frequency of the load circuit.

If that natural frequency exceeds the upper limit of the required value f , the suitable values of frequency and factor γ can be obtained by connecting in parallel capacitors C_p and resistors R_p of appropriate values. The resistors R_p shall be practically non-inductive.

It is recommended that, as a first step, each of the three phases of the load circuit be adjusted separately. The adjustment is then completed by successively connecting, in each possible combination, the high-frequency generator to one phase in series with the other two in parallel as shown in Figure 16; the adjustment is refined if necessary so that the specified values of f and γ are obtained in each combination.

NOTE 1 A higher value of frequency obtained from the generator G facilitates the observation on the screen and improves the resolution.

NOTE 2 Other methods of determining frequency and factor γ (such as the impression of a square-wave current on the load circuit) may can also be used.

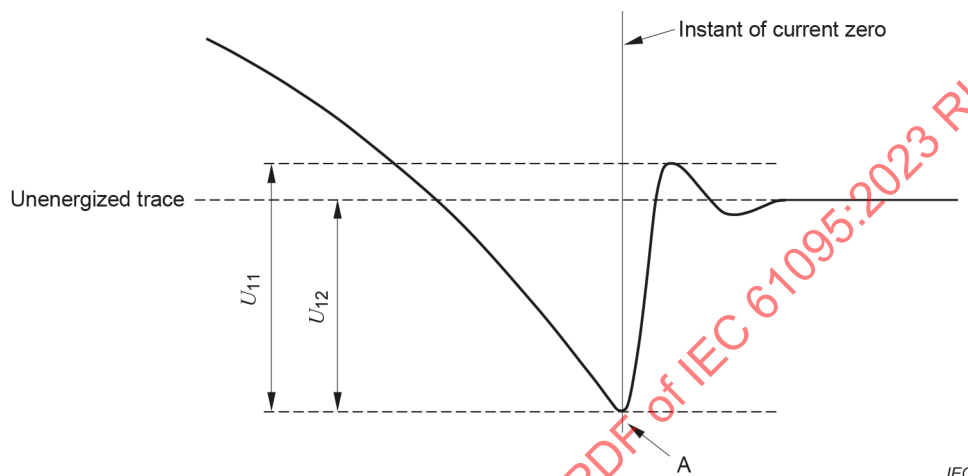


Figure C.1 – Determination of the actual value of the factor γ

Annex D (normative)

Determination of short-circuit power-factor

D.1 General

There is no method by which the short-circuit power-factor can be determined with precision, but for the purpose of this document, the determination of the power-factor of the test circuit ~~may~~ can be made by one of the following methods.

NOTE Other methods for determining the short-circuit power-factor are under consideration.

D.2 Method I – Determination from DC component

The angle φ ~~may~~ can be determined from the curve of the DC component of the asymmetrical current wave between the instant of the short-circuit and the instant of contact separation as follows:

- 1) To determine the time-constant L/R from the formula for the DC component.

The formula for the DC component is:

$$i_d = I_{do} e^{-Rt/L}$$

where

i_d is the value of the DC component at the instant t ;

I_{do} is the value of the DC 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 Napierian logarithms.

The time-constant L/R can be determined by:

- a) measuring the value of I_{do} at the instant of short-circuit and the value of i_d at another instant t before contact separation,
- b) determining the value of $e^{-Rt/L}$ by dividing i_d by I_{do} ,
- c) determining the value of $-\chi$ corresponding to the ratio i_d/I_{do} , from a table of values of $e^{-\chi}$

The value χ represents Rt/L , from which R/L is obtained.

- 2) To determine the angle φ from: $\varphi = \arctan(\omega L/R)$

where ω is 2π times the actual frequency.

This method should not be used when the currents are measured by current transformers, except if suitable precautions are taken to eliminate errors due to:

- the time-constant of the transformer and its burden in relation to that of the primary circuit;
- magnetic saturation which can result from the transient flux conditions combined with possible remanence.

D.3 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~~ **can** 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.

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Annex E (normative)

Measurement of creepage distances and clearances

E.1 Basic principles

The widths X of grooves specified in Figure E.2 to Figure E.12 basically apply to all examples as a function of pollution degree as given in Table E.1:

Table E.1 – Minimum values of width of grooves according to the pollution degrees

Pollution degrees	Minimum values of width X of grooves mm
1	0,25
2	1,0
3	1,5
4	2,5

If the associated clearance is less than 3 mm, the minimum groove width ~~may~~ can be reduced to one-third of this clearance.

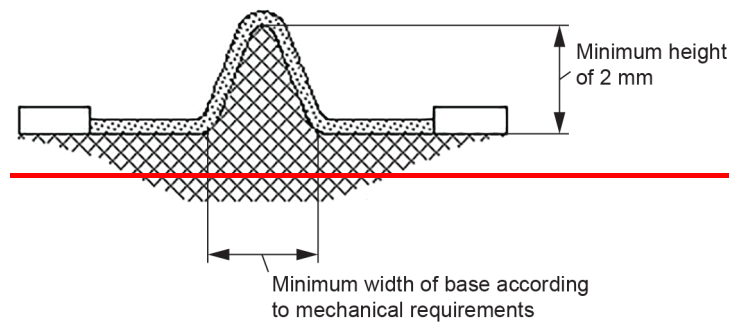
The methods of measuring creepage distances and clearances are indicated in the following Figure E.2 to Figure E.12. These examples do not differentiate between gaps and grooves or between types of insulation.

Furthermore:

- any corner is assumed to be bridged with an insulating link of X mm width moved into the most unfavourable position (see Figure E.4);
- when the distance across the top of a groove is X mm or more, a creepage distance is measured along the contours of the groove (see Figure E.3);
- creepage distances and clearances measured between parts moving in relation to each other are measured when these parts are in their most unfavourable positions.

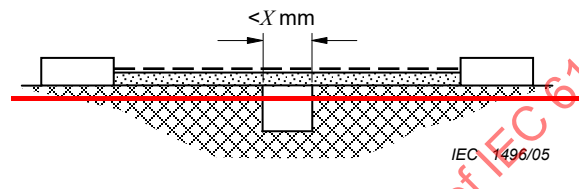
E.2 Use of ribs

Because of their influence on contamination and their better drying-out effect, ribs decrease considerably the formation of leakage current. Creepage distances can therefore be reduced to 0,8 times the required value, provided the minimum height of the ribs is 2 mm.



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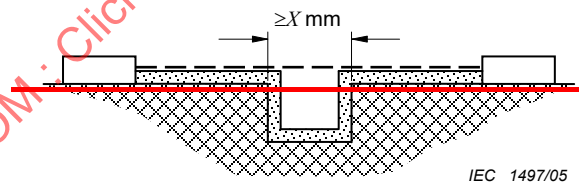
Figure E.1 — Measurement of ribs



Condition: This creepage distance path includes a parallel or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

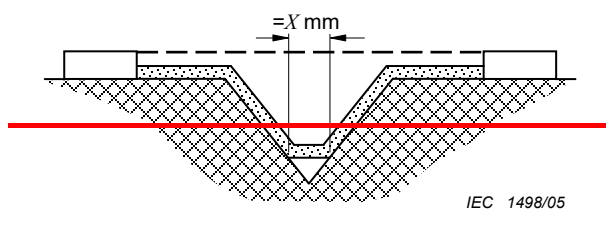
Figure E.2 — Creepage distance example 1



Condition: This creepage distance path includes a parallel-sided groove of any depth and a width equal to or more than X mm.

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

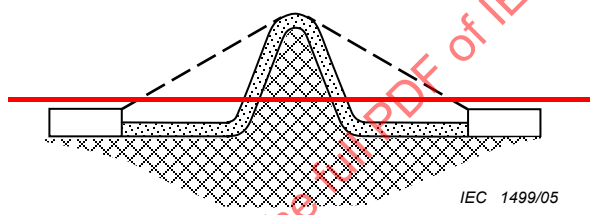
Figure E.3 — Creepage distance example 2



Condition: This creepage distance path includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

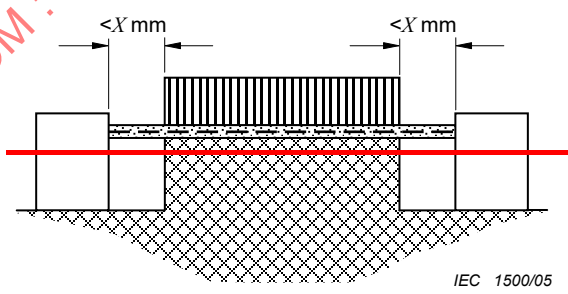
Figure E.4 – Creepage distance example 3



Condition: This creepage distance path includes a rib.

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

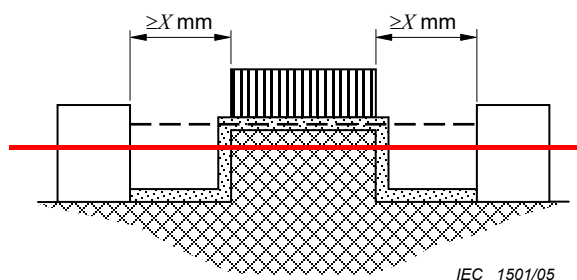
Figure E.5 – Creepage distance example 4



Condition: This creepage distance path includes an uncemented joint with grooves less than X mm wide on each side.

Rule: Creepage distance and clearance path is the "line-of-sight" distance shown.

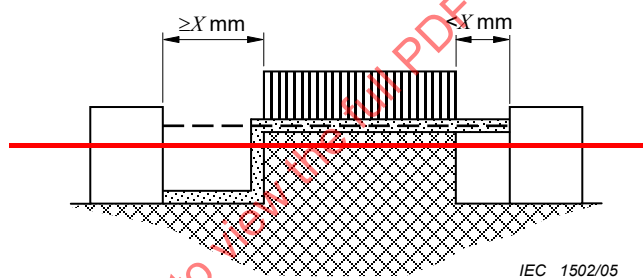
Figure E.6 – Creepage distance example 5



Condition: This creepage distance path includes an uncemented joint with grooves equal to or more than X mm wide on each side.

Rule: Clearance is the “line-of-sight” distance. Creepage distance path follows the contour of the grooves.

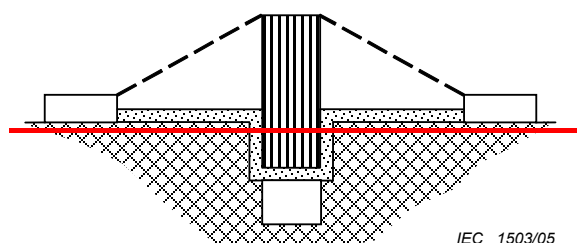
Figure E.7 – Creepage distance example 6



Condition: This creepage distance path includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage distance paths are as shown.

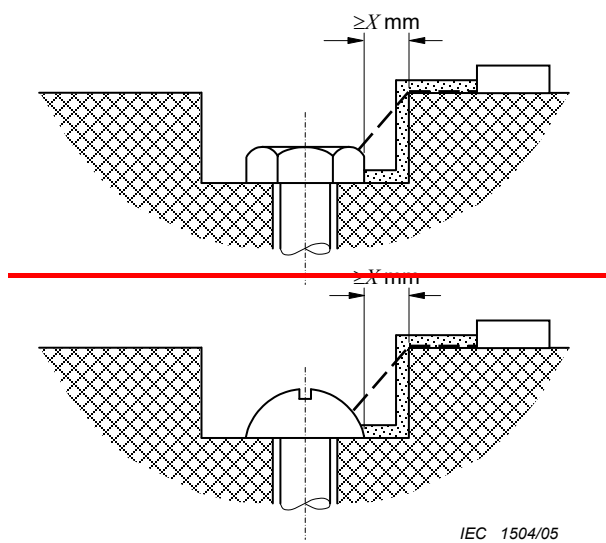
Figure E.8 – Creepage distance example 7



Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

Rule: Clearance is the shortest direct air path over the top of the barrier.

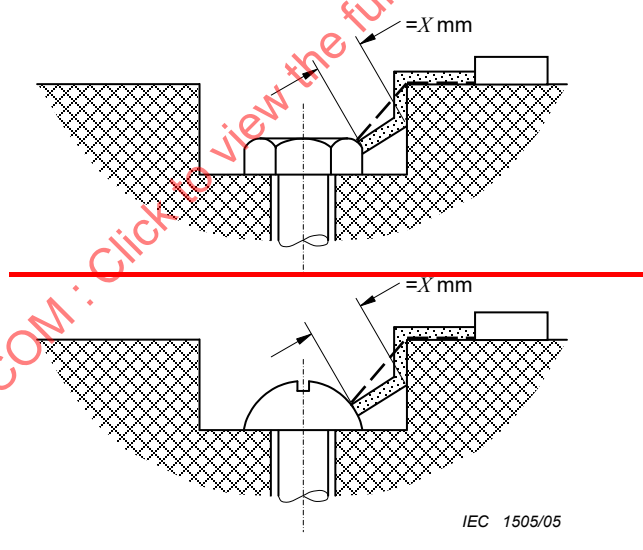
Figure E.9 – Creepage distance example 8



Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

Rule: Clearance and creepage distance paths are as shown.

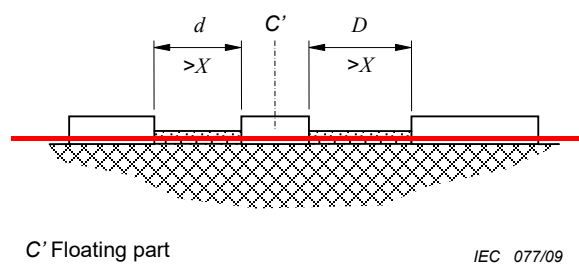
Figure E.10 – Creepage distance example 9



Condition: Gap between head of screw and wall of recess too narrow to be taken into account.

Rule: Measurement of creepage distance is from screw to wall when the distance is equal to X mm.

Figure E.11 – Creepage distance example 10



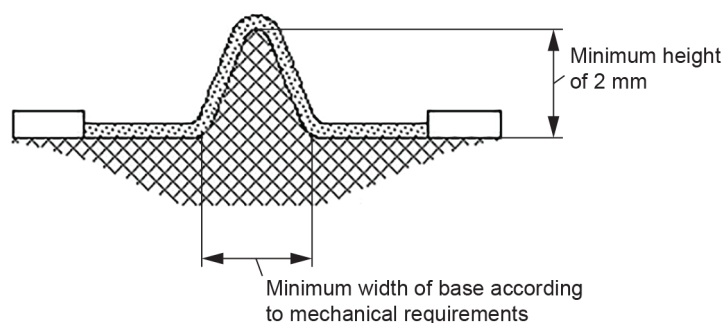
Clearance is the distance = $d + D$

Creepage distance is also = $d + D$

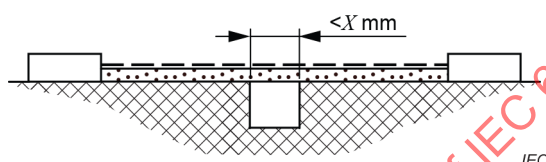
Figure E.12 — Creepage distance example 11



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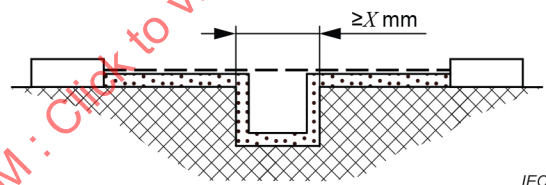


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Figure E.1 – Measurement of ribs

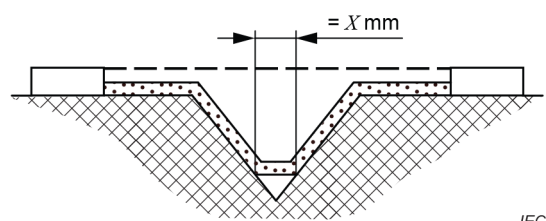
IEC

Condition: This creepage distance path includes a parallel- or converging-sided groove of any depth with a width less than X mm. Rule: Creepage distance and clearance are measured directly across the groove as shown.

Figure E.2 – Creepage distance example 1

IEC

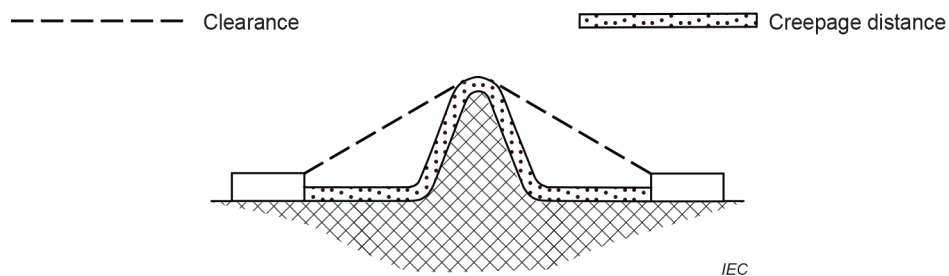
Condition: This creepage distance path includes a parallel-sided groove of any depth and a width equal to or more than X mm. Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the groove.

Figure E.3 – Creepage distance example 2

IEC

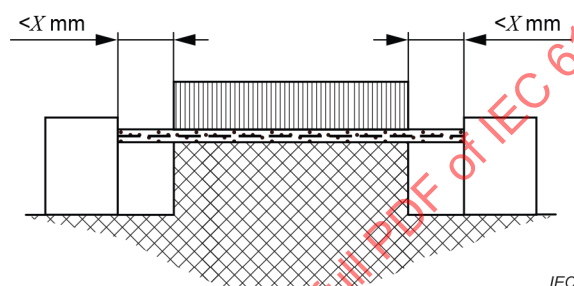
Condition: This creepage distance path includes a V-shaped groove with a width greater than X mm. Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

Figure E.4 – Creepage distance example 3



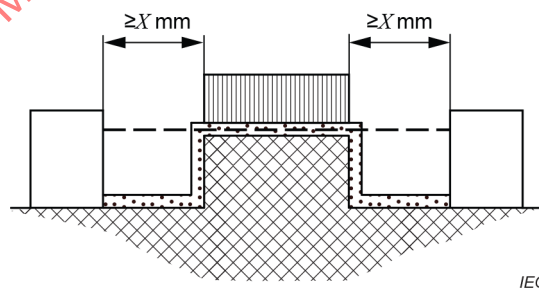
Condition: This creepage distance path includes a rib. Rule: Clearance is the shortest air path over the top of the rib. Creepage path follows the contour of the rib.

Figure E.5 – Creepage distance example 4



Condition: This creepage distance path includes an uncemented joint with grooves less than X mm wide on each side. Rule: Creepage distance and clearance path is the "line-of-sight" distance shown.

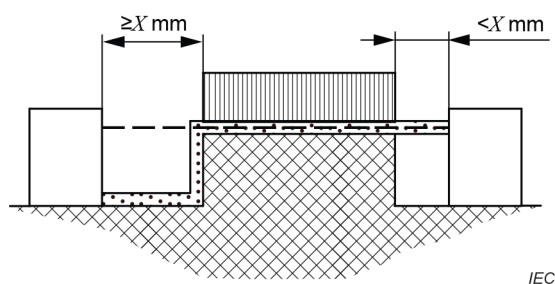
Figure E.6 – Creepage distance example 5



Condition: This creepage distance path includes an uncemented joint with grooves equal to or more than X mm wide on each side. Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the grooves.

Figure E.7 – Creepage distance example 6



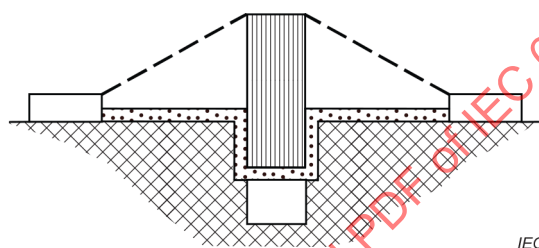


Condition: This creepage distance path includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule:

Clearance and creepage distance paths are as shown.

Figure E.8 – distance example 7

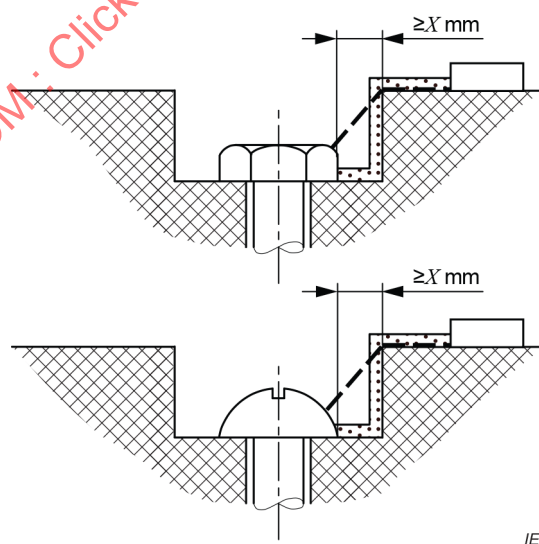


Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

Rule:

Clearance is the shortest direct air path over the top of the barrier.

Figure E.9 – Creepage distance example 8



Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

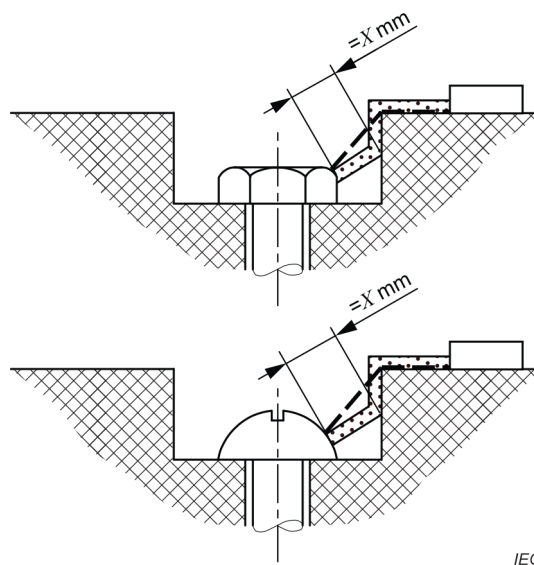
Rule:

Clearance and creepage distance paths are as shown.

Figure E.10 – Creepage distance example 9

— — — — — Clearance

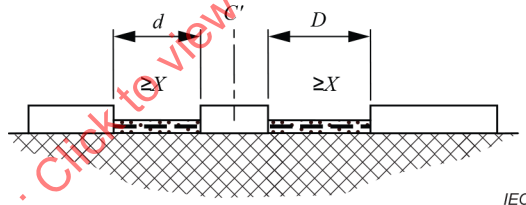
..... Creepage distance



Condition: Gap between head of screw and wall of recess too narrow to be taken into account.

Rule: Measurement of creepage distance is from screw to wall when the distance is equal to X mm.

Figure E.11 – Creepage distance example 10



Clearance is the distance = $d + D$

Creepage distance is also = $d + D$

Figure E.12 – Creepage distance example 11

----- Clearance

..... Creepage distance

Annex F (normative)

Correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of a contactor

This annex is intended to give the necessary information concerning the choice of a contactor for use in a circuit within an electrical system or part thereof.

Table F.1 provides examples of the correlation between supply system voltages and the corresponding rated impulse withstand voltage of a contactor.

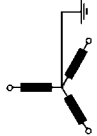
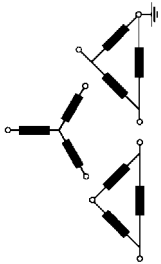
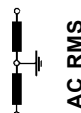
The values of rated impulse withstand voltage given in Table F.1 are based on the performance characteristics of surge arresters.

It should also be recognized that control of overvoltages with respect to the values in Table F.1 can also be achieved by conditions in the supply system such as the existence of a suitable impedance or cable feed.

In such cases where the control of overvoltages is achieved by means other than surge arresters, guidance for the correlation between the nominal supply system voltage and the equipment rated impulse withstand voltage is given in IEC 60364-4-44.

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Table F.1 – Correspondence between the nominal voltage of the supply system and the contactor rated impulse withstand voltage, in case of overvoltage protection by surge-arresters according to IEC 60099-1^a

Maximum value of rated operational voltage to earth AC RMS or DC V	Nominal voltage of the supply system (≤ rated insulation voltage of the equipment)				Preferred values of rated impulse withstand voltage (1,2/50 µs) at 2 000 m kV			
	 AC RMS V	 AC RMS V	 AC RMS or CD V	 AC RMS or DC V	IV Origin of installation (service entrance) level	III Distribution circuit level	II Load (appliance, equipment) level	I Specially protected level
50	–	–	12,5, 24, 25 30, 42, 48	60-30	1,5	0,8	0,5	0,33
100	66/115	66	60	–	2,5	1,5	0,8	0,5
150	120/208 127/220	115, 120 127	110, 120	220-110, 240-120	4	2,5	1,5	0,8
300	220/380, 230/400 240/415, 260/440 277/480	220, 230 240, 260 277	220	440-220	6	4	2,5	1,5

^a This publication was withdrawn.

Annex G (normative)

Hot wire ignition test

G.1 Five samples of each material shall be tested. The samples shall be 150 mm long by 13 mm wide and of uniform thickness representing the thinnest section of the part.

Edges shall be free from burrs, fins, etc.

G.2 A 250 mm $\pm$ 5 mm length of nichrome wire (80 % nickel, 20 % chromium, iron free) approximately 0,5 mm diameter and having a cold resistance of approximately 5,28 Ω /m shall be used. The wire shall be connected in a straight length to a variable source of power which is adjusted to cause a power dissipation of 0,26 W/mm in the wire for a period of 8 s to 12 s. After cooling, the wire shall be wrapped around a sample to form five complete turns spaced 6 mm apart.

G.3 The wrapped sample shall be supported in a horizontal position and the ends of the wire connected to the variable power source which is again adjusted to dissipate 0,26 W/mm in the wire (see Figure G.1).

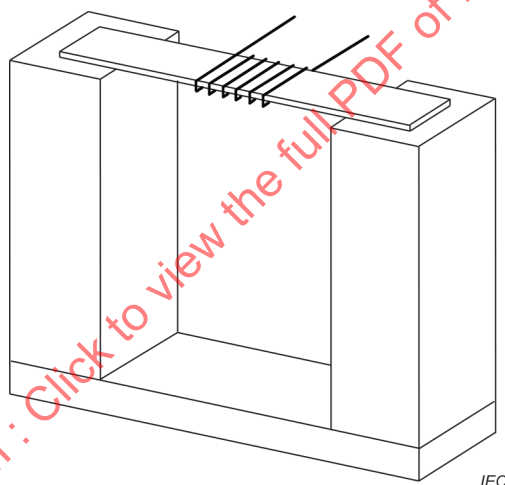


Figure G.1 – Test fixture for hot wire ignition test

G.4 Start the test by energizing the circuit so that a current is passed through the heater wire yielding a linear power density of 0,26 W/mm.

G.5 Continue heating until the test specimen ignites. When ignition occurs, shut off power and record time to ignite. Discontinue the test if ignition does not occur within 120 s.

For specimens that melt through the wire without ignition, discontinue the test when the specimen is no longer in intimate contact with all five turns of the heater wire.

G.6 The test shall be repeated on the remaining samples.

G.7 The hot wire ignition time of the material shall be recorded as the average ignition time of the specimens tested.

Annex H (normative)

Degrees of protection of enclosed contactor

H.0 Guide to the use of Annex H

Where an IP code is stated by the manufacturer for a contactor with integral enclosure or for an enclosed contactor, the requirements of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013 apply with the following.

NOTE ~~Figure H.1 gives further information to facilitate the understanding of the IP code covered by IEC 60529.~~ To understand the IP code, graphical representation of IP ratings can be seen on IEC website at: <https://www.iec.ch/ip-ratings>.

Clauses and subclauses of IEC 60529 applicable to a contactor with integral enclosure and to an enclosed contactor are explicitly detailed in this annex.

Clause and subclause numbers of this annex are sometimes discontinuous because they correspond to those of IEC 60529.

H.1 Scope and object

This annex applies to the degrees of protection of a contactor with integral enclosure and of an enclosed contactor at rated voltages not exceeding 440 V AC hereafter referred to as "device".

Clause 1 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999 apply with the additional requirements of this annex.

H.3 Terms and definitions

Clause 3 of IEC 60529:1989 applies except that "enclosure" (3.1) is replaced by the following, Note 1 and Note 2 remaining as they are.

"A part providing a specified degree of protection of device against certain external influences and a specified degree of protection against approach to or contact with live parts and moving parts."

[IEC 60050-441:1984, 441-13-01, modified — The definition was slightly modified.]

NOTE This definition given in 3.1.16 of this document is similar to IEC 60050-441:1984, 441-13-01 which applies to assemblies.

H.4 Designation

Clause 4 of IEC 60529:1989 applies except for letters H, M, S and W.

H.5 Degrees of protection against access to hazardous parts and against ingress of solid foreign objects indicated by the first characteristic numeral

Clause 5 of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013 apply.

H.6 Degrees of protection against ingress of water indicated by the second characteristic numeral

Clause 6 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 apply.

H.7 Degrees of protection against access to hazardous parts indicated by the additional letter

Clause 7 of IEC 60529:1989 applies.

H.8 Supplementary letters

Clause 8 of IEC 60529:1989 applies except for letters H, M and S.

H.9 Examples of designations with IP Code

Clause 9 of IEC 60529:1989 applies.

H.10 Marking

Clause 10 of IEC 60529:1989 applies with the following addition.

If the IP Code is designated for one mounting position only, it shall be indicated by the symbol of ISO 7000-0623 (2014-06) placed next to the IP Code specifying this position of the device, e.g. vertical:



H.11 General requirements for tests

H.11.1 Subclause 11.1 of IEC 60529:1989 applies

H.11.2 Subclause 11.2 of IEC 60529:1989 applies with the following additions

All tests are made in the unenergized state.

Certain devices (e.g. exposed faces of push-buttons) can be verified by inspection.

The temperature of the test sample shall not deviate from the actual ambient temperature by more than 5 K.

Where device is mounted in an empty enclosure which already has an IP Code (see 11.5 of IEC 60529:1989) the following requirements apply.

a) For IP1X to IP4X and additional letters A to D.

This shall be verified by inspection and compliance with the enclosure manufacturer's instructions.

b) For IP6X dust test.

This shall be verified by inspection and compliance with the enclosure manufacturer's instructions.

c) For IP5X dust test and IPX1 to IPX8 water tests.

Testing of the enclosed device is only required where the ingress of dust or water ~~may~~ can impair the operation of the device.

NOTE IP5X dust and IPX1 to IPX8 water tests allow the ingress of a certain amount of dust and water provided that there are no harmful effects. Every internal device configuration should, therefore, be separately considered.

H.11.3 Subclause 11.3 of IEC 60529:1989 applies with the following addition

Drain and ventilating holes are treated as normal openings.

H.11.4 Subclause 11.4 of IEC 60529:1989 applies

H.11.5 Where an empty enclosure is used as a component of an enclosed device, 11.5 of IEC 60529:1989 applies

H.12 Tests for protection against access to hazardous parts indicated by the first characteristic numeral

Clause 12 of IEC 60529:1989 applies except for 12.3.2.

H.13 Tests for protection against ingress of solid foreign objects indicated by the first characteristic numeral

Clause 13 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999 apply except for:

H.13.4 Dust test for first characteristic numerals 5 and 6

The following text to be added:

Enclosed device having a degree of protection IP5X shall be tested according to category 2 of 13.4 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999.

Enclosed device having a degree of protection IP6X shall be tested according to category 1 of 13.4 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999.

NOTE For enclosed device according to this document, a degree of protection IP5X is generally deemed satisfactory.

H.13.5.2 Acceptance conditions for first characteristic numeral 5

The following text to be added:

Where dust deposits could raise doubts as to the correct functioning and safety of device, a preconditioning and a dielectric test shall be conducted as follows:

The preconditioning, after the dust test, shall be verified by test Cab: damp heat, steady state, according to IEC 60068-2-78, under the following test conditions.

The device shall be prepared so that the dust deposits are subject to the test by leaving open the lid and/or removing parts, where possible without the aid of tool.

Before being placed in the test chamber the device shall be stored at room temperature for at least 4 h before the test.

The test duration shall be 24 consecutive hours.

After this period, the device is to be removed from the test chamber within 15 min and submitted to a power-frequency dielectric test for 1 min, the value being $2 U_e$ max with a minimum of 1 000 V. The application of the test voltage and the acceptance criteria shall be as specified in 9.3.3.4, item b) 3) and item b) 4).

H.14 Tests for protection against water indicated by the second characteristic numeral

H.14.1 Subclause 14.1 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 apply

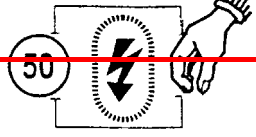
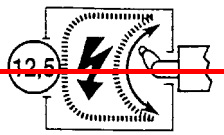
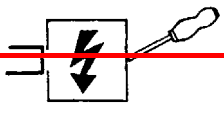
H.14.2 Subclause 14.2 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 apply

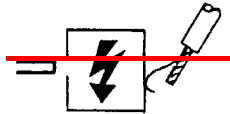
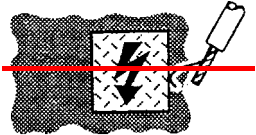
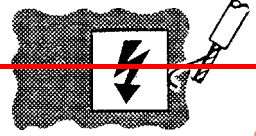
H.14.3 Subclause 14.3 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 apply with the following addition

The device is then submitted to a power-frequency dielectric test for 1 min, the value being $2 U_e$ max. with a minimum of 1 000 V. The application of the test voltage and the acceptance criteria shall be as specified in 9.3.3.4.1, item b) 3) and item b) 4).

H.15 Tests for protection against access to hazardous parts indicated by the additional letter

Clause 15 of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013 apply.

H.1a – FIRST NUMERAL			
Protection against ingress of solid objects			Protection of persons against access to hazardous parts with:
IP	Requirements	Examples	
0	No protection		Non-protected
4	Full penetration of 50 mm diameter sphere not allowed. Contact with hazardous parts not permitted		Back of hand
2	Full penetration of 12,5 mm diameter sphere not allowed. The jointed test finger shall have adequate clearance from hazardous parts		Finger
3	The access probe of 2,5 mm diameter shall not penetrate		Tool

4	The access probe of 1,0 mm diameter shall not penetrate		Wire
5	Limited ingress of dust permitted (no harmful deposit)		Wire
6	Totally protected against ingress of dust		Wire

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Figure H.1 — IP Codes

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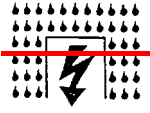
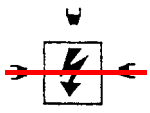
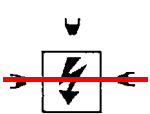
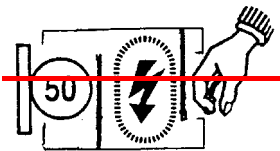
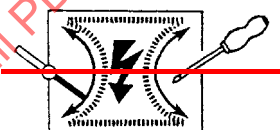
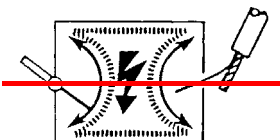
H.1b—SECOND NUMERAL			
Protection against harmful ingress of water			Protection from water
IP	Prescriptions	Examples	
0	No protection		Non-protected
1	Protected against vertically falling drops of water. Limited ingress permitted		Vertically dripping
2	Protected against vertically falling drops of water with enclosure tilted 15° from the vertical. Limited ingress permitted		Dripping up to 15° from the vertical
3	Protected against sprays to 60° from the vertical. Limited ingress permitted		Limited spraying
4	Protected against water splashed from all directions. Limited ingress permitted		Splashing from all directions
5	Protected against jets of water. Limited ingress permitted		Hosing jets from all directions
6	Protected against strong jets of water. Limited ingress permitted		Strong hosing jets from all directions
7	Protected against the effects of immersion between 15 cm and 1 m		Temporary immersion
8	Protected against long periods of immersion under pressure		Continuous immersion

Figure H.1 (continued)

H.1c – ADDITIONAL LETTER (optional)			
IP	Requirements	Examples	Protection of persons against access to hazardous parts with :
A For use with first numeral 0	Penetration of 50 mm diameter sphere up to barrier must not contact hazardous parts		Back of hand
B For use with first numerals 0 and 1	Test finger penetration to a maximum of 80 mm must not contact hazardous parts		Finger
C For use with first numerals 1 and 2	Wire of 2,5 mm diameter × 100 mm long must not contact hazardous parts when spherical stop face is partially entered		Tool
D For use with first numerals 2 and 3	Wire of 1,0 mm diameter × 100 mm long must not contact hazardous parts when spherical stop face is partially entered		Wire

IEC 081/09

Figure H.1 (continued)

Annex I (normative)

Requirements and tests for equipment with protective separation

I.1 General

This annex applies to a device one or more circuits of which being able to be used in SELV (PELV) circuit (the device by itself ~~may not~~ cannot be Class III, see 7.5 of IEC 61140:20012016).

The purpose of this annex is to harmonize as far as practicable all rules and requirements applicable to low voltage switchgear and controlgear having a protective separation between parts intended to be used in SELV (PELV) circuits and others, in order to obtain uniformity of requirements and tests and to avoid the need for testing to different standards.

I.2 Terms and definitions

I.2.1

functional insulation

insulation between conductive parts which is necessary only for the proper functioning of the equipment

I.2.2

basic insulation

insulation of hazardous live parts which provides basic protection against electric shock

Note 1 to entry: The term basic insulation does not apply to insulation used exclusively for functional purposes. (See I.2.1)

I.2.3

supplementary insulation

independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation

I.2.4

double insulation

insulation comprising both basic insulation and supplementary insulation

I.2.5

reinforced insulation

insulation of hazardous live parts which provides a degree of protection against electric shock equivalent to double insulation

Note 1 to entry: Reinforced insulation ~~may~~ can comprise several layers which cannot be tested singly as basic or supplementary insulation.

I.2.6

protective separation

<electrically> separation of one electric circuit from another by means of:

- double insulation, or
- basic insulation and electrically protective screening, or
- reinforced insulation

[SOURCE: IEC 60050-195:2021, 195-06-19, modified — Replacement of “basic protection and fault protection” with “double insulation, or basic insulation and electrically protective screening, or reinforced insulation”.]

I.2.7**SELV circuit**

electrical circuit in which the voltage cannot exceed ELV:

- under normal conditions, and
- under single-fault conditions, including earth faults in other circuits

Note 1 to entry: Definition adapted from the definition of SELV system given in 3.26.1 of IEC 61140:2004/2016.

I.2.8**PELV circuit**

electrical circuit in which the voltage cannot exceed ELV:

- under normal conditions, and
- under single-fault conditions, except earth faults in other circuits

Note 1 to entry: Definition adapted from the definition of PELV system given in 3.26.2 of IEC 61140:2004/2016.

I.2.9**limitation of steady-state touch current and charge**

protection against electric shock by circuit or equipment design such that under normal and fault conditions the steady-state touch current and charge are limited to non-hazardous levels

I.2.10**protective impedance device**

component or assembly of components the impedance and construction of which are such as to ensure that steady-state touch current and charge are limited to non-hazardous levels

I.3 Requirements**I.3.1 General**

The only method considered in this document to achieve the protective separation is based on double (or reinforced) insulation between SELV (PELV) circuit(s) and other circuits. If any component is connected between the separated circuits, that component shall comply with the requirements for protective impedance devices according to 5.3.4 of IEC 61140:2004/2016 (see Figure I.1).

The effects of electrical arcs normally produced in the breaking chambers of switchgears and controlgears on insulation are deemed to be taken into account in the dimensioning of creepage distances and no specific verification is required.

Partial discharge effects are not taken into consideration.

I.3.2 Dielectric requirements**I.3.2.1 Creepages**

It shall be verified that the creepage distances between SELV (PELV) circuit and other circuits are equal or higher than twice those given for basic insulation in Table 18 and corresponding to the voltage of the circuit having the highest rated voltage value.

NOTE This requirement follows the principles given in IEC 60664-1.

The creepage distances shall be verified in accordance with I.4.2.1.

I.3.2.2 Clearances

The clearances between SELV (PELV) circuit and other circuits of the device shall be dimensioned to withstand the rated impulse voltage as determined in accordance with Annex F relevant to the basic insulation for the specific utilisation class but one step higher in the series value (or a value equal to 160 % of the voltage value required for the basic insulation) following the principles given in 5.2.5 of IEC 60664-1:2007. The test conditions are given in I.4.2.2.

I.3.3 Construction requirements

Construction measures should be taken regarding:

- materials employed regarding aging;
- thermal stresses or mechanical risks of failure which will impair insulation between circuits;
- risks of electrical contact between different circuits in case of accidental disconnection of wiring.

Subclause I.4.3 gives examples of constructional risks which have to be taken into consideration.

I.4 Tests

I.4.1 General

These tests are normally conducted as type tests. Where the constructional design cannot ensure without doubt that the insulation intended for protective separation cannot be impaired by the effects of product conditions, the manufacturer ~~may~~ can also conduct all or parts of these tests as routine tests.

Tests verification shall be made between the SELV (PELV) circuit and each other circuits, such as main circuit, control and auxiliary circuits.

Tests shall be done in all operating conditions of the device: open, close, trip positions.

I.4.2 Dielectric tests

I.4.2.1 Creepages verification

Conditions of measuring are those given in 9.3.3.4 and Annex E.

I.4.2.2 Clearances verification

I.4.2.2.1 Condition of the device for test

Tests shall be made on devices mounted as for service, including internal wiring and in a clean and dry condition.

I.4.2.2.2 Application of the test voltage

For each circuit of the device under test, external terminals shall be connected together.

I.4.2.2.3 Impulse test voltage

It shall be an impulse test voltage having a 1,2/50 μ s wave form as described in 9.3.3.4, the value of which being chosen as defined in I.3.2.2.

I.4.2.2.4 Test

Clearances are verified by application of the test voltage of I.4.2.2.3. The test shall be conducted for a minimum of five impulses of each polarity with an interval of at least 1 s between pulses in accordance with in 9.3.3.4.1.

Application of test voltage ~~may~~ can be avoided where clearances are equal or higher than those given in Table 17 for the determined test voltage value.

I.4.2.2.5 Results to be obtained

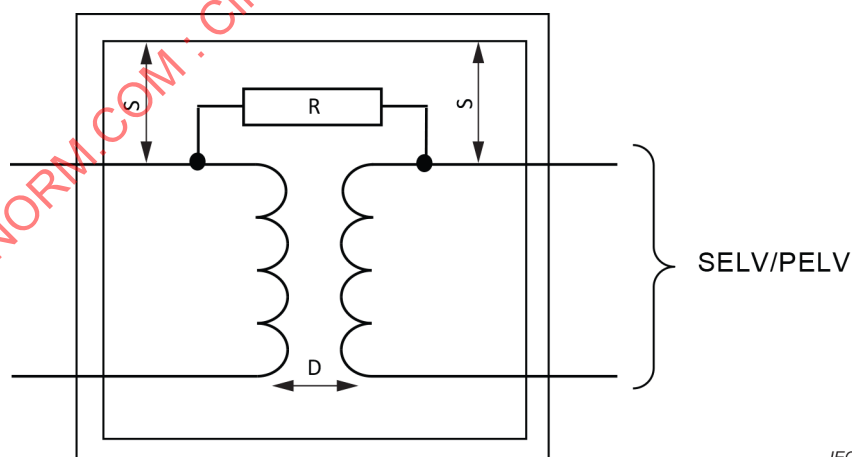
When the voltage is applied, the test is considered to have been passed if there is no puncture or flashover.

I.4.3 Examples of constructional measures

Measures should be taken that a single mechanical fault – e.g. a bent solder pin, a detached soldering point or a broken winding (coil), a loosened and fallen screw – should not have the result of impairing the insulation to such a degree that it no longer fulfils the requirements of the basic insulation; the design, however, should not consider that two or more of these events will appear simultaneously.

Examples of constructional measures:

- sufficient mechanical stability;
- mechanical barriers;
- employment of captive screws;
- impregnation or casting of components;
- inserting pins into an insulating sleeve;
- to avoid sharp-edges in the vicinity of conductors.



IEC

Key

D double (or reinforced) insulation between circuits (including SELV/PELV circuit)

R component complying with protective impedance devices requirements

S basic insulation

Figure I.1 – Example of application with component connected between separated circuits

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² This publication was withdrawn.

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INTERNATIONAL STANDARD

NORME INTERNATIONALE



Electromechanical contactors for household and similar purposes

Contacteurs électromécaniques pour usages domestiques et analogues

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ELECTROMECHANICAL CONTACTORS FOR HOUSEHOLD AND SIMILAR PURPOSES

FOREWORD

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IEC 61095 has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low voltage, in conjunction with subcommittee 23E: Circuit-breakers and similar equipment for household use, of IEC technical committee 23: Electrical accessories. It is an International Standard.

This third edition cancels and replaces the second edition published in 2009. This edition constitutes a technical revision.

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

- a) addition of requirements for screwless terminals;
- b) addition of requirements for the switching of LED lamps. Contactors for domestic and similar applications can be used for controlling lighting loads which is increasingly using LED lamp technology. A specific category for contactors is created: AC-7d. Requirements and tests

are added to cover this market development, mainly for making and breaking and conventional operational performance;

- c) addition of requirements for contactors with electronically controlled electromagnet. Household contactors with electronically controlled electromagnet are available for years on the market. To fully cover such device, requirements and tests are added, dealing mainly with operating limits, behaviour in abnormal conditions, breakdown of components, EMC tests, etc.
- d) Embedded software. More and more contactors are incorporating electronic circuits with embedded software. A reference is provided to guide the design of the software.

The text of this document is based on the following documents:

Draft	Report on voting
121A/566/FDIS	121A/573/RVD

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

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

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

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

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

This document gives requirements for contactors household and similar purposes, including contactors for distribution control in buildings.

Contactors for such purposes have particular requirements which include test sequences and sampling plans to facilitate testing.

Contactors according to this document are limited in the range of operational currents and operational voltages to values appropriate to the applications. Such contactors are for use in circuits of limited prospective short-circuit fault current for which they are co-ordinated with an appropriate short-circuit protective device to provide suitable co-ordination.

This document defines in a single document the specific utilization category for a described application and states the relevant requirements. As far as possible, it is in line with the requirements contained in IEC 60947-4-1.

This document also applies to contactors which are components of an appliance, unless otherwise stated in the standard covering the relevant appliance.

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ELECTROMECHANICAL CONTACTORS FOR HOUSEHOLD AND SIMILAR PURPOSES

1 Scope

This document applies to electromechanical air break contactors for household and similar purposes provided with main contacts intended to be connected to circuits the rated voltage of which does not exceed 440 V AC (between phases) with rated operational currents less than or equal to 63 A for utilization category AC-7a, and 32 A for utilization categories AC-7b, AC-7c and AC-7d (expressed in rated power), and rated conditional short-circuit current less than or equal to 6 kA.

NOTE Today, most LED lamp manufacturers provide information in Watt. So, the main contactor characteristic for utilization category AC-7d is expressed in Watt to be directly applicable to the corresponding LED lamp load.

Specific requirements apply to contactors equipped with screwless-type terminals.

This document does not apply to

- contactors complying with IEC 60947-4-1;
- semiconductor contactors;
- contactors designed for special applications;
- auxiliary contacts of contactors. These are dealt with in IEC 60947-5-1.

This document states

- 1) the characteristics of contactors.
- 2) the conditions with which contactors comply with reference to:
 - a) their operation and behaviour;
 - b) their dielectric properties;
 - c) the degrees of protection provided by their enclosures, where applicable;
 - d) their construction;
 - e) their electromagnetic compatibility characteristics.
- 3) the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests.
- 4) the test sequences and the number of samples.
- 5) the information to be given with contactors or in the manufacturer's literature.

2 Normative references

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

IEC 60028:1925, *International standard of resistance for copper*

IEC 60068-2-78:2012, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60073:2002, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60112:2020, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

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

IEC 60445:2021, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC 60447:2004, *Basic and safety principles for man-machine interface, marking and identification – Actuating principles*

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

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

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

IEC 60695-2-10:2021, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:2021, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end products (GWEPT)*

IEC 60695-11-10:2013, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60947-4-1:2018, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

IEC 60947-5-1:2016, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3 : Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

IEC 61000-4-34, *Electromagnetic compatibility (EMC) – Part 4-34: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current more than 16 A per phase*

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61180:2016, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

CISPR 14-1:2020, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

ISO 7000:2019, *Graphical symbols for use on equipment – Registered symbols*

ISO 2039-2:1987, *Plastics – Determination of hardness – Part 2: Rockwell hardness*

3 Terms and definitions

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

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

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

3.1 General terms

3.1.1

overcurrent

current exceeding the rated current

[SOURCE: IEC 60050-441:1984, 441-11-06]

3.1.2

short-circuit

accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal to or close to zero

[SOURCE: IEC 60050-151:2001, 151-12-04]

3.1.3

short-circuit current

overcurrent resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[SOURCE: IEC 60050-441:1984, 441-11-07]

3.1.4

overload

operating conditions in an electrically undamaged circuit, which cause an overcurrent

[SOURCE: IEC 60050-441:1984, 441-11-08]

3.1.5

overload current

overcurrent occurring in an electrically undamaged circuit

3.1.6

ambient air temperature

temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

Note 1 to entry: For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

[SOURCE: IEC 60050-441:1984, 441-11-13]

3.1.7

conductive part

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

[SOURCE: IEC 60050-441:1984, 441-11-09]

3.1.8

exposed conductive part

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

Note 1 to entry: Typical exposed conductive parts are walls of enclosures, operating handles, etc.

[SOURCE: IEC 60050-441:1984, 441-11-10]

3.1.9

electric shock

physiological effect resulting from an electric current through a human or livestock

[SOURCE: IEC 60050-826:2022, 826-12-01]

3.1.10

live part

conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-826:2022, 826-12-08, modified — Rewording of the definition and addition of a Note 1 to entry.]

3.1.11

protective conductor (identification: PE)
conductor provided for purposes of safety

EXAMPLE Protection against electric shock.

Note 1 to entry: In an electrical installation, the conductor identified PE is normally also considered as protective earthing conductor.

[SOURCE: IEC 60050-826:2022, 826-13-22, modified — Rewording of the definition, addition of a new example and a new Note 1 to entry.]

3.1.12**neutral conductor**

conductor electrically connected to the neutral point and capable of contributing to the distribution of electric energy

[SOURCE: IEC 60050-826:2021, 826-14-07]

3.1.13**PEN conductor**

conductor combining the functions of both a protective earthing conductor and a neutral conductor

[SOURCE: IEC 60050-826:2022, 826-13-25]

3.1.14**PEM conductor**

conductor combining the functions of both a protective earthing conductor and a mid-point conductor

[SOURCE: IEC 60050-826:2022, 826-13-26]

3.1.15**PEL conductor**

conductor combining the functions of both a protective earthing conductor and a line conductor

[SOURCE: IEC 60050-826:2022, 826-13-27]

3.1.16**enclosure**

part providing a specified degree of protection of equipment against certain external influences and a specified degree of protection against approach to or contact with live parts and moving parts

Note 1 to entry: This definition is similar to IEC 60050-441:1984, 441-13-01, which applies to assemblies.

[SOURCE: IEC 60050-441:1984, 441-13-01, modified — Rewording of the definition and new Note 1 to entry.]

3.1.17**integral enclosure**

enclosure which forms an integral part of the equipment

3.1.18

utilization category

<switching device or fuse> combination of specified requirements related to the condition in which the switching device or the fuse fulfils its purpose, selected to represent a characteristic group of practical applications

Note 1 to entry: The specified requirements can concern e.g. the values of making capacities (if applicable), breaking capacities and other characteristics, the associated circuits and the relevant conditions of use and behaviour.

[SOURCE: IEC 60050-441:1984, 441-17-19]

3.2 Switching devices

3.2.1

switching device

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

Note 1 to entry: A switching device can perform one or both of these operations.

[SOURCE: IEC 60050-441:1984, 441-14-01, modified — Addition of a Note 1 to entry.]

3.2.2

mechanical switching device

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

Note 1 to entry: Any mechanical switching device can be designated according to the medium in which its contacts open and close, e.g. air, SF₆, oil.

[SOURCE: IEC 60050-441:1984, 441-14-02]

3.2.3

semiconductor switching device

switching device designed to make and/or break the current in an electric circuit by means of the controlled conductivity of a semiconductor

Note 1 to entry: This definition differs from IEC 60050-441:1984, 441-14-03 since a semiconductor switching device is also designed for breaking the current.

[SOURCE: IEC 60050-441:1984, 441-14-03, modified — Addition of “and/or break” and new Note 1 to entry.]

3.2.4

fuse

device that, by the fusing of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time

Note 1 to entry: The fuse comprises all the parts that form the complete device

[SOURCE: IEC 60050-441:1984, 441-18-01]

3.2.5

circuit-breaker

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

[SOURCE: IEC 60050-441:1984, 441-14-20, modified — “Duration” replaced with “time”.]

3.2.6**mechanical contactor
contactor**

mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

Note 1 to entry: The term "operated otherwise than by hand" means that the device is intended to be controlled and kept in working position from one or more external supplies.

Note 2 to entry: A household contactor can have a handle as additional means for operation. In some countries, contactors can be controlled by a signal from the energy supplier during off-peak hours. An end user is allowed to open or close manually the contactor if necessary.

Note 3 to entry: A contactor is usually intended to operate frequently.

[SOURCE: IEC 60050-441:1984, 441-14-33, modified — Addition of Notes to entry.]

3.2.7**electromagnetic contactor**

contactor, in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by an electromagnet

Note 1 to entry: The electromagnet can be electronically controlled.

3.2.8**electronically controlled electromagnet**

electromagnet in which the coil is controlled by a circuit with active electronic elements

3.2.9**latched contactor**

contactor, the moving elements of which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized

Note 1 to entry: The latching, and the release of the latching, can be mechanical, electromagnetic, pneumatic, etc.

Note 2 to entry: Because of the latching, the latched contactor actually acquires a second position of rest and, according to 3.2.6 is not, strictly speaking, a contactor. However, since the latched contactor in both its utilization and its design is more closely related to contactors in general than to any other classification of switching device, it is considered proper to require that it complies with the specifications for contactors wherever they are appropriate.

[SOURCE: IEC 60050-441:1984, 441-14-34]

3.2.10**semiconductor contactor****solid state contactor**

device which performs the function of a contactor by utilizing a semiconductor switching device

Note 1 to entry: A semiconductor contactor can also contain mechanical switching devices.

3.2.11**pilot switch**

non-manual control switch actuated in response to specified conditions of an actuating quantity

Note 1 to entry: The actuating quantity can be pressure, temperature, velocity, liquid level, elapsed time, etc.

[SOURCE: IEC 60050-441:1984, 441-14-48]

3.2.12

push-button

control switch having an actuator intended to be operated by force exerted by a part of the human body, usually the finger or palm of the hand, and having stored energy (spring) return

[SOURCE: IEC 60050-441:1984, 441-14-53]

3.2.13

short-circuit protective device

SCPD

device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them

3.2.14

surge arrester

device designed to protect the electrical apparatus from high transient overvoltages and to limit the duration and frequently the amplitude of the follow-on current

[SOURCE: IEC 60050-614:2016, 614-03-51, modified — Addition of “to protect the electrical apparatus from high transient overvoltages and”.]

3.3 Parts of switching devices

3.3.1

pole

<switching device> portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

Note 1 to entry: A switching device is called single-pole if it has only one pole. If it has more than one pole, it can be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[SOURCE: IEC 60050-441:1984, 441-15-01]

3.3.2

main circuit

<switching device> all the conductive parts of a switching device included in the circuit which it is designed to close or open

[SOURCE: IEC 60050-441:1984, 441-15-02]

3.3.3

control circuit

<switching device> all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[SOURCE: IEC 60050-441:1984, 441-15-03]

3.3.4

auxiliary circuit

<switching device> all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit and the control circuits of the device

Note 1 to entry: Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they can be part of the control circuit of another switching device.

[SOURCE: IEC 60050-441:1984, 441-15-04]

**3.3.5
contact**

<mechanical switching device> conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[SOURCE: IEC 60050-441:1984, 441-15-05]

**3.3.6
contact
contact piece**

one of the conductive parts forming a contact

[SOURCE: IEC 60050-441:1984, 441-15-06]

**3.3.7
main contact**

contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[SOURCE: IEC 60050-441:1984, 441-15-07]

**3.3.8
auxiliary contact**

contact included in an auxiliary circuit and mechanically operated by the switching device

[SOURCE: IEC 60050-441:1984, 441-15-10]

**3.3.9
auxiliary switch**

<mechanical switching device> switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[SOURCE: IEC 60050-441:1984, 441-15-11]

**3.3.10
"a" contact
make contact**

control or auxiliary contact which is closed when the main contacts of the mechanical switching device are closed and open when they are open

[SOURCE: IEC 60050-441:1984, 441-15-12]

**3.3.11
"b" contact
break contact**

control or auxiliary contact which is open when the main contacts of the mechanical switching device are closed and closed when they are open

[SOURCE: IEC 60050-441:1984, 441-15-13]

3.3.12

release

<mechanical switching device> device, mechanically connected to a mechanical switching device, which releases the holding means and permits the opening or the closing of the switching device

Note 1 to entry: A release can have instantaneous, time-delay, etc. operation.

[SOURCE: IEC 60050-441:1984, 441-15-17]

3.3.13

actuating system

<mechanical switching device> whole of the operating means of a mechanical switching device which transmits the actuating force to the contact pieces

Note 1 to entry: The operating means of an actuating system can be mechanical, electromagnetic, hydraulic, pneumatic, thermal, etc.

3.3.14

actuator

part of the actuating system to which an external actuating force is applied

Note 1 to entry: The actuator can take the form of a handle, knob, push-button, roller, plunger, etc.

[SOURCE: IEC 60050-441:1984, 441-15-22]

3.3.15

position indicating device

part of a mechanical switching device which indicates whether it is in the open, closed, or, where appropriate, earthed position

[SOURCE: IEC 60050-441:1984, 441-15-25]

3.3.16

terminal

conductive part of a device provided for electrical connection to external circuits

3.3.17

screw-type terminal

terminal intended for the connection and disconnection of conductors or for the interconnection of two or more conductors, the connection being made, directly or indirectly, by means of screws or nuts of any kind

3.3.18

screwless-type terminal

terminal intended for the connection and disconnection of conductors or for the interconnection of two or more conductors, the connection being made, directly or indirectly, by means of springs, wedges, eccentrics or cones, etc.

3.3.19

universal terminal

terminal for the connection and disconnection of all types of conductors (solid, stranded and flexible)

[SOURCE: IEC 60998-2-2:2002, 3.101.1, modified – "(rigid and flexible)" replaced with "(solid, stranded and flexible)".]

3.3.20**non-universal terminal**

terminal for the connection and disconnection of a certain kind of conductor only (for example, solid conductors only or solid and stranded conductors only)

[SOURCE: IEC 60998-2-2:2002, 3.101.2, modified – "rigid [solid and stranded]" replaced with "solid and stranded".]

3.3.21**push-wire terminal**

non-universal terminal in which the connection is made by pushing in solid or stranded conductors

[SOURCE: IEC 60998-2-2:2002, 3.101.3, modified – "rigid (solid or stranded)" replaced with "solid or stranded".]

3.3.22**thread-forming tapping screw**

tapping screw having an uninterrupted thread

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

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

3.3.23**thread-cutting tapping screw**

tapping screw having an interrupted thread

Note 1 to entry: The thread is intended to remove material from the hole.

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

3.3.24**clamping unit**

part of a terminal necessary for the mechanical clamping and the electrical connection of the conductor(s)

3.3.25**unprepared conductor**

conductor which has been cut and the insulation of which has been removed for insertion into a terminal

Note 1 to entry: A conductor, the shape of which is arranged for introduction into a terminal or the strands of which are twisted to consolidate the end is considered to be an unprepared conductor.

3.3.26**prepared conductor**

a conductor the end of which is fitted with an attachment such as eyelet, sleeve or cable lug

[SOURCE: IEC 60050-442:1998, 442-01-27]

3.3.27

solid conductor

conductor consisting of a single wire

Note 1 to entry: The cross-section of the solid conductor can be circular or shaped.

Note 2 to entry: Solid conductor is defined as class 1 conductor in IEC 60228, or by IEC TR 60344, or equivalent AWG/kcmil.

[SOURCE: IEC 60050-461:2008, 461-01-06, modified – In Note 1 to entry, "may" changed to "can", and Note 2 to entry has been added.]

3.3.28

stranded conductor

conductor consisting of a number of wires, all or some of which are wound in a helix

Note 1 to entry: Stranded conductor is defined as class 2 conductor in IEC 60228, or by IEC TR 60344, or equivalent AWG/kcmil.

[SOURCE: IEC 60050-151:2001, 151-12-36, modified – Note 1 to entry has been added.]

3.3.29

rigid conductor

solid or stranded conductor having wires of such diameters, or so assembled, that the conductor is not suitable for use in a flexible cable.

[SOURCE: IEC 60947-1:2020, 3.5.31]

3.3.30

flexible conductor

stranded conductor having wires of diameters small enough and so assembled that the conductor is suitable for use in a flexible cable

Note 1 to entry: Flexible conductor is defined as class 5 or class 6 conductor in IEC 60228, or by IEC TR 60344, or equivalent AWG/kcmil.

[SOURCE: IEC 60050-461:2008, 461-01-11, modified – Note 1 to entry has been added.]

3.4 Operation of switching devices

3.4.1

operation

<mechanical switching device> transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a circuit-breaker, this can be a closing operation or an opening operation.

Note 2 to entry: If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[SOURCE: IEC 60050-441:1984, 441-16-01]

3.4.2

operating cycle

<mechanical switching device> succession of operations from one position to another and back to the first position through all other positions, if any

[SOURCE: IEC 60050-441:1984, 441-16-02]

3.4.3**operating sequence**

<mechanical switching device> succession of specified operations with specified time intervals

[SOURCE: IEC 60050-441:1984, 441-16-03]

3.4.4**closing operation**

<mechanical switching device> operation by which the device is brought from the open position to the closed position

[SOURCE: IEC 60050-441:1984, 441-16-08]

3.4.5**opening operation**

<mechanical switching device> operation by which the device is brought from the closed position to the open position

[SOURCE: IEC 60050-441:1984, 441-16-09]

3.4.6**closed position**

<mechanical switching device> position in which the predetermined continuity of the main circuit of the device is secured

[SOURCE: IEC 60050-441:1984, 441-16-22]

3.4.7**open position**

<mechanical switching device> position in which the predetermined dielectric withstand voltage requirements are satisfied between open contacts in the main circuit of the device

Note 1 to entry: This definition differs from IEC 60050-441:1984, 441-16-23 to meet the requirements of dielectric properties.

[SOURCE: IEC 60050-441:1984, 441-16-23, modified — Replacement of “clearance” with “dielectric withstand voltage requirements are satisfied”.]

3.4.8**position of rest**

<contactor> position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized

[SOURCE: IEC 60050-441:1984, 441-16-24]

3.4.9**inching****jogging**

energizing a motor or solenoid repeatedly for short periods to obtain small movements of the driven mechanism

3.4.10**plugging**

stopping or reversing a motor rapidly by reversing the motor primary connections while the motor is running

3.5 Characteristic quantities

3.5.1

nominal value

value of a quantity used to designate and identify a component, device, equipment, or system

Note 1 to entry: The nominal value is generally a rounded value.

[SOURCE: IEC 60050-151:2001, 151-16-09]

3.5.2

limiting value

in a specification of a component, device, equipment, or system, the greatest or smallest admissible value of a quantity

[SOURCE: IEC 60050-151:2001, 151-16-10]

3.5.3

rated value

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.5.4

rating

set of rated values and operating conditions

[SOURCE: IEC 60050-151:2001, 151-16-11]

3.5.5

prospective current

<of a circuit and with respect to a switching device or a fuse> current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

Note 1 to entry: The method to be used to evaluate and to express the prospective current is specified in the relevant publications.

[SOURCE: IEC 60050-441:1984, 441-17-01]

3.5.6

prospective peak current

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

Note 1 to entry: The definition assumes that the current is made by an ideal switching device, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, e.g. polyphase circuits, it further assumes that the current is made simultaneously in all poles, even if only the current in one pole is considered.

[SOURCE: IEC 60050-441:1984, 441-17-02]

3.5.7

maximum prospective peak current

<AC circuit> prospective peak current when initiation of the current takes place at the instant which leads to the highest possible value

Note 1 to entry: For a multipole device in a polyphase circuit, the maximum prospective peak current refers to a single pole only.

[SOURCE: IEC 60050-441:1984, 441-17-04]

3.5.8**breaking current**

<switching device or fuse> current in a pole of a switching device or in a fuse at the instant of initiation of the arc during a breaking process

Note 1 to entry: For AC the current is expressed as the symmetrical RMS value of the AC component.

[SOURCE: IEC 60050-441:1984, 441-17-07, modified — Addition of a new Note 1 to entry.]

3.5.9**breaking capacity**

<switching device or fuse> value of prospective current that a switching device or a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

Note 1 to entry: The voltage to be stated and the conditions to be prescribed are dealt with in the relevant product standard.

Note 2 to entry: For AC, the current is expressed as the symmetrical RMS value of the AC component.

Note 3 to entry: For short-circuit breaking capacity, see 3.5.11.

[SOURCE: IEC 60050-441:1984, 441-17-08, modified — Addition of Notes 2 and 3 to entry.]

3.5.10**making capacity**

<switching device> value of prospective making current that a switching device is capable of making at a stated voltage under prescribed conditions of use and behaviour

Note 1 to entry: The voltage to be stated and the conditions to be prescribed are dealt with in the relevant product standard.

Note 2 to entry: For short-circuit making capacity, see 3.5.12.

[SOURCE: IEC 60050-441:1984, 441-17-09, modified — Addition of a new Note 2 to entry.]

3.5.11**short-circuit breaking capacity**

breaking capacity for which the prescribed conditions include a short-circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:1984, 441-17-11]

3.5.12**short-circuit making capacity**

making capacity for which prescribed conditions include a short circuit at the terminals of the switching device

[SOURCE: IEC 60050-441:1984, 441-17-10]

3.5.13**joule integral** **I^2t**

integral of the square of the current over a given time interval

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

[SOURCE: IEC 60050-441:1984, 441-18-23, modified — Deletion of Notes to entry.]

3.5.14

cut-off current

let-through current

maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

Note 1 to entry: This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

[SOURCE: IEC 60050-441:1984, 441-17-12]

3.5.15

applied voltage

<switching device> voltage which exists across the terminals of a pole of a switching device just before the making of the current

Note 1 to entry: This definition applies to a single-pole device. For a multipole device, it is the phase-to-phase voltage across the supply terminals of the device.

[SOURCE: IEC 60050-441:1984, 441-17-24, modified — New Note 1 to entry.]

3.5.16

recovery voltage

voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current

Note 1 to entry: This voltage can be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power frequency voltage or the steady-state recovery voltage alone exists.

Note 2 to entry: This definition applies to a single-pole device. For a multipole device it is the phase-to-phase voltage across the supply terminals of the device.

[SOURCE: IEC 60050-441:1984, 441-17-25, modified — New Note 2 to entry.]

3.5.17

transient recovery voltage

TRV

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

Note 1 to entry: The transient voltage can be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit, the switching device or the fuse. It includes the voltage shift of the neutral of a polyphase circuit.

[SOURCE: IEC 60050-441:1984, 441-17-26, modified — Replacement in the note of “and the switching device” with the “switching device or the fuse”.]

3.5.18

power-frequency recovery voltage

recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:1984, 441-17-27]

3.5.19

DC steady-state recovery voltage

recovery voltage in a DC circuit after the transient voltage phenomena have subsided, expressed by the mean value where ripple is present

[SOURCE: IEC 60050-441:1984, 441-17-28]

3.5.20**clearance**

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

[SOURCE: IEC 60050-441:1984, 441-17-31]

3.5.21**creepage distance**

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

Note 1 to entry: A joint between two pieces of insulating material is considered part of the surface.

3.5.22**working voltage**

highest RMS value of the AC voltage or the highest value of the DC voltage which can occur (locally) across any insulation at rated supply voltage, transients being disregarded, in open circuit conditions or under normal operating conditions

3.5.23**impulse withstand voltage**

highest peak value of an impulse voltage, of prescribed form and polarity, which does not cause breakdown under specified conditions of test

3.5.24**power-frequency withstand voltage**

RMS value of a power-frequency sinusoidal voltage which does not cause breakdown under specified conditions of test

3.5.25**pollution**

any addition of foreign matter, solid, liquid or gaseous (ionized gases) that can affect dielectric strength or surface resistivity

3.5.26**pollution degree**

<environmental conditions> conventional number based on the amount of conductive or hygroscopic dust, ionized gas or salt and on the relative humidity and its frequency of occurrence, resulting in hygroscopic absorption or condensation of moisture leading to reduction in dielectric strength and/or surface resistivity

Note 1 to entry: The pollution degree of the micro-environment to which equipment is exposed can be different from that of the macro-environment where the equipment is located because of protection offered by means such as an enclosure or internal heating to prevent absorption or condensation of moisture.

Note 2 to entry: For the purposes of this document, the pollution degree is that of the micro-environment.

3.5.27**micro-environment**

<clearance or creepage distance> ambient conditions which surround the clearance or creepage distance under consideration

Note 1 to entry: The micro-environment of the creepage distance or clearance and not the environment of the equipment determines the effect on the insulation. The micro-environment can be better or worse than the environment of the equipment. It includes all factors influencing the insulation such as climatic and electromagnetic conditions, generation of pollution, etc.

3.5.28

overvoltage category

<in a circuit or within an electrical system> conventional number based on limiting (or controlling) the values of prospective transient overvoltages occurring in a circuit (or within an electrical system having different nominal voltages) and depending on the means employed to influence the overvoltages

Note 1 to entry: In an electrical system, the transition from one overvoltage category to one of a lower category is obtained through appropriate means complying with interface requirements, such as an overvoltage protective device or a series-shunt impedance arrangement capable of dissipating, absorbing, or diverting the energy in the associated surge current, to lower the transient overvoltage value to that of the desired lower overvoltage category.

3.5.29

co-ordination of insulation

correlation of insulating characteristics of electrical equipment with the expected overvoltages and the characteristics of overvoltage protective devices on the one hand, and with the expected micro-environment and the pollution protective means on the other hand

3.5.30

homogeneous field

uniform field

electric field which has an essentially constant voltage gradient between electrodes, such as that between two spheres where the radius of each sphere is greater than the distance between them

3.5.31

inhomogeneous field

non-uniform field

electric field which does not have an essentially constant voltage gradient between electrodes

3.5.32

tracking

progressive formation of conducting paths which are produced on the surface of a solid insulating material, due to the combined effects of electric stress and electrolytic contamination on that surface

3.5.33

comparative tracking index

CTI

numerical value of the maximum voltage in volts at which a material withstands 50 drops of a test solution without tracking

Note 1 to entry: The value of each test voltage and the CTI are divisible by 25.

Note 2 to entry: This definition is based on 3.5 of IEC 60112:2020.

4 Classification

Subclause 5.2 gives all data which can be used as criteria for classification.

5 Characteristics of contactors

5.1 Summary of characteristics

The characteristics shall be stated in the following terms, where such terms are applicable:

- type of contactor (see 5.2);
- rated and limiting values for main circuits (see 5.3);
- utilization category (see 5.4);

- control circuits (see 5.5);
- auxiliary circuits (see 5.6);
- co-ordination with short-circuit protective devices (see 5.7).

5.2 Type of contactor

5.2.1 General

The following shall be stated (see also Clause 6):

5.2.2 Number of poles

5.2.3 Method of control

- automatic (by pilot switch or sequence control);
- non-automatic (e.g. by hand operation or by push-buttons);
- semi-automatic (i.e. partly automatic, partly non-automatic).

5.3 Rated and limiting values for main circuits

5.3.1 General

The rated values established for a contactor shall be stated in accordance with 5.3.2 to 5.4 and 5.7.

5.3.2 Rated voltages

5.3.2.1 General

A contactor is defined by the rated voltages given in 5.3.2.2 to 5.3.2.4.

5.3.2.2 Rated operational voltage (U_o)

A rated operational voltage of a contactor is a value which, combined with a rated operational current, determines the application of the contactor and to which the relevant tests and the utilization categories are referred.

For a single-pole contactor, the rated operational voltage is generally stated as the voltage across the pole.

For a multipole contactor, it is generally stated as the voltage between phases.

NOTE 1 A contactor can be assigned a number of combinations of rated operational voltages and rated operational currents or powers for different duties and utilization categories.

NOTE 2 A contactor can be assigned a number of rated operational voltages and associated making and breaking capacities for different duties and utilization categories.

NOTE 3 Attention is drawn to the fact that the operational voltage can differ from the working voltage (see 3.5.22) within a contactor.

5.3.2.3 Rated insulation voltage (U_i)

The rated insulation voltage of a contactor is the value of voltage to which dielectric tests voltage and creepage distances are referred.

In no case shall the maximum value of the rated operational voltage exceed that of the rated insulation voltage.

NOTE For contactors without a specified rated insulation voltage, the highest value of the rated operational voltage is considered to be the rated insulation voltage.

5.3.2.4 Rated impulse withstand voltage (U_{imp})

The peak value of an impulse voltage of prescribed form and polarity which the contactor is capable of withstanding without failure under specified conditions of test and to which the values of the clearances are referred.

The rated impulse withstand voltage of a contactor shall be equal to or higher than the values stated for the transient overvoltages occurring in the circuit in which the contactor is fitted.

NOTE Preferred values of rated impulse withstand voltage are given in Table 16.

5.3.3 Currents or powers

5.3.3.1 General

A contactor is defined by the currents given in 5.3.3.2 to 5.3.3.4.

5.3.3.2 Conventional free air thermal current (I_{th})

The conventional free air thermal current is the maximum value of test current to be used for temperature-rise tests of an unenclosed contactor in free air (see 9.3.3.3).

The value of the conventional free air thermal current shall be at least equal to the maximum value of the rated operational current (see 5.3.3.4) of the unenclosed contactor in eight-hour duty (see 5.3.5.2).

Free air is understood to be air in normal indoor conditions, reasonably free from draughts and external radiation.

NOTE 1 This current is not a rating and is not mandatorily marked on the contactor.

NOTE 2 An unenclosed contactor is a contactor supplied by the manufacturer without an enclosure or a contactor supplied by the manufacturer with an integral enclosure which is not normally intended to be the sole contactor protective enclosure. An unenclosed contactor is characterised by IP00.

5.3.3.3 Conventional enclosed thermal current (I_{the})

The conventional enclosed thermal current is the value of current stated by the manufacturer to be used for the temperature-rise tests of the contactor when mounted in a specified enclosure. Such tests shall be in accordance with 9.3.3.3 and are mandatory if the contactor is described as an enclosed contactor in the manufacturer's catalogues and normally intended for use with one or more enclosures of specified type and size (see Note 2 of 5.3.3.2).

The value of the conventional enclosed thermal current shall be at least equal to the maximum value of the rated operational current (see 5.3.3.4) of the enclosed contactor in eight-hour duty (see 5.3.5.2).

If the contactor is normally intended for use in unspecified enclosures, the test is not mandatory if the test for conventional free air thermal current (I_{th}) has been made. In this case, the manufacturer shall be prepared to give guidance on the value of the enclosed thermal current or the derating factor.

NOTE 1 This current is not a rating and is not mandatorily marked on the contactor.

NOTE 2 An enclosed contactor is a contactor normally intended for use with a specified type and size of enclosure or intended for use with more than one type of enclosure.

5.3.3.4 Rated operational currents (I_e) or rated powers

A rated operational current of a contactor is stated by the manufacturer and takes into account the rated operational voltage (see 5.3.2.2), the conventional free air or enclosed thermal current, the rated frequency (see 5.3.4), the rated duty (see 5.3.5), the utilization category (see 5.4) and the type of protective enclosure, if any.

In the case of a contactor for the direct switching of individual motors or LED lamps, the indication of a rated operational current can be replaced or supplemented by an indication of the maximum rated power, at the rated operational voltage considered, of the load for which the contactor is intended. The manufacturer shall be prepared to state the relationship assumed between the operational current and the power.

5.3.4 Rated frequency

The supply frequency for which a contactor is designed and to which the other characteristic values correspond.

NOTE The same contactor can be assigned a number or a range of rated frequencies.

5.3.5 Rated duties

5.3.5.1 General

The rated duties considered as normal are given in 5.3.5.2 to 5.3.5.5.

5.3.5.2 Eight-hour duty (continuous duty)

A duty in which the main contacts of a contactor remain closed while carrying a steady current long enough for the contactor to reach thermal equilibrium but not for more than eight hours without interruption.

NOTE 1 This is the basic duty on which the conventional thermal currents I_{th} and I_{the} of the contactor are determined.

NOTE 2 Interruption means breaking the current by operating the contactor.

5.3.5.3 Intermittent periodic duty or intermittent duty

A duty with on-load periods, during which the main contacts of a contactor remain closed, having a definite relation to off-load periods, both periods being too short to allow the contactor to reach thermal equilibrium.

Intermittent duty is characterized by the value of the current, the duration of the current flow and by the on-load factor which is the ratio of the in-service period to the entire period, often expressed as a percentage.

According to the number of operating cycles which they are capable of carrying out per hour, contactors are divided into the following preferred classes:

– class	1:	1	operating cycle per hour;
– class	3:	3	operating cycles per hour;
– class	12:	12	operating cycles per hour;
– class	30:	30	operating cycles per hour;
– class	120:	120	operating cycles per hour;
– class	300:	300	operating cycles per hour;
– class	1 200:	1 200	operating cycles per hour.

A contactor intended for intermittent duty can be designated by the characteristics of intermittent duty.

EXAMPLE An intermittent duty comprising a current flow of 32 A for 2 min within every 5 min can be stated as: 32 A, class 12, 40 %.

5.3.5.4 Temporary duty

Duty in which the main contacts of a contactor remain closed for periods insufficient to allow the contactor to reach thermal equilibrium, the on-load periods being separated by off-load periods of sufficient duration to restore equality of temperature with the cooling medium.

5.3.5.5 Periodic duty

A type of duty in which operation, whether at constant or variable load, is regularly repeated.

5.3.6 Normal load and overload characteristics

5.3.6.1 General

This subclause gives general requirements concerning ratings under normal load and overload conditions.

Detailed requirements are given in 8.2.4.

5.3.6.2 Ability to withstand motor switching overload currents

A contactor intended for switching motors shall be capable of withstanding the thermal stresses due to starting and accelerating a motor to normal speed and due to operating overloads.

Requirements to meet these conditions are given in 8.2.4.4.

5.3.6.3 Rated making capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.2. The rated making and breaking capacities are only valid when the contactor is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.6.4 Rated breaking capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.2. The rated making and breaking capacities are only valid when the contactor is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.6.5 Conventional operational performance

Specified as a series of making and breaking operations in 8.2.4.3.

5.3.7 Rated conditional short-circuit current

The rated conditional short-circuit current of a contactor is the value of prospective current stated by the manufacturer, that the contactor, protected by a short-circuit protective device specified by the manufacturer, can withstand satisfactorily for the operating time of this device under the test conditions specified in 9.3.4.

The details of the specified short-circuit protective device shall be stated by the manufacturer.

NOTE The rated conditional short-circuit current is expressed by the RMS value of the AC component.

5.4 Utilization category

5.4.1 General

The utilization category of a contactor defines the intended application and is characterized by one or more of the following service conditions:

- current(s), expressed as multiple(s) of the rated operational current;
- voltage(s), expressed as multiple(s) of the rated operational voltage;
- power-factor.

The standard utilization categories are given in Table 1.

Each utilization category is characterized by the values of the currents, voltages, power-factors and other data of Table 7 and Table 9 and by the test conditions specified in this document.

It is therefore unnecessary to specify separately the rated making and breaking capacities as these values depend directly on the utilization category as shown in Table 7.

Unless otherwise stated, contactors of utilization category AC-7b are designed on the basis of the starting characteristics of the motors compatible with the making capacities of Table 7. When the starting current of a motor, with stalled rotor, exceeds these values, the operational current should be decreased accordingly.

5.4.2 Assignment of utilization categories based on the results of tests

A contactor which has been tested for one utilization category or at any combination of parameters (such as highest operational voltage and current, etc.) can be assigned another utilization category without testing provided that the test currents, voltages, power-factors, number of operating cycles, ON and OFF times given in Table 7 and Table 9 and the test circuit for the assigned utilization category are not more severe than those at which the contactor has been tested and the temperature-rise has been verified at a current not less than the highest assigned rated operational current in continuous duty.

Table 1 – Utilization categories

Utilization categories ^a	Typical loads
AC-7a	Slightly inductive
AC-7b	Motor ^b
AC-7c	Switching of compensated electric discharge lamp control ^c
AC-7d	LED lamp
^a Contactors can have other utilization categories, in which case they shall comply with the requirements of IEC 60947-4-1 for such categories. ^b The AC-7b category can be used for occasional inching (jogging) or plugging for limited time periods; during such limited time periods the number of operations should not exceed 5/min or more than 10 in a 10-minute period. ^c This category is similar to a capacitive switching category AC-6b as defined in IEC 60947-4-1 for the switching of capacitor banks, the characteristic being very dependent on the capacitance value of the lamp circuit.	

5.5 Control circuits

The characteristics of control circuits are:

- kind of current;
- rated frequency;
- rated control circuit voltage U_c (nature and frequency);
- rated control supply voltage U_s (nature and frequency), where applicable;
- suitability to be connected to SELV circuits.

NOTE A distinction has been made above between the control circuit voltage, which would appear across the "a" contacts (see 3.3.10) in the control circuit, and the control supply voltage, which is the voltage applied to the input terminals of the control circuit of the contactor and which can be different from the control circuit voltage owing to the presence of built-in transformers, rectifiers, resistors, etc.

The rated control circuit voltage and rated frequency, if any, are the values on which the operating and temperature-rise characteristics of the control circuit are based.

5.6 Auxiliary circuits

The characteristics of auxiliary circuits are the number and kind of contacts ("a" contact, "b" contact, etc.) in each of these circuits and their ratings according to IEC 60947-5-1.

The characteristics of auxiliary contacts and switches shall comply with the requirements of IEC 60947-5-1.

5.7 Co-ordination with short-circuit protective devices

Contactors are characterized by the type, ratings and characteristics of the short-circuit protective devices (SCPD) to be used to provide adequate protection of the contactor against short-circuit currents. Requirements are given in 8.2.5.

6 Product information

6.1 Nature of information

6.1.1 General

The information given in 6.1.2 to 6.1.3 shall be given by the manufacturer.

6.1.2 Identification

- a) the manufacturer's name or trade mark;
- b) type designation or serial number;
- c) number of this document.

6.1.3 Characteristics, basic rated values and utilization

- d) rated operational voltages (see 5.3.2.2);
- e) utilization category and rated operational currents (or rated powers), at the rated operational voltage (see 5.3.3.4 and 5.4);
- f) value of the rated frequency/frequencies, e.g.: 50 Hz or 50 Hz/60 Hz;
- g) rated duty with indication of the class of intermittent duty, if any (see 5.3.5).

Associated values:

- h) rated making and breaking capacities. These indications can be replaced, where applicable, by the indication of the utilization category (see Table 7);

Safety and installation:

- i) rated insulation voltage (see 5.3.2.3);
- j) rated impulse withstand voltage (see 5.3.2.4), the marking of U_{imp} is not required if equal to 4 kV;
- k) IP code, in case of an enclosed contactor (see 8.1.11);
- l) pollution degree (see 7.1.4.2);
- m) rated conditional short-circuit current (see 5.3.7) and the type, current rating and characteristics of the associated SCPD;
- n) For non-universal screwless terminals:
 - "s" or "sol" for terminals declared for solid conductors;
 - "r" for terminals declared for solid and stranded conductors;
 - "f" for terminals declared for flexible conductors.

Control circuits (see 5.5):

The following information concerning control circuits shall be placed either on the coil or on the contactor:

- o) rated control circuit voltage (U_c), nature of current and rated frequency;
- p) if necessary, nature of current, rated frequency and rated control supply voltage (U_s);

For contactors, the control circuit of which is intended to be connected to a SELV supply:

- q) suitability of the control circuit to be connected to a SELV supply, the main circuit being supplied with a voltage having a value greater than that of the SELV circuit.
- r) In case the control circuit is supplied by another means than the main power supply (e.g., control circuit connected to a SELV supply), additional characteristics or the reference type should be provided for selection criteria of the power supply unit.

Auxiliary circuits:

- s) ratings of auxiliary circuits (see 5.6).

6.2 Marking

Markings shall be indelible and easily legible.

Marking of the manufacturer's name or trademark and type designation or serial number is mandatory on the contactor, preferably on the nameplate if any, to enable complete data to be obtained from the manufacturer.

NOTE 1 In the USA and Canada, the rated operational voltage U_e can be marked as follows:

- a) on equipment for use on three-phase – four-wire systems, by both the value of phase-to-earth voltage and that of phase-to-phase voltage, e.g. 277/480 V;
- b) on equipment for use on three-phase – three-wire systems, by the value of phase-to-phase voltage, e.g. 480 V.

The following information shall be marked and visible after mounting:

- direction of movement of the actuator (see 8.1.5.3), if applicable;
- indication of the position of the actuator (see also 8.1.6.1 and 8.1.6.2);

The following information shall be marked and visible after wiring, before installation of covers or lids:

- for miniaturized contactors, symbol, colour code or letter code;
- terminal identification and marking (see 8.1.7.4);
- IP code and class of protection against electric shock, when applicable (marked preferably on the contactor as far as possible).

Markings shall not be placed on screws, removable washers or other removable parts.

Data under k) shall be indicated on the enclosure, if any.

Data under c) shall be marked on the product.

Data under n), if relevant, shall be indicated on the nameplate, or marked on the contactor or, if the space available is not sufficient, on the smallest package unit or in technical information provided with the product or in the manufacturer's published literature. In the case of a group of terminals located together, a single marking on the device is acceptable. An appropriate marking indicating the length of insulation to be removed before insertion of the conductor into the terminal shall be shown on the contactor.

Data under d) to j), l), m) and o) to s) shall be included on the nameplate, or on the contactor, or in the manufacturer's published literature.

The manufacturer's published literature can be provided digitally for example using an electronically readable identifier on the equipment or its packaging (see IEC 63365).

The marking of terminals shall be in accordance with Annex A of this document.

NOTE 2 Additional utilization categories according to IEC 60947-4-1 can also be marked (see footnote a to Table 1).

6.3 Instructions for installation, operation and maintenance

The contactor shall be installed in accordance with all specifications given in 6.1, considering its intended use.

Information shall be provided if the control circuit is to be protected by a short circuit protective device.

Maintenance is unusual for contactors intended for household applications.

7 Normal service, mounting and transport conditions

7.1 Normal service conditions

7.1.1 General

Contactors complying with this document shall be capable of operating under the following standard conditions.

7.1.2 Ambient air temperature

The ambient air temperature does not exceed +40 °C and its average over a period of 24 h does not exceed +35 °C.

The lower limit of the ambient air temperature is –5 °C.

Ambient air temperature is that existing in the vicinity of the contactor if supplied without enclosure, or in the vicinity of the enclosure if supplied with an enclosure.

Contactors intended to be used in ambient air temperatures above +40 °C (particularly in tropical countries) or below –5 °C shall either be specially designed or be used according to the information given in the manufacturer's catalogue.

7.1.3 Altitude

The altitude of the site of installation does not exceed 2 000 m.

For installations at higher altitudes than 2000 m, instruction shall be provided in the contactor documentation.

7.1.4 Atmospheric conditions

7.1.4.1 Humidity

The relative humidity of the air does not exceed 50 % at a maximum temperature of +40 °C. Higher relative humidity can be permitted at lower temperatures, e.g. 90 % at +20 °C.

NOTE The pollution degrees given in 7.1.4.2 define the environmental conditions more precisely.

7.1.4.2 Pollution degree

The pollution degree (see 3.5.26) refers to the environmental conditions for which the contactor is intended.

NOTE The micro-environment of the creepage distance or clearance and not the environment of the contactor determines the effect on the insulation. The micro-environment can be better or worse than the environment of the contactor. It includes all the factors influencing the insulation, such as climatic and electromagnetic conditions, generation of pollution, etc.

For contactors intended for use within an enclosure or provided with an integral enclosure, the pollution degree of the environment in the enclosure is applicable.

For the purposes of evaluating clearances and creepage distances, the following four degrees of pollution of the micro-environment are established (the clearances and creepage distances being according to the different pollution degrees given in Table 17 and Table 18)

Pollution degree 1:

No pollution or only dry, non-conductive pollution occurs.

Pollution degree 2:

Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation can be expected.

Pollution degree 3:

Conductive pollution occurs, or dry, non-conductive pollution occurs which becomes conductive due to condensation.

Pollution degree 4:

The pollution generates persistent conductivity caused, for instance, by conductive dust or by rain or snow.

Standard pollution degree of household and similar applications:

Contactors for household and similar applications are generally for use in a pollution degree 2 environment.

7.1.5 Normal electromagnetic environmental conditions

The normal electromagnetic environmental conditions are those which relate to low-voltage public networks such as residential, commercial and light industrial locations/installations.

7.2 Conditions during transport and storage

The conditions during transport and storage, e.g. temperature and humidity, are those defined in 7.1, except that, unless otherwise specified, the following temperature range applies during transport and storage: between $-25\text{ }^{\circ}\text{C}$ and $+55\text{ }^{\circ}\text{C}$ and, for short periods not exceeding 24 h, up to $+70\text{ }^{\circ}\text{C}$.

7.3 Mounting

The contactor shall be mounted in accordance with the manufacturer's instructions.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

The contactor with its enclosure, if any, whether integral or not, shall be designed and constructed to withstand the stresses occurring during installation and normal use and, in addition, shall provide a specified degree of resistance to abnormal heat and fire.

NOTE An enclosed contactor is a contactor mounted in an enclosure, designed and dimensioned to contain one contactor only.

Protection against hazards caused by the electronic circuits shall be maintained under normal and single fault conditions, as specified in this document.

8.1.2 Materials

8.1.2.1 General

The suitability of materials used is verified by making the following tests on the contactor and/or, if not practicable, on parts taken from it.

- resistance to ageing (see 8.1.2.2)
- resistance to humidity (see 8.1.2.3)
- resistance to heat (see 8.1.2.4)
- resistance to abnormal heat and fire (see 8.1.2.5)
- resistance to rusting (see 8.1.2.6)

As far as resistance to heat, abnormal heat and fire hazard are concerned, priority shall be given to tests made on the contactor or on a suitable part taken from the contactor.

However, in certain cases, tests on materials can be used, for practical reasons, as an alternative to tests on the contactor.

8.1.2.2 Resistance to ageing

Contactors shall be resistant to ageing.

In general, it is only necessary to test contactors having (or supplied with) enclosures or parts of p.v.c. or similar thermoplastic material and parts of rubber such as sealing rings and gaskets.

Compliance is checked by inspection and, if necessary, by a test according to 9.2.2.1.

8.1.2.3 Resistance to humidity

The contactor shall be protected against the effects of humidity which can occur in normal service.

Compliance shall be verified by the test specified in 9.2.2.2.

8.1.2.4 Resistance to heat

All parts of enclosed, partially enclosed and unenclosed contactors intended to prevent access to live parts shall not be adversely affected by the highest temperature likely to be reached during normal service.

Compliance shall be verified by the tests specified in 9.2.2.3.1 and 9.2.2.3.2.

8.1.2.5 Resistance to abnormal heat and fire

Parts of insulating material which might be exposed to thermal stresses due to electrical effects, the deterioration of which might impair the safety of the contactor, shall not be adversely affected by abnormal heat or fire.

Compliance shall be verified by the test specified in 9.2.2.4.

If a test has to be made at more than one place on the same sample, care shall be taken to ensure that any deterioration caused by previous tests does not affect the test to be made. Small parts with surface dimensions not exceeding 14 mm × 14 mm are not subjected to the test.

8.1.2.6 Resistance to rusting

Ferrous parts of the contactor including enclosures and covers, but excluding pole faces of electromagnets, shall be protected against rusting.

Compliance shall be verified by the test specified in 9.2.2.5.

8.1.3 Strength of screws or nuts other than those on terminals which are intended to be operated during installation or maintenance

Screws or nuts intended to be operated during installation or maintenance, as recommended by the manufacturer, shall withstand the mechanical stresses occurring in normal service.

Thread-forming tapping screws and thread-cutting tapping screws intended only for mechanical assembly can be used provided they are supplied together with the piece in which they are intended to be inserted.

An example of a thread-forming tapping screw is shown in Figure 1. An example of a thread-cutting tapping screw is shown in Figure 2. In addition, thread-cutting tapping screws intended to be operated by the installer shall be captive with the relevant part of the accessory.

Screws or nuts which transmit contact pressure shall be in engagement with metal threads.

For electrical connections, no contact pressure shall be transmitted through insulating material other than ceramic or other material with characteristics not less suitable and compensated for any possible shrinkage or yielding.

Compliance shall be verified by inspection and by the test of 9.2.3.

8.1.4 Vacant

8.1.5 Actuator

8.1.5.1 General

The requirements of 8.1.5.2 and 8.1.5.3 apply to contactors provided with a manually operated actuator.

8.1.5.2 Insulation

The actuator of the contactor shall be insulated from the live parts for the rated insulation voltage and, if applicable, the rated impulse withstand voltage.

Moreover:

- if the activator is made of metal, it shall be capable of being satisfactorily connected to a protective conductor unless it is provided with additional reliable insulation;
- if it is made of or covered by insulating material, any internal metal part which might become accessible in the event of insulation failure shall also be insulated from live parts for the rated insulation voltage.

8.1.5.3 Direction of movement

The direction of operation for actuators of devices shall normally comply with IEC 60447. Where devices cannot comply with these requirements, e.g. due to special applications or alternative mounting positions, they shall be clearly marked such that there is no doubt as to the "I" and "O" positions and the direction of the operation.

8.1.5.4 Mounting

Actuators mounted on removable panels or opening doors shall be so designed that when the panels are replaced or the doors closed, the actuator will engage correctly with the associated mechanism.

8.1.6 Indication of the OFF and ON positions

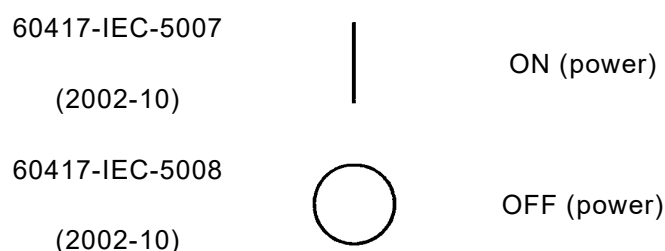
8.1.6.1 Indicating means

When a contactor is provided with means for indicating the closed and open positions, these positions shall be unambiguous and clearly indicated.

NOTE In the case of enclosed contactors, the indication can be visible from the outside.

This is done by means of a position indicating device (see 3.3.15).

If symbols are used, they shall indicate the closed and open positions respectively, in accordance with IEC 60417:



For contactors operated by means of two push-buttons, only the push-button designated for the opening operation shall be red or marked with the symbol "O".

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

The colours of other push-buttons, illuminated push-buttons and indicator lights shall be in accordance with IEC 60073.

8.1.6.2 Indication by the actuator

When the actuator is used to indicate the position of the contacts, it shall automatically take up or stay in, when released, the position corresponding to that of the moving contacts; in this case, the actuator shall have two distinct rest positions corresponding to those of the moving contacts, but for automatic opening, a third distinct position of the actuator can be provided.

8.1.7 Terminals

8.1.7.1 Constructional requirements

All parts of terminals which maintain contact and carry current shall be of metal having adequate mechanical strength.

Terminal connections shall be such that the force to connect the conductors can be applied by screws, screwless-type or other equivalent means to ensure that the necessary contact pressure is maintained.

Terminals shall be so constructed that the conductors can be clamped between suitable surfaces without any significant damage either to conductors or terminals.

Terminals shall not allow the conductors to be displaced or be displaced themselves in a manner detrimental to the operation of the contactor and the insulation voltage shall not be reduced below the rated values.

Screwless terminals shall be so designed and constructed that each conductor is clamped individually.

Screwless-type clamping units, unless otherwise specified by the manufacturer, shall accept solid, stranded and flexible conductors.

On screwless-type clamping unit, the connection or disconnection of conductors shall be made as follows:

- on universal clamping units by the use of a general-purpose tool or a convenient device, integral with the clamping unit to open it for the insertion or withdrawal of the conductors;

- on push-wire clamping units by simple insertion. For the disconnection of the conductors an operation other than a pull only on the conductor shall be necessary. The use of a general-purpose tool or of a convenient device, integral with the clamping unit is allowed in order to "open" it and to assist the insertion or the withdrawal of the conductor.

Examples of screwless terminals are given in Figure 23

The requirements of this subclause shall be verified by the tests of 9.2.5.3, 9.2.5.4, 9.2.5.5, 9.2.5.7 and 9.2.5.8 as applicable.

NOTE North American countries have particular requirements for terminals suitable for aluminium conductors and marking to identify the use of aluminium conductors.

8.1.7.2 Connecting capacity

The manufacturer shall state the type (rigid – solid or stranded – or flexible), the minimum and the maximum cross-sections of conductors for which the terminal is suitable and, if applicable, the number of conductors simultaneously connectable to the terminal. However, the maximum cross-section shall not be smaller than that stated in 9.3.3.3 for the temperature-rise test and the terminal shall be suitable for conductors of the same type (rigid – solid or stranded – or flexible) at least two sizes smaller, as given in the appropriate column of Table 2.

Standard values of cross-sections of round copper conductors (both metric and AWG/MCM sizes) are shown in Table 2 which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

Table 2 – Standard cross-sections of round copper conductors

ISO cross-sections mm ²	AWG/MCM	
	Sizes	Equivalent cross-sections mm ²
0,2	24	0,205
–	22	0,324
0,5	20	0,519
0,75	18	0,82
1	–	–
1,5	16	1,3
2,5	14	2,1
4	12	3,3
6	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6

NOTE The dash, when it appears, counts as a size when considering connecting capacity.

8.1.7.3 Connection

Terminals for connection to external conductors shall be readily accessible during installation.

Clamping screws and nuts shall not serve to fix any other component although they can hold the terminals in place or prevent them from turning.

8.1.7.4 Terminal identification and marking

Terminals shall be clearly and permanently identified in accordance with IEC 60445.

Terminals intended exclusively for the neutral conductor shall be identified by the letter "N", in accordance with IEC 60445.

The protective earth terminal shall be identified in accordance with 8.1.9.3.

Additional requirements for terminal identification and marking are given in Annex A.

8.1.8 Additional requirements for contactors provided with a neutral pole

When a contactor is provided with a pole intended only for connecting the neutral, this pole shall be clearly identified to that effect by the letter "N" (see 8.1.7.4).

A switched neutral pole shall not break before and shall not make after the other poles.

The value of the conventional thermal current shall be identical for all poles.

8.1.9 Provisions for earthing

8.1.9.1 Constructional requirements

The exposed conductive parts (e.g. chassis, framework and fixed parts of metal enclosures) other than those which cannot constitute a danger shall be electrically interconnected and connected to a protective earth terminal for connection to an earth electrode or to an external protective conductor.

This requirement can be met by the normal structural parts providing adequate electrical continuity and applies whether the contactor is used on its own or incorporated in an assembly.

Exposed conductive parts are not considered to constitute a danger if they cannot be touched on large areas or grasped with the hand or if they are of small size (approximately 50 mm × 50 mm) or are so located as to exclude any contact with live parts.

Examples of these are screws, rivets, nameplates, transformer cores, electromagnets and certain parts of releases, irrespective of their size.

8.1.9.2 Protective earth terminal

The protective earth terminal shall be readily accessible and so placed that the connection of the contactor to the earth electrode or to the protective conductor is maintained when the cover or any other removable part is removed.

The protective earth terminal shall be suitably protected against corrosion.

In the case of contactors with conductive structures, enclosures, etc., means shall be provided if necessary, to ensure electrical continuity between the exposed conductive parts of the contactors and the metal sheathing of connecting conductors.

The protective earth terminal shall have no other function, except when it is intended to be connected to a PEN conductor. In that case, it shall also have the function of a neutral terminal in addition to meeting the requirements applicable to the protective earth terminal.

8.1.9.3 Protective earth terminal marking and identification

The protective earth terminal shall be clearly and permanently identified by its marking.

The identification shall be achieved by colour (green-yellow mark) or by the notation PE, or PEN as applicable, in accordance with Clause 7 of IEC 60445:2021, or, in the case of PEN, by a graphical symbol for use on contactors.

The graphical symbol to be used is symbol:

60417-IEC-5019 (2006-08)  Protective earth (ground) of IEC 60417.

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

8.1.10 Enclosures

8.1.10.1 General

The requirements of 8.1.10.2 and 8.1.10.3 are applicable only to enclosures supplied or intended to be used with the contactor.

8.1.10.2 Design

The enclosure shall be so designed that when it is opened and other protective means, if any, have been removed, all parts requiring access for installation and maintenance, as prescribed by the manufacturer, are readily accessible.

Sufficient space shall be provided inside the enclosure for the accommodation of external conductors from their point of entry into the enclosure to the terminals to ensure adequate connection.

The fixed parts of a metal enclosure shall be electrically connected to the other exposed conductive parts of the contactor and connected to a terminal which enables them to be earthed or connected to a protective conductor.

Under no circumstances shall a removable metal part of the enclosure be insulated from the part carrying the earth terminal when the removable part is in place.

The removable parts of the enclosure shall be firmly secured to the fixed parts by a device such that they cannot be accidentally loosened or detached owing to the effects of operation of the contactor or its vibrations.

For enclosures having a degree of protection IP1X up to and including IP4X, sufficient space shall be provided for establishing a drain-hole. Subclause 11.3 of IEC 60529:1989 applies with the following addition:

Drain and ventilating holes are treated as normal openings.

Enclosures shall have adequate mechanical strength (see 8.1.12).

Furthermore, it shall not be possible to remove any cover of the enclosure without the use of a tool.

An integral enclosure is considered to be a non-removable part.

If the enclosure is used for mounting push-buttons, it shall not be possible to remove the buttons from the outside of the enclosure.

8.1.10.3 Insulation

If, in order to prevent accidental contact between a metallic enclosure and live parts, the enclosure is partly or completely lined with insulating material, this lining shall be securely fixed to the enclosure.

Compliance shall be verified by inspection.

8.1.11 Degrees of protection of enclosed contactors

IEC 60529 defines degrees of protection for enclosed equipment and guidance for the application of that standard to contactors is under consideration.

8.1.12 Resistance to impact

The external parts of enclosed, partially enclosed, and parts of unenclosed contactors, shall withstand impacts which might be expected in normal service.

Compliance shall be verified by the test specified in 9.2.6.

8.1.13 Durability of markings

The contactor shall be provided with a nameplate marked in a durable manner.

Compliance shall be verified by the test specified in 9.2.7.

8.1.14 Fault and abnormal conditions

This clause applies to contactors incorporating electronic circuits only. For the purpose of this document, "electronic circuit" excludes circuits in which all components are passive (including diodes, resistors, varistors, capacitors, surge suppressors, inductors).

The product shall be designed to avoid operating modes or sequences that can cause a fault condition or component failure leading to a hazard, unless other measures to prevent the hazard are provided by the installation and are described in the installation information provided with the product. The requirements in this clause also apply to abnormal operating conditions as applicable.

Circuit analysis or testing shall be performed to determine whether or not failure of a particular component (including insulation systems) would result in hazard.

This analysis shall include situations where a failure of the component or the insulation (basic and supplementary) would result in:

- an impact on the risk of electric shock
- a risk of degradation resulting in emission of flame, burning particles or molten metal.

The analysis or testing shall include the effect of short-circuit and open-circuit conditions of the component. Testing is necessary unless analysis can conclusively show that, in short-circuit and open circuit conditions, no shock and fire hazard will result from failure of the component.

Compliance shall be checked by test of 9.2.8.

Contactors already tested according to Clauses 101 and 102 of IEC 60669-2-1:2021 are deemed to fulfil the requirements of 8.1.14 and therefore, 9.2.8 is covered.

Components evaluated for their reliability according to relevant product standards are considered to meet these requirements and do not need any further investigation, if tested under conditions that fulfil the conditions for which the product is designed.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

The contactor shall be operated in accordance with the manufacturer's instructions.

The moving contacts of multipole contactors intended to make and break together shall be so mechanically coupled that all poles make and break substantially together (however, for switched neutral pole, see 8.1.8) whether operated manually or automatically.

8.2.1.2 Limits of operation

Contactors shall close satisfactorily at any value between 85 % and 110 % of their rated control supply voltage U_s . Where a range is declared, 85 % shall apply to the lower value and 110 % to the higher.

The limits between which contactors shall drop out and open fully are 75 % to 20 % of their rated control supply voltage U_s . Where a range is declared, 20 % shall apply to the higher value and 75 % to the lower.

The limits between which a contactor with an electronically controlled electromagnet shall drop out and open fully are 75 % to 20 % of their rated control supply voltage U_s , or 75 % to 10 % of their rated control supply voltage U_s if specified by the manufacturer. In that case, the contactor shall, in addition, be submitted to the capacitive drop out test as follows:

A capacitor C shall be inserted in series in the supply circuit U_s , the total length of the connecting conductors being ≤ 3 m.

The capacitor is short-circuited by a switch of negligible impedance. The supply voltage shall then be adjusted to 110 % U_s .

It shall be verified that the equipment drops out when the switch is operated to the open position.

The value of the capacitor shall be

$$C = 30 + 200\,000 / (f \times U)$$

where C is expressed in nF; f is the minimum rated frequency expressed in Hz; U is the maximum value of U_s expressed in V.

For example, for a coil rated 12...24 V – 50 Hz, the capacitor value is 196 nF (calculation made with U_s max). The test voltage is the highest value of the declared rated supply voltage range U_s .

NOTE The value of the capacitor simulates a typical control wiring of 100 m long cable of 1,5 mm² (0,3 nF/m that is 30 nF for 100 m) connected to a static output having a 1,3 mA leakage current (200 000 in the formula $\approx \frac{10^9 \times 1,3 \times 10^{-3}}{2 \times \pi}$).

Limits for closing are applicable after the coils have reached a stable temperature corresponding to indefinite application of 100 % U_s in an ambient temperature of +40 °C.

Limits for drop-out are applicable with the coil circuit resistance at –5 °C. This can be verified by calculation using values obtained at normal ambient temperature.

The limits apply at declared frequency, if any.

8.2.2 Temperature-rise

8.2.2.1 General

The temperature-rises of the several parts of the contactor measured during a test carried out under the conditions specified in 9.3.3.3 shall not exceed the limiting values stated in Table 3 and in 8.2.2.2 and 8.2.2.3.

In the case of an electronically controlled electromagnet, coil temperature measuring by variation of resistance can be impracticable; in such a case, other methods are permitted, e.g. thermocouples, calculation or other suitable methods.

NOTE 1 Temperature-rises in normal service can differ from the test values, depending on the installation conditions and the size of connected conductors.

Table 3 – Temperature-rise limits for insulated coils in air

Classes of insulating materials	Temperature-rise limits (measured by resistance variation)
	K
	Coils in air
A	85
E	100
B	110
F	135
H	160
NOTE The insulation classification is that given in IEC 60085.	

NOTE 2 The temperature-rise limits given in Table 3 and in Table 5 are applicable only if the ambient air temperature remains within the limits –5 °C, + 40 °C.

8.2.2.2 Terminals

The temperature-rise of terminals shall not exceed the values stated in Table 4.

Table 4 – Temperature-rise limits of terminals

Terminal materials	Temperature-rise limits
	K ^a
Bare copper	60
Bare brass	65
Tin-plated copper or brass	65
Silver- or nickel-plated copper or brass	70 ^a
Other metals	^b
^a The terminal temperature-rise limit of 70 K is based on the connection of PVC cables. The use in service of connected conductors significantly smaller than those listed in Table 15 could result in higher terminal and internal part temperatures and such conductors should not be used without the manufacturer's consent since higher temperatures could lead to contactor failure. ^b Temperature-rise limits to be based on service experience or life tests but not to exceed 65 K.	

8.2.2.3 Accessible parts

The temperature-rise of accessible parts shall not exceed the values stated in Table 5.

Table 5 – Temperature-rise limits of accessible parts

Accessible parts	Temperature-rise limits ^a
	K
Manual operating means:	
Metallic	15
Non-metallic	25
Parts intended to be touched but not hand-held:	
Metallic	30
Non-metallic	40
Parts which need not be touched for normal operation:	
Metallic	40
Non-metallic	50
Parts not intended to be touched during normal operation	
Exteriors of enclosures adjacent to cable entries:	
Metallic	40
Non-metallic	50
^a Different values can be prescribed for different test conditions and for devices of small dimensions but not exceeding by more than 10 K the values of this table.	

8.2.2.4 Ambient air temperature

The temperature-rise limits given in Table 4 and Table 5 are applicable only if the ambient air temperature remains within the limits given in 7.1.2.

8.2.2.5 Main circuit

The main circuit of a contactor shall be capable of carrying without the temperature-rises exceeding the limits specified in 8.2.2.2 when tested in accordance with 9.3.3.3.4:

- for a contactor intended for continuous duty: its conventional thermal current (see 5.3.3.2 and/or 5.3.3.3);
- for a contactor intended for intermittent or temporary duty: the relevant rated operational current (see 5.3.3.4).

8.2.2.6 Control circuits

The control circuits of a contactor shall permit the rated duty according to 5.3.5 and also the temperature-rise tests specified in 9.3.3.3.5 to be made without the temperature-rise exceeding the limits specified in Table 3, Table 4 and Table 5.

8.2.2.7 Windings of coils and electromagnets

8.2.2.7.1 Eight-hour duty (continuous duty) windings

With the maximum value of current according to 8.2.2.5 flowing through the main circuit, the windings of the coils shall withstand under continuous load and at the rated frequency their rated control supply voltage without the temperature-rise exceeding the limits specified in Table 3 and 8.2.2.3.

NOTE Depending on the technology, e.g. for some kinds of electronically controlled electromagnets, the control supply voltage cannot be directly applied on the coil winding when connected as in normal service.

8.2.2.7.2 Intermittent duty windings

With no current flowing through the main circuit, the windings of the coils shall withstand, at the rated frequency, their rated control supply voltage applied as detailed in Table 6, according to their intermittent duty class, without the temperature-rise exceeding the limits specified in Table 3 and 8.2.2.3.

NOTE Depending on the technology, e.g. for some kinds of electronically controlled electromagnets, the control supply voltage cannot be directly applied on the coil winding when connected as in normal service.

Table 6 – Intermittent duty test cycle data

Intermittent duty classes	One close-open operating cycle every	Interval of time during which the supply to the control coil is maintained
1	3 600 s	"ON" time shall normally correspond to the on-load factor specified by the manufacturer
3	1 200 s	
12	300 s	
30	120 s	
300	12 s	
1 200	3 s	

8.2.2.7.3 Specially rated (short-time and periodic duty) windings

Specially rated windings shall be tested under operating conditions corresponding to the most severe duty for which they are intended and their ratings shall be stated by the manufacturer.

8.2.2.8 Auxiliary circuits

Auxiliary circuits of a contactor including auxiliary switches shall be capable of carrying their conventional thermal current without the temperature-rise exceeding the limits specified in Table 4 and Table 5 when tested in accordance with 9.3.3.3.7.

NOTE If an auxiliary circuit forms an integral part of the contactor, it suffices to test it at the same time as the main circuit, but at its actual service current.

8.2.2.9 Other parts

The temperature-rises obtained during the test shall not cause damage to current-carrying parts of adjacent parts of the contactor. In particular, for insulating materials, the manufacturer shall demonstrate compliance either by reference to the insulation temperature index (determined for example by the methods of IEC 60216 (all parts) or by compliance with IEC 60085.

8.2.3 Dielectric properties

8.2.3.1 General

The dielectric properties are based on basic safety publications IEC 60664-1 and IEC 61140.

- a) The following requirements provide the means of achieving co-ordination of insulation of a contactor with the conditions within the installation.
- b) The contactor shall be capable of withstanding:
 - the rated impulse withstand voltage (see 5.3.2.4 in accordance with the overvoltage category given in Annex F;
 - the power-frequency withstand voltage.

NOTE The correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of the contactor is given in Annex F.

The rated impulse withstand voltage for a given rated operational voltage shall be not less than that corresponding in Annex F to the nominal voltage of the supply system of the circuit at the point where the contactor is to be used, and the appropriate overvoltage category.

- c) The requirements of this subclause shall be verified by the tests of 9.3.3.4.

8.2.3.2 Impulse withstand voltage

a) Main circuit

- 1) Clearances from live parts to parts intended to be earthed and between poles shall withstand the test voltage given in Table 16 appropriate to the rated impulse withstand voltage.
- 2) Solid insulation of contactor associated with clearances item a) 1) above shall be subjected to the impulse voltage specified in item a) 1).

b) Auxiliary and control circuits

- 1) For auxiliary and control circuits which operate directly from the main circuit at the rated operational voltage, clearances from live parts to parts intended to be earthed and between poles shall withstand the test voltage given in Table 16 appropriate to the impulse withstand voltage of the main circuit. See also 8.2.3.2, item a) 2).
- 2) Auxiliary and control circuits which do not operate directly from the main circuit can have an overvoltage withstand capacity different from that of the main circuit. Clearances and associated solid insulation of such circuits, whether AC or DC, shall withstand the appropriate voltage in accordance with Annex F.

8.2.3.3 Power-frequency withstand voltage of the main, auxiliary and control circuits

a) Power-frequency dielectric tests are used in the following cases:

- dielectric tests as type tests for the verification of solid insulation;
- dielectric withstand verification, as a criterion of failure, after switching or short-circuit type tests;
- routine tests.

b) Type tests of dielectric properties

The tests of dielectric properties, as type tests, shall be made in accordance with 9.3.3.4.

c) Verification of dielectric withstand after switching or short-circuit tests

The verification of dielectric withstand after switching and short-circuit tests as a criterion of failure, is always made at power-frequency voltage in accordance with item d) of 9.3.3.4.1.

d) Verification of dielectric withstand during routine tests

Tests to detect faults in materials and workmanship are made at power-frequency voltage, in accordance with item b) of 9.3.3.4.2.

8.2.3.4 Clearances

Clearances shall be sufficient to enable the equipment to withstand the rated impulse withstand voltage, according to 8.2.3.2.

Clearances shall be higher than the values given in Table 17, for case B (homogeneous field) (see 3.5.30) and verified by a sampling test according to 9.3.3.4.3. This test is not required if the clearances, related to the rated impulse withstand voltage and pollution degree, are higher than the values given in Table 17 for case A (inhomogeneous field).

The method of measuring clearances is given in Annex E.

8.2.3.5 Creepage distances

a) Dimensioning

For pollution degrees 1 and 2, creepage distances shall be not less than the associated clearances selected according to 8.2.3.4. For pollution degree 3, the creepage distances shall be not less than the case A clearances (Table 17) to reduce the risk of disruptive discharge due to overvoltages, even if the clearances are smaller than the values of case A as permitted in 8.2.3.4.

The method of measuring creepage distances is given in Annex E.

Creepage distances shall correspond to a pollution degree as specified in 7.1.4.2 and to the corresponding material group at the rated insulation or working voltage given in Table 18.

Material groups are classified as follows, according to the range of values of the comparative tracking index (CTI) (see 3.5.33):

- Material group I $600 \leq \text{CTI}$
- Material group II $400 \leq \text{CTI} < 600$
- Material group IIIa $175 \leq \text{CTI} < 400$
- Material group IIIb $100 \leq \text{CTI} < 175$

NOTE The CTI values refer to the values obtained in accordance with IEC 60112, method with Solution A, for the insulating material used.

b) Use of ribs

A creepage distance can be reduced to 0,8 of the relevant value of Table 18 by using ribs of 2 mm minimum height, irrespective of the number of ribs. The minimum base of the rib is determined by mechanical requirements (see E.2).

8.2.3.6 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with item c) of 9.3.3.4.1, or DC tests if AC tests cannot be applied.

Dimensioning rules for solid insulation and DC test voltages are under consideration.

8.2.3.7 Spacing between separate circuits

For dimensioning clearances, creepage distances and solid insulation between separate circuits, the highest voltage ratings shall be used (rated impulse withstand voltage for clearances and associated solid insulation and rated insulation voltage or working voltage for creepage distances).

8.2.3.8 Requirements for contactor with protective separation

Requirements for contactor with protective separation are given in Annex I.

8.2.4 Normal load and overload performance requirements**8.2.4.1 General**

Requirements concerning normal load and overload characteristics according to 5.3.6 are given in 8.2.4.2, 8.2.4.3 and 8.2.4.4 below.

8.2.4.2 Making and breaking capacities

Contactors shall be capable of making and breaking currents without failure under the conditions stated in Table 7 for the required utilization categories and the number of operations indicated as specified in 9.3.3.5.

The values of off-time and on-time given in Table 7 and Table 8 shall not be exceeded.

Table 7 – Making and breaking capacities. Making and breaking conditions corresponding to the utilization categories

Categories	Making and breaking conditions						
	I_c/I_e	P_t/P	U_r/U_e	$\cos \varphi$	On-time ^a s	Off-time s	Number of operating cycles
AC-7a	1,5		1,05	0,80	0,05	b	50
AC-7b	8,0		1,05	0,45	0,05	b	50
AC-7c ^c	1,5		1,05	c	0,05	b	50
AC-7d ^d		1,5 ^e	1,05	d	0,05	10 s	50
I_c is the current made and broken, expressed in RMS symmetrical values, but it is understood that the actual peak value in the making operation can assume a higher value than the symmetrical peak value; I_e is the rated operational current; P_t is the power corresponding to I_{peak} and I^2t test values (See Table 20) P is the rated power; U_r is the power frequency recovery voltage; U_e is the rated operational voltage; $\cos \varphi$ is the power factor of the test circuit.							
^a Time can be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.							
^b See Table 8.							
^c The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 2)).							
^d The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 3)).							
^e P_t shall be calculated with a ratio 1,5 (with a tolerance of $\pm 0,2$) to correspond to a value of Table 20.							

Table 8 – Relationship between current broken I_c and off-time for the verification of rated making and breaking capacities

Current broken I_c A	Off-time s
$I_c \leq 100$	10
$100 < I_c \leq 200$	20
$200 < I_c \leq 300$	30

The values of off-time can be reduced if agreed by the manufacturer.

8.2.4.3 Conventional operational performance

Tests concerning the operational performance of a contactor are intended to verify that the contactor is capable of making, carrying and breaking without failure the currents flowing in its main circuit under conditions corresponding to the specified utilization category, where relevant.

Contactors shall be capable of making and breaking currents without failure under the conventional conditions stated in Table 9 for the required utilization categories and the number of operations indicated as specified in 9.3.3.6.

Table 9 – Conventional operational performance. Making and breaking conditions corresponding to the utilization categories

Categories	Making and breaking conditions						
	I_c/I_e	Pt/P	U_r/U_e	$\cos \varphi$	On-time ^a s	Off-time s	Number of operating cycles
AC-7 ^a	1,0		1,05	0,80	0,05	b	30 000
AC-7 ^b	d		c	0,45	0,05	b	30 000
AC-7c ^e	1,0		1,05	e	0,05	b	30 000
AC-7d ^f		1	1,05	f	0,05	10 s	30 000
I_c is the current made and broken, expressed in RMS symmetrical values, but it is understood that the actual peak value in the making operation can assume a higher value than the symmetrical peak value; I_e is the rated operational current; Pt is the power corresponding to I_{peak} and I^2t test values (See Table 20) P is the rated power; U_r is the power frequency recovery voltage; U_e is the rated operational voltage; $\cos \varphi$ is the power factor of the test circuit.							
^a Time can be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening. ^b These OFF times shall be not greater than the values specified in Table 8. ^c $U_r/U_e = 1,0$ for making and $U_r/U_e = 0,17$ for breaking. ^d $I_c/I_e = 6,0$ for making and $I_c/I_e = 1,0$ for breaking. ^e The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 2)). ^f The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 3)).							

8.2.4.4 Ability to withstand overload currents

Contactors with utilization category AC-7b shall withstand the overload currents given in Table 10 as specified in 9.3.5.

Table 10 – Overload current withstand requirements

Test current	Duration of test
$8 \times I_e \text{ max/AC-7b}$	10 s

8.2.5 Co-ordination with short-circuit protective devices

The rated conditional short-circuit current of contactors backed up by short-circuit protective device(s) (SCPDs) shall be verified by short-circuit tests as specified in 9.3.4. These tests shall be made:

- at the appropriate value of prospective current shown in Table 24 (test current I_r) and
- at the rated conditional short-circuit current I_Q , if higher than test current I_r .

The rating of the SCPD shall be adequate for any given rated operational current, rated operational voltage and the corresponding utilization category.

Test conditions are given in 9.3.4.3.

Co-ordination requires that, under short-circuit conditions, the contactor shall cause no danger to persons or installations. It is permissible that it is not suitable for further use.

NOTE Use of an SCPD not in compliance with the manufacturer's recommendations can invalidate the co-ordination.

8.3 EMC Electromagnetic compatibility

8.3.1 General

Contactors not incorporating electronic circuits are not sensitive to electromagnetic disturbances and do not generate significant disturbances in normal service conditions, and therefore no EMC tests are required.

For the purpose of this document, "electronic circuit" excludes circuits in which all components are passive (including diodes, resistors, varistors, capacitors, surge suppressors, inductors).

8.3.2 Immunity

The behaviour of electromechanical contactors for household and similar purposes in case of voltage amplitude variations is specified in 8.2.1.2.

Contactors incorporating electronic circuits shall have a satisfactory immunity to electromagnetic disturbances.

For the appropriate tests, to verify the compliance with these requirements, see 9.4.2.

8.3.3 Emission

Contactors for household and similar purposes which do not incorporate electronic circuits can only generate electromagnetic disturbances during switching operations. The duration of the disturbances is of the order of milliseconds.

Provisionally, until further study is carried out, the frequency and the level of these emissions are considered as part of the normal electromagnetic environment of electromechanical contactors for household and similar purposes, and no electromagnetic emission tests are necessary.

Harmonic tests are not required for contactors incorporating electronically controlled electromagnet because no electronic are used on the main circuit.

The high-frequency (greater than 9 kHz) continuous emissions from equipment incorporating electronic switching circuits shall not exceed the limits specified in 9.4.3.

8.4 Embedded software

Guidance for the development of embedded software for switchgear and controlgear including secure coding is provided by IEC TR 63201, especially by establishing:

- a software management plan according to Clause 5 of IEC TR 63201:2019;
- a design lifecycle management according to Clause 7 of IEC TR 63201:2019.

9 Tests

9.1 Types of test

9.1.1 General

Tests shall be made to prove compliance with the requirements laid down in this document. If relevant, tests can be carried out in sequences, see test sequences in Annex B.

9.1.2 Type tests

Type tests are intended to verify compliance of the contactor's design with this document. They comprise the verification of:

- a) temperature-rise limits (see 9.3.3.3);
- b) dielectric properties (see 9.3.3.4);
- c) rated making and breaking capacities (see 9.3.3.5);
- d) conventional operational performance (see 9.3.3.6);
- e) operation and operating limits (see 9.3.3.1 and 9.3.3.2);
- f) overload current withstand capability (see 9.3.5);
- g) performance under short-circuit conditions (see 9.3.4);
- h) mechanical properties of terminals (see 9.2.5);
- i) degrees of protection of enclosed contactors (see 9.2.4);
- j) resistance to ageing (see 9.2.2.1);
- k) resistance to humidity (see 9.2.2.2);
- l) resistance to heat (see 9.2.2.3);
- m) resistance to abnormal heat and fire (see 9.2.2.4);
- n) resistance to rusting (see 9.2.2.5);
- o) resistance to tracking (see 9.2.2.6);
- p) screws or nuts other than those on terminals which are intended to be operated during installation or maintenance (see 9.2.3);
- q) resistance to impact (see 9.2.6);
- r) durability of marking (see 9.2.7);
- s) Breakdown of components (see 9.2.8);
- t) Tests for EMC (see 9.4).

If relevant, type tests are grouped in test sequences.

Test sequences, number of samples and results to be obtained are indicated in Annex B.

Unless otherwise specified, each test (or test sequence) is performed on a new sample in clean condition.

Unless otherwise specified, the contactors are tested at an ambient air temperature of $25\text{ °C} \pm 10\text{ °C}$.

9.1.3 Routine tests

Routine tests are intended to detect faults in materials and workmanship and to ascertain proper functioning of the contactor. They shall be made on each individual contactor under the same or equivalent conditions as those specified for type tests (see 9.3.6.1).

Routine tests for contactors comprise:

- operation and operating limits (see 9.3.6.2);
- dielectric tests (see 9.3.6.3).

9.1.4 Sampling tests for clearance verification

Sampling tests for clearance verification are made according to 9.3.3.4.3. Sampling plans and test procedures are under consideration.

9.2 Compliance with constructional requirements

9.2.1 General

Verification of compliance with the constructional requirements stated in 8.1 concerns, for example:

- the materials;
- the contactor;
- the degree of protection of enclosed contactors;
- the mechanical properties of terminals;
- the actuator;
- the position indicating device (see 3.3.15).

9.2.2 Materials

9.2.2.1 Test of resistance to ageing

Contactors incorporating separate gaskets, screwed glands, membranes and parts manufactured from rubber, p.v.c. or similar thermoplastic materials are subjected to a test in a heating cabinet with an atmosphere having the composition and pressure of the ambient air and ventilated by natural circulation, gaskets, glands and membranes being suspended freely.

The temperature in the cabinet is $70\text{ °C} \pm 2\text{ °C}$.

The samples shall be kept in the cabinet for seven days (168 h). The use of an electrically heated cabinet is recommended. Natural air circulation can be provided by holes in the walls of the cabinet.

After treatment the samples shall be removed from the cabinet and kept at room temperature and relative humidity between 45 % and 55 % for at least four days (96 h).

The samples shall show, with normal or corrected vision without further magnification, neither surface crack nor shrinkage impairing their further use, nor shall the material have become sticky or greasy, this being judged as follows:

- with the forefinger wrapped in a dry piece of rough cloth the sample shall be pressed with a force of 5 N.

The force of 5 N can be obtained in the following way:

- the sample is placed on one of the pans of a balance and the other pan is loaded with a mass equal to the mass of the sample plus 500 g. Equilibrium is then restored by pressing the sample with the forefinger wrapped in a dry piece of rough cloth.

No trace of the cloth shall remain on the sample and the material of the sample shall not stick to the cloth.

9.2.2.2 Test of resistance to humidity

The contactor resistance to humidity shall be verified by test Ca: damp heat, steady state of IEC 60068-2-78 under the following test conditions:

Inlet openings, if any, shall be left open; if knock-outs are provided, one of them shall be opened. Parts which can be removed without the aid of a tool shall be removed and subjected to the humidity treatment with the main parts: spring lids shall be open during this treatment.

Before being placed in the test chamber, the samples shall be stored at room temperature for at least 4 h before the test. The test duration shall be four days.

After this period, the contactor is removed from the test chamber, the removed parts are reinstalled and the lid closed. The contactor is then submitted to a dielectric test as specified in 9.3.3.4.1, item c).

9.2.2.3 Test of resistance to heat

9.2.2.3.1 Tests on contactor

- a) Parts of insulating material, if any, necessary to retain in position current-carrying parts and parts of the earthing circuit shall be subjected to a ball pressure test at $125\text{ °C} \pm 2\text{ °C}$, except that insulating parts of an enclosure necessary to retain in position the earthing terminal, if any, shall be tested as specified in item b) hereafter.

The ball-pressure apparatus is shown in Figure 3.

The surface of the part to be tested shall be placed in a horizontal position and supported by a steel plate of at least 5 mm thickness and a steel ball of 5 mm diameter shall be pressed against this surface with a force of 20 N.

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

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

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

When it is not possible to make the test on the complete sample, the test shall be carried out on a suitable part of it of at least 2 mm thickness.

NOTE The thickness of 2 mm can be obtained by using several layers.

- b) External parts of insulating material not necessary to retain in position current-carrying parts and parts of the earthing circuit even though they can be in contact with them, shall be subjected to a ball-pressure test in accordance with item a) above, except that the test is made at a temperature of $70\text{ °C} \pm 2\text{ °C}$ or $40\text{ °C} \pm 2\text{ °C}$ plus the highest temperature-rise determined for the relevant part during the temperature-rise test, whichever is the higher.
- c) Before being placed in the heating cabinet, the contactor under test shall be stored at room temperature for at least 4 h before the test.

The contactor shall be kept for the time sufficient to reach thermal equilibrium, but not less than 1 hour in the heating cabinet at a temperature of $100\text{ °C} \pm 2\text{ °C}$.

The sample shall then be allowed to cool to approximately room temperature.

The standard test finger (see Figure 10) shall be applied to the external surfaces which are accessible during normal service with a force not exceeding 5 N, and there shall be no access to live parts when the contactor is mounted as in normal use. After the test, markings shall still be legible.

9.2.2.3.2 Tests on materials

A sample of the material, of at least 2 mm thickness, is subjected to the test(s) of 9.2.2.3.1, a) and/or b).

NOTE The manufacturer can provide data from the insulating material manufacturer (or other reliable source) to demonstrate compliance with these requirements.

9.2.2.4 Tests of resistance to abnormal heat and fire

9.2.2.4.1 Tests on parts of the contactor

The test to be performed for the verification of resistance to abnormal heat and fire is the glow-wire test, which simulates the thermal stresses produced by sources of heat or ignition in order to simulate fire hazard.

The glow-wire test shall be made according to IEC 60695-2-10 and IEC 60695-2-11 under the following conditions:

- for parts of insulating material, necessary to retain in position current-carrying parts by the test made at a temperature of 850 °C, for the purpose of this test a protective conductor, if any, is not considered as a current-carrying part,
- for parts of insulating material not necessary to retain in position current-carrying parts and parts of the earthing circuit, if any, even though they can be in contact with them, by the test made at a temperature of 650 °C.

9.2.2.4.2 Tests on materials

Suitable specimens of the material shall be subjected to the following tests:

NOTE The manufacturer can provide data from the insulating material manufacturer (or other reliable source) to demonstrate compliance with the requirements of 8.1.2.5.

- a) Flammability classification test, in accordance with IEC 60695-11-10.
- b) Hot wire ignition (HWI) test, as described in Annex G.

9.2.2.5 Test of resistance to rusting

All grease shall be removed from the parts to be tested, by immersion and agitation for 10 min in a cold chemical degreaser such as refined petrol.

The parts shall then be immersed for 10 min in a 10 % solution of ammonium chloride in water at a temperature of 20 °C ± 5 °C.

Without drying, but after shaking off any drops, the parts shall then be placed for 10 min in a box containing air saturated with moisture at a temperature of 20 °C ± 5 °C.

After the parts have been dried for 10 min in a heating cabinet at a temperature of 100 °C ± 5 °C, their surface shall show no signs of rust.

Traces of rust on sharp edges and any yellowish film removable by rubbing shall be ignored.

For small springs and the like, and for inaccessible parts exposed to abrasion, a layer of grease can provide sufficient protection against rusting.

Such parts shall only be subjected to the test if there is doubt about the effectiveness of the grease film, the test shall then be made without previous removal of the grease.

NOTE A revision of this test is under consideration.

9.2.2.6 Test of resistance to tracking

This test shall be made on a suitable part taken from the contactor or, if agreed for practical reasons, on a suitable specimen of the insulating material, according to IEC 60112, Solution A.

9.2.3 Test on screws or nuts other than those on terminals which are intended to be operated during installation or maintenance

The screws or nuts shall be tightened and loosened:

- 10 times when 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 shall be completely removed and reinserted each time.

The test shall be made with a suitable screwdriver or spanner, applying a torque as given in Table 11 or as specified by the manufacturer.

The screws or nuts shall be tightened without jerks.

When a screw has a hexagonal head with a slot for tightening with a screwdriver and when Table 11 is used and the values in columns II and III are different, the test shall be made twice:

- first applying to the hexagonal head, the torque specified in column III by means of the spanner,
- then, on a new sample, applying the torque specified in column II by means of the screwdriver.

If the values in columns II and III are the same, only the test with the screwdriver shall be made.

During the test, the screwed connections 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, or damage to enclosures and covers, that will impair the further use of the contactor.

9.2.4 Verification of the degrees of protection of enclosed contactors

See Annex H.

9.2.5 Mechanical properties of terminals

9.2.5.1 General

This subclause does not apply to aluminium terminals or to terminals for the connection of aluminium conductors.

9.2.5.2 General conditions for tests

Unless otherwise stated by the manufacturer, each test shall be made on terminals in a clean and new condition.

When tests are made with round copper conductors, the copper shall be according to IEC 60028.

9.2.5.3 Tests of mechanical strength of terminals

Tests shall be made with the appropriate type of conductor having the maximum cross-sectional area.

The conductor shall be connected and disconnected five times.

For screw-type terminals, the tightening torque shall be in accordance with Table 11 or 110 % of the torque specified by the manufacturer, whichever is the greater.

The test shall be conducted on two separate clamping units.

When a screw has a hexagonal head with means 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 set of samples, 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.

Each time the clamping screw or nut is loosened, a new conductor shall be used for each tightening test.

During the test, clamping units and 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 screwed connections.

Table 11 – Tightening torques for the verification of the mechanical strength of screw-type terminals

Diameter of thread mm		Tightening torque Nm.		
Metric standard values	Range of diameter	I	II	III
2,5	≤2,8	0,2	0,4	0,4
3,0	>2,8 up to and including 3,0	0,25	0,5	0,5
–	>3,0 up to and including 3,2	0,3	0,6	0,6
3,5	>3,2 up to and including 3,6	0,4	0,8	0,8
4	>3,6 up to and including 4,1	0,7	1,2	1,2
4,5	>4,1 up to and including 4,7	0,8	1,8	1,8
5	>4,7 up to and including 5,3	0,8	2,0	2,0
6	>5,3 up to and including 6,0	1,2	2,5	3,0
8	>6,0 up to and including 8,0	2,5	3,5	6,0
10	>8,0 up to and including 10,0	–	4,0	10,0
Column I	applies to screws without heads which, when tightened, do not protrude from the hole, and to other screws which cannot be tightened by means of a screwdriver with a blade wider than the root diameter of the screw.			
Column II	applies to nuts and screws which are tightened by means of a screwdriver.			
Column III	applies to nuts and screws which can be tightened by means other than a screwdriver.			

9.2.5.4 Tests for damage to and accidental loosening of conductors (flexion test)

The test applies to terminals for the connection of unprepared round copper conductors, of number, cross-section and type (flexible and/or rigid [stranded and/or solid]), specified by the manufacturer.

The following tests shall be carried out using two new samples with:

- a) the maximum number of conductors of the smallest cross-section connected to the terminal;
- b) the maximum number of conductors of the largest cross-section connected to the terminal;
- c) the maximum number of conductors of the smallest and largest cross-sections connected to the terminal.

Terminals intended for connection of either flexible or rigid (solid and/or stranded) conductors shall be tested with each type of conductor with different sets of samples.

Terminals intended for connection of both flexible and rigid (solid and/or stranded) conductors simultaneously shall be tested as stated in c) above.

For screwless terminal of several clamping-units, each clamping-unit shall be equipped with one conductor according to a), b) and c) if applicable.

The test should be carried out with suitable test equipment. The specified number of conductors shall be connected to the terminal. The length of the test conductors should be 75 mm longer than the height H specified in Table 12. The clamping screws shall be tightened with a torque in accordance with Table 11 or with the torque specified by the manufacturer. The device tested shall be secured as shown in Figure 4.

Table 12 – Test values for flexion and pull-out tests for round copper conductors

Conductor cross-section		Diameter of bushing hole ^a	Height $H \pm 13$ mm	Mass	Pulling force
mm ²	AWG/MCM	mm	mm	kg	N
0,2	24	6,4	260	0,3	10
–	22	6,4	260	0,3	20
0,5	20	6,4	260	0,3	30
0,75	18	6,4	260	0,4	30
1,0	–	6,4	260	0,4	35
1,5	16	6,4	260	0,4	40
2,5	14	9,5	279	0,7	50
4,0	12	9,5	279	0,9	60
6,0	10	9,5	279	1,4	80
10	8	9,5	279	2,0	90
16	4	12,7	298	2,9	100
25	6	12,7	298	4,5	135
–	3	14,3	318	5,9	156
35	2	14,3	318	6,8	190

^a If a bushing with the hole diameter given is not adequate to accommodate the conductor without binding, a bushing having the next larger hole can be used.

Each conductor is subjected to circular motions according to the following procedure:

The end of the conductor under test shall be passed through an appropriate size bushing in a platen positioned at a height H below the contactor terminal, as given in Table 12. The other conductors shall be bent in order not to influence the result of the test. The bushing shall be positioned in the horizontal platen concentric with the conductor. The bushing shall be moved so that its centre-line describes a circle of 75 mm diameter about its centre in the horizontal plane at 10 r.p.m. $\pm$ 2 r.p.m. The distance between the mouth of the terminal and the upper surface of the bushing shall be within 13 mm of the height H in Table 12. The bushing shall be lubricated to prevent binding, twisting or rotation of the insulated conductor. A mass as specified in Table 12 is to be suspended from the end of the conductor. The test shall consist of 135 continuous revolutions.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

Immediately after the flexion test, each conductor under test shall be submitted in the test equipment to the test of 9.2.5.5 (pull-out test).

9.2.5.5 Pull-out test for round copper conductors

Following the test of 9.2.5.4, the pulling force given in Table 12 shall be applied to the conductor tested in accordance with 9.2.5.4.

The clamping screws shall not be tightened again for this test.

The force shall be applied without jerks for 1 min, in the direction of the axis of the conductor.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

9.2.5.6 Test for insertability of unprepared round copper conductors having the maximum specified cross-section

9.2.5.6.1 Test procedure

The test shall be carried out with the gauges specified in Table 13. The measuring section of the gauge shall be able to penetrate into the terminal aperture under the weight of the gauge to the full depth of the terminal (see also Note to Table 13).

Table 13 – Maximum conductor cross-sections and corresponding gauges

Conductor cross-sections		Gauges (see Figure 5)			
Flexible conductors mm ²	Rigid conductors (solid or stranded) mm ²	Form and marking	Diameter <i>a</i> mm	Width <i>b</i> mm	Permissible deviations for <i>a</i> and <i>b</i> mm
1,5	1,5	A1	2,4	1,5	0 –0,05
2,5	2,5	A2	2,8	2,0	
2,5	4	A3	2,8	2,4	
4	6	A4	3,6	3,1	0 –0,06
6	10	A5	4,3	4,0	
10	16	B6	5,3	–	
16	25	B7	6,9	–	0 –0,07
25	35	B8	8,7	–	
35	50	B9	10,0	–	

NOTE For conductor cross-sections other than those given in the table, an unprepared conductor of appropriate cross-section can be used as the gauge, the force of insertion being not greater than 5 N.

Alternatively, the test can be carried out by inserting the largest conductor of type and rated cross-section among those recommended by the manufacturer. The stripped end of the conductor shall be able to enter completely within the clamping unit aperture, without use of undue force.

NOTE The manufacturer can specify the test method.

9.2.5.6.2 Construction of gauges

The construction of the gauges is shown in Figure 5.

Details of dimensions *a* and *b* and their permissible deviations are shown in Table 13. The measuring section of the gauge shall be made from gauge steel.

9.2.5.7 Electrical performance of screwless-type clamping units

The electrical performance of screwless-type clamping units is verified by the following test, which is made on at least 6 new samples of each design which have not been used for any other test.

NOTE A sample can include either one pole or two clamping units.

The insertion and disconnection of the conductors shall be made in accordance with the manufacturer's instructions.

A suitable test arrangement is shown in Figure 24. If the measurement points cannot be positioned within the 10 mm to the point of contact, the voltage difference between the ideal and the actual measuring points shall be deducted from the voltage drop measured. This voltage difference within the part of the conductor shall be determined with a suitable measurement method on one sample at a stabilised temperature. The measurement methods and the results shall be documented in the test report.

The device sample can be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal.

The test is made with new copper conductors having the minimum and the maximum cross-section area:

- universal clamping units shall be tested with rigid (solid or stranded) and flexible conductor;
- non universal clamping units for solid only shall be tested with solid conductor;
- non universal clamping units for rigid shall be tested with both solid and stranded conductor;
- non universal clamping units for flexible only shall be tested with flexible conductor.

A conductor having the minimum cross-section area is connected, as in normal use, to each of 3 samples and a conductor having the maximum cross-section area is connected, as in normal use, to each of the 3 other samples. This for each type of conductors, as applicable.

The clamping units are loaded for 1 h with the rated operational current.

The control circuit is loaded at U_s .

When screwless terminals are used for the control circuit, they can be tested during the test on the load circuit, if applicable.

Immediately after this period and with the same current flowing, the voltage drop across each clamping unit is measured as near as possible to the area of contact on the clamping unit.

In no case shall the voltage drop exceed 15 mV.

9.2.5.8 Ageing test for screwless-type clamping units

The screwless-type clamping units already subjected to the determination of the voltage drops specified in 9.2.5.7, are placed in a heating cabinet, which is initially kept at a temperature of $20\text{ °C} \pm 2\text{ °C}$.

During the test, a current equal to the rated operational current passes through terminals, except during the cooling period.

The control circuit is loaded at U_s .

The conductor of 1 m is connected in series between two terminals to be tested as shown in Figure 25.

The device sample can be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal.

The whole test arrangement, including the conductors, shall not be moved until all the following voltage drop tests have been completed.

The clamping units are then subjected to 192 temperature cycles, each cycle having a duration of approximately 1 h, as follows:

The air temperature in the cabinet is raised in approximately 20 min to 40 °C .

It is maintained within $\pm 5\text{ °C}$ of this value for approximately 10 min. The clamping units are then allowed to cool down, during approximately 20 min to a temperature of approximately 30 °C , forced cooling being allowed.

They are kept at this temperature for approximately 10 min and, if necessary, for measuring the voltage drop, allowed to cool down further, to a temperature of $20\text{ °C} \pm 2\text{ °C}$.

The voltage drop is measured using the current and, test arrangement previously specified in 9.2.5.7 after the 24th temperature cycle and after the 192 temperature cycles are completed.

The allowable voltage drop shall not exceed the smaller of the two following values:

- either 22,5 mV,
- or 1,5 times the value measured after the 24th cycle.

The temperature in the heating cabinet is measured at a distance of at least 50 mm from the specimens.

After this test an inspection by the naked eye, with normal or corrected vision and without additional magnification, shall show no changes obviously preventing further use, such as cracks, deformations or the like.

9.2.6 Test of resistance to impact

9.2.6.1 Test procedure

Unenclosed contactors, exposed parts of partially enclosed contactors, covers and cover plates of contactors shall be tested with the pendulum hammer test apparatus (see 9.2.6.2.1) with a shock energy of 0,5 J.

Enclosures designed and dimensioned to contain a contactor shall be tested with the sphere test apparatus (see 9.2.6.2.2) with a shock energy of 2 J.

The ambient air temperature shall be $25\text{ °C} \pm 10\text{ °C}$.

The sample with cover, or the enclosure, if any, shall be fixed as in normal use or placed against a rigid support.

Cable entries which are not provided with knock-outs shall be left open. If they are provided with knock-outs, two of them shall be opened.

Before applying the blows, fixing screws of bases, covers and the like shall be tightened with a torque equal to two thirds of that specified in Table 11.

The samples are subjected to ten blows, which are evenly distributed over the sample. The blows are not applied to knock-outs, fragile parts such as windows, pilot lights, etc.

In general, five of the blows are applied as follows:

- for flush-type contactors, one blow in the centre, one at each extremity of the area over the recess in the block, and the other two approximatively midway between the previous blows, preferably on the ridge, if any, the sample being moved horizontally;
- for other contactors and for mounting boxes, one blow in the centre, one at each side of the sample after it has been turned as far as possible, but not through more than 60°, about a vertical axis, and the other two approximatively midway between the previous blows, preferably on the ridge, if any.

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.

After the test, the sample shall show no damage within the meaning of this document.

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

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

Damage to the appearance, for example surface cracks, small dents which do not reduce the clearances or creepage distances below the values specified in 8.2.3.4 and 8.2.3.5, and small chips which do not adversely affect the protection against electric shock shall be neglected.

9.2.6.2 Test apparatus

9.2.6.2.1 Pendulum hammer test apparatus (0,5 J test)

The test apparatus shown in Figure 6, Figure 7 and Figure 8 shall be used.

The design of the test apparatus shall be 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 striking element, having a mass of 0,25 kg, shall be allowed to fall from a height of 0,20 m on to surfaces which are exposed when the contactor is mounted as in normal conditions of use so that the point of impact lies in the vertical plane through the axis of the pivot of the pendulum.

The height of fall shall be 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 shall be 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.

The head of the striking element shall have a hemispherical face of radius 10 mm and shall be of polyamide having a Rockwell hardness of $R\ 100$. The striking element 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 shall be pivoted at its upper end in such a way that it swings only in a vertical plane.

The axis of the pivot shall be $1\ 000\ \text{mm} \pm 1\ \text{mm}$, above the axis of the striking element.

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

- diameter of the ball: $12,7\ \text{mm} \pm 0,002\ 5\ \text{mm}$,
- initial load: $100\ \text{N} \pm 2\ \text{N}$,
- overload: $500\ \text{N} \pm 2,5\ \text{N}$.

Additional information concerning the determination of the Rockwell hardness of plastics is given in ISO 2039-2. Surface-mounting contactors shall be mounted on a sheet of plywood, 8 mm thick and 175 mm square, secured at its top and bottom edges to a rigid bracket, which shall be part of the mounting support as shown in Figure 7.

The mounting support shall have a mass of $10\ \text{kg} \pm 1\ \text{kg}$ and shall be mounted on a rigid frame by means of pivots.

9.2.6.2.2 Sphere test apparatus (2 J test) (see Figure 9)

The impact shall be produced by dropping or swinging a steel sphere 50 mm in diameter and weighing 0,5 kg from a height of 0,4 m as shown in Figure 9.

H indicates the vertical distance the sphere shall travel to produce the desired impact. The sphere is to contact the test sample when the wire is in the vertical position.

The wire shall have a negligible mass in comparison with the sphere.

The supporting surface shall consist of a layer of tongue-and-groove oak flooring mounted on two layers of 19 mm plywood.

The oak flooring shall be nominally 19 mm thick. The assembly shall rest on a concrete floor. An equivalent non-resilient supporting surface can be used.

The backing support shall consist of 19 mm plywood over a rigid surface of concrete.

An equivalent non-resilient backing support can be used.

9.2.7 Test of durability of marking

Compliance with the requirements of 8.1.13 is checked by inspection, also by lightly rubbing the marking by hand for 15 s with a piece of cloth soaked with water and again for 15 s with a piece of cloth soaked with petroleum spirit.

Petroleum spirit used in the test should consist of aliphatic solvent hexane with a content of aromatics of maximum 0,1 % by volume, a kauri butanol value of 29, an initial boiling point of approximately 65 °C, a dry-point of approximately 69 °C and a density of approximately 0,68 g/cm³.

After this test the marking shall be easily legible. It shall not be easily possible to remove labels and these shall show no curling.

The marking shall also remain easily legible after all the tests of this document.

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

9.2.8 Breakdown of components

9.2.8.1 General

The breakdown of a component, identified as a result of the circuit analysis of 8.1.14, shall be tested with the product operating with the load creating the more severe condition.

NOTE A possible loss of main function can be applied.

The test is not required:

- when circuit analysis indicates that no other component or portion of the circuit will be overloaded as a result of open- or short-circuit failure mode of another component;
- for components in circuits supplied by limited energy sources in compliance with IEC 60947-4-1:2018, 8.1.14;
- on power semiconductor devices when equivalent testing is accomplished during short-circuit tests;
- for components that have previously been positively evaluated considering their failure modes and the circuit conditions in which the component is used within the device.

9.2.8.2 Breakdown of components test

Each identified component shall be subjected to a breakdown of components test in open- and or short-circuit failure modes, whichever is most severe.

NOTE 1 The breakdown of components test can be done only with those circuits of the device that can affect the result of the test being fully energized and in operation.

During this test, there shall be no emission of flame or molten metal, nor ignition of cotton. The fusible element shall not open.

Components, such as capacitors or diodes, are short- or open-circuited. For device without a dedicated enclosure, an outer metal enclosure or a wire mesh cage (with surrounded cotton on the cage) that is 1,5 times the size of the device (or different, according to manufacturer declarations) shall be provided to simulate the potential grounded parts around the device. In case of dedicated enclosure, the cotton shall be placed over all openings. The outer dedicated enclosure or wire mesh cage (when provided) and any grounded or exposed dead metal part shall be connected through a fusible element F, according to subclause 9.3.3.5.2 g), to the supply circuit.

NOTE 2 Explanations about enclosed equipment are given in 5.3.3.2 NOTE 2 (unenclosed contactor) and 5.3.3.3 NOTE 2 (enclosed contactor).

9.3 Compliance with performance requirements

9.3.1 Test sequences

The sequence of tests and the corresponding samples are indicated in Annex B.

9.3.2 General test conditions

9.3.2.1 General requirements

The contactors to be tested shall agree in all their essential details with the design of the type which they represent.

Unless otherwise stated in the relevant test clauses, the tests shall be made with the same kind of current (and, at the rated frequency and with the same number of phases) as in the intended service.

If, for convenience of testing, it appears desirable to increase the severity of a test (e.g. to adopt a higher rate of operation in order to reduce the duration of the test), this can be done only with the consent of the manufacturer.

The contactor under test shall be mounted complete on its own support or an equivalent support and connected as in normal service, in accordance with the manufacturer's instructions and under the ambient conditions stated in 7.1.

Enclosed contactors shall be mounted complete and any opening normally closed in service shall be closed for tests. Contactors intended for use in an individual enclosure shall be tested in the smallest of such enclosures stated by the manufacturer.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one contactor only.

Contactors not intended to be used in an individual enclosure shall be tested in free air. In this case, unless otherwise specified in the relevant test clauses of this document, for tests concerning making and breaking capacities and performance under short-circuit conditions, a wire mesh shall be placed at all points of the contactor likely to be a source of external phenomena capable of producing a breakdown, in accordance with the arrangements and distances specified by the manufacturer. Details, including distances from the contactor under test to the wire-mesh, shall be stated in the test report.

Maintenance or replacement of parts is not permitted, unless otherwise specified in this document.

The contactor can be operated without load prior to beginning a test.

For the tests, the actuating system, if any, shall be operated as for the intended use in service stated by the manufacturer and at the rated values of control quantities (such as voltage), unless otherwise specified in this document.

9.3.2.2 Test quantities

9.3.2.2.1 Values of test quantities

All the tests shall be made with the values of test quantities corresponding to the ratings assigned by the manufacturer, in accordance with the relevant tables and data of this document.

9.3.2.2.2 Tolerances on test quantities

The test recorded in the test report shall be within the tolerances given in Table 14, unless otherwise specified in the relevant subclauses. However, with the agreement of the manufacturer, the tests can be made under more severe conditions than those specified.

Table 14 – Tolerances on test quantities

All tests	Tests under no load, normal load and overload conditions	Tests under short-circuit conditions
– current: $\begin{smallmatrix} +5 \\ 0 \end{smallmatrix}$ %	– power factor: $\pm 0,5$	– power factor: $\begin{smallmatrix} 0 \\ -0,05 \end{smallmatrix}$
– voltage: $\begin{smallmatrix} +5 \\ 0 \end{smallmatrix}$ % (including power frequency recovery voltage)	– frequency: ± 5 %	– frequency ± 5 %
NOTE 1 Where maximum and/or minimum operating limits are stated in this document, the above tolerances do not apply.		
NOTE 2 Tests made at 50 Hz are valid for operation at 60 Hz and vice-versa.		

9.3.2.2.3 Recovery voltage

a) Power-frequency recovery voltage

For all breaking capacity and short-circuit breaking capacity tests, the value of the power-frequency recovery voltage shall be 1,05 times the value of the rated operational voltage.

NOTE 1 The value of 1,05 times the rated operational voltage for the power-frequency recovery voltage is deemed to cover the effects of the variations of the system voltage under normal service conditions.

NOTE 2 The applied voltage can possibly be increased but the prospective peak-making current is not preferably be exceeded without the consent of the manufacturer.

NOTE 3 The upper limit of the power-frequency recovery voltage can be increased with the approval of the manufacturer (see 9.3.2.2.2).

b) Transient recovery voltage

Transient recovery voltages, where required in this document, are determined according to 9.3.3.5.3.

9.3.2.3 Evaluation of test results

The behaviour of the contactor during the tests and its condition after the tests are specified in the relevant test clauses of this document.

9.3.2.4 Test reports

Written reports on type tests proving compliance with this document shall be made available by the manufacturer. The details of test arrangements such as type and size of the enclosure, if any, size of conductors, distance from the live parts to the enclosure or to parts normally earthed in service, method of operation of the actuating system, etc., shall be given in the test report.

Test values and parameters shall form part of the test report.

9.3.3 Performance under no load, normal load and overload conditions

9.3.3.1 Operation

It shall be verified that contactors operate according to the requirements of 8.2.1.1.

9.3.3.2 Operating limits

Contactors shall be tested to verify the performance according to the requirements given in 8.2.1.2.

9.3.3.3 Temperature-rise

9.3.3.3.1 Ambient air temperature

The ambient air temperature shall be recorded during the last quarter of the test period by at least two temperature sensing means, e.g. thermometers or thermocouples, equally distributed around the contactor at about half its height and at a distance of about 1 m from the contactor. The temperature sensing means shall be protected against air currents, heat radiation and indicating errors due to rapid temperature changes.

During the tests, the ambient air temperature shall be between +10 °C and +40 °C and not vary by more than 10 K.

9.3.3.3.2 Measurement of the temperature of parts

For parts other than coils, the temperature of the different parts shall be measured by suitable temperature sensing means at those points most likely to attain the maximum temperature; these points shall be stated in the test report.

The temperature sensing means shall not significantly affect the temperature-rise.

Good thermal conductivity between the temperature sensing means and the surface of the part under test shall be ensured.

For electromagnet coils, the method of measuring the temperature by variation of resistance shall generally be used. Other methods are permitted only if it is impracticable to use the resistance method.

The temperature of the coils before beginning the test shall not differ from that of the surrounding medium by more than 3 K.

For copper conductors, the value of the hot temperature T_2 can be obtained from the value of the cold temperature T_1 as a function of the ratio of the hot resistance R_2 to the cold resistance R_1 by the following formula:

$$T_2 = \frac{R_2}{R_1} (T_1 + 234,5) - 234,5$$

where

T_1 and T_2 are expressed in degrees Celsius.

The test shall be made for a time sufficient for the temperature-rise to reach a steady-state value, but not exceeding 8 h. It is assumed that a steady-state is reached when the variation does not exceed 1 K per hour.

9.3.3.3.3 Temperature-rise of a part

The temperature-rise of a part is the difference between the temperature of that part measured in accordance with 9.3.3.3.2 and the ambient air temperature measured in accordance with 9.3.3.3.1.

9.3.3.3.4 Temperature-rise of the main circuit

The contactor shall be mounted as specified in 9.3.2.1 and shall be protected against abnormal external heating or cooling.

The main circuit shall be loaded as stated in 8.2.2.5.

All auxiliary circuits which normally carry current shall be loaded at their maximum rated operational current (see 5.6) and the control circuits shall be energized at their rated voltage.

Contactors having an integral enclosure and contactors only intended for use with a specified type of enclosure shall be tested in their enclosure for the conventional thermal current test. No opening giving false ventilation shall be allowed.

Contactors intended for use with more than one type of enclosure shall be tested either in the smallest enclosure stated by the manufacturer to be suitable or tested without an enclosure. If tested without an enclosure the manufacturer shall be prepared to state a value of conventional enclosed thermal current (see 5.3.3.3).

For tests with multiphase currents, the current shall be balanced in each phase within $\pm 5\%$, and the average of these currents shall be not less than the appropriate test current.

Unless otherwise specified in this document, the temperature-rise test of the main circuit is made at one or both of the conventional thermal currents, as defined in 5.3.3.2 and 5.3.3.3 and can be made at any convenient voltage.

When the heat exchange between the main circuit, the control circuit and the auxiliary circuits can be of significance, the temperature-rise tests stated in 9.3.3.3.4, 9.3.3.3.5, 9.3.3.3.6 and 9.3.3.3.7 shall be made simultaneously.

In the case of multipole contactors, the test can be carried out but, subject to the manufacturer's agreement, with single-phase current with all poles connected in series.

At the end of the test, the temperature-rise of the different parts of the main circuit shall not exceed the values given in Table 4 and Table 5.

The following test connection arrangements shall be used:

- a) The connections shall be single-core, p.v.c.-insulated, copper conductors with cross-sections as given in Table 15.
- b) The connections shall be in free air and spaced at approximately the distance existing between the terminals.
- c) For single-phase or multi-phase tests, the minimum length of any temporary connection from a terminal to another terminal or to the test supply or to a star point shall be 1 m.

Table 15 – Test copper conductors

Range of test current ^a		Conductor size ^{b, c}	
		mm ²	AWG/MCM
0	8	1,0	18
8	12	1,5	16
12	15	2,5	14
15	20	2,5	12
20	25	4,0	10
25	32	6,0	10
32	50	10	8
50	65	16	6
65	85	25	4

^a The value of the test current shall be greater than the first value in the first column and less than or equal to the second value in that column.

^b For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current can be used.

^c The table gives alternative sizes for conductors in the metric and AWG/MCM systems.

9.3.3.3.5 Temperature-rise of control circuits

The temperature-rise of control circuits shall be measured during the test of 9.3.3.3.4.

The temperature-rise tests of control circuits shall be made with the specified current and at the rated frequency. Control circuits shall be tested at their rated voltage.

Circuits intended for continuous operation shall be tested for a sufficient time for the temperature-rise to reach a steady-state value.

At the end of these tests the temperature-rise of the different parts of the control circuits shall not exceed the values specified in 8.2.2.6.

9.3.3.3.6 Temperature-rise of coils of electromagnets

Coils and electromagnets shall be tested according to the conditions given in 8.2.2.7.

They shall be tested for a sufficient time for the temperature-rise to reach a steady-state value.

The temperature shall be measured when thermal equilibrium is reached in both the main circuit and the coil of the electromagnet.

Coils and electromagnets of contactors shall be tested as follows:

- Electromagnets of contactors intended for a duty period of 8 h (continuous duty) shall be subjected only to the test prescribed in 8.2.2.7.1, with the corresponding rated current flowing through the main circuit for the duration of the test. The temperature-rise shall be measured during the test of 9.3.3.3.4.
- Electromagnets of contactors intended for intermittent duty shall be subjected to the test as stated above, and also to the test prescribed in 8.2.2.7.2 dealing with their duty class, with no current flowing through the main circuit.
- Specially rated (short-time and periodic duty) windings shall be tested as stated in 8.2.2.7.3 without current in the main circuit.

At the end of these tests the temperature-rise of the different parts shall not exceed the values specified in 8.2.2.7.

9.3.3.3.7 Temperature-rise of auxiliary circuits

The temperature-rise tests of auxiliary circuits shall be made during the test of 9.3.3.3.4 under the same conditions as those specified in 9.3.3.3.5 but can be carried out at any convenient voltage.

At the end of these tests the temperature-rise of the auxiliary circuits shall not exceed the values specified in 8.2.2.8.

9.3.3.4 Dielectric properties

9.3.3.4.1 Type tests

a) General conditions for withstand voltage tests

The contactor to be tested shall comply with the general requirements of 9.3.2.1.

If the contactor is to be used without an enclosure, it shall be mounted on a metal plate and all exposed conductive parts (frame, etc.) intended to be connected to the protective earth in normal service shall be connected to that plate.

When the base of the contactor is of insulating material, metallic parts shall be placed at all of the fixing points in accordance with the conditions of normal installation of the contactor and these parts shall be considered as part of the frame of the contactor.

Any actuator of insulating material and any integral non-metallic enclosure of contactor intended to be used without an additional enclosure shall be covered by a metal foil and connected to the frame or the mounting plate. The foil shall only be applied to those parts of surface which can be touched with the standard test finger (see Figure 10) during operation or adjustment of the contactor. If the insulation part of an integral enclosure cannot be touched by the standard test finger due to the presence of an additional enclosure, no foil shall be required.

For the dielectric test between phases, all circuits between these phases can be disconnected for the test.

NOTE 1 The purpose of this tests is to check the functional insulation only.

Where the control circuit normally connected to the main circuit is disconnected, the method used to maintain the main contacts closed shall be indicated in the test report.

b) Verification of impulse withstand voltage

1) General

The contactor shall comply with the requirements stated in 8.2.3.2.

The verification of the insulation is made by a test at the rated impulse withstand voltage.

Clearances equal to or larger than the values of case A of Table 17 can be verified by measurement, according to the method described in Annex E.

2) Test voltage

The test voltage shall be that specified in 8.2.3.2.

For contactor incorporating overvoltage suppressing means, the energy content of the test current shall not exceed the energy rating of the overvoltage suppressing means. The latter shall be suitable for the application.

NOTE 2 Such ratings are under consideration.

The test equipment shall be calibrated to produce a 1,2/50 μ s waveform as defined in IEC 61180. The output is then connected to the contactor to be tested and the impulse applied five times for each polarity at intervals of 1 s minimum. The influence of the contactor under test on the waveshape, if any, is ignored.

3) Application of test voltage

With the contactor mounted and prepared as specified in item 1) above, the test voltage is applied as follows:

- i) between all the terminals of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and the enclosure or mounting plate, with the contacts in all normal positions of operation;
- ii) between each pole of the main circuit and the other poles connected together and to the enclosure or mounting plate, with the contacts in all normal positions of operation;
- iii) between each control and auxiliary circuit not normally connected to the main circuit and:
 - the main circuit,
 - the other circuits,
 - the exposed conductive parts,
 - the enclosure or mounting plate,
 which, wherever appropriate, can be connected together;

4) Acceptance criteria

There shall be no unintentional disruptive discharge during the tests.

NOTE 3 An exception is an intentional disruptive discharge, for example by transient overvoltage suppressing means.

NOTE 4 The term "disruptive discharge" related to phenomena associated with the failure of insulation under electrical stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero.

NOTE 5 The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric.

NOTE 6 The term "flashover" is used when a disruptive discharge occurs over the surface of a dielectric in a gaseous or liquid medium.

NOTE 7 The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

NOTE 8 A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric, the loss can be only temporary.

c) Power-frequency withstand verification of solid insulation

1) General

This test applies to the verification of solid insulation and the ability to withstand temporary overvoltages.

The values of Table 19 are deemed to cover the ability to withstand temporary overvoltages (see Footnote a of Table 19).

2) Test voltage

The test voltage shall have a practically sinusoidal waveform and a frequency between 45 Hz and 65 Hz. The high-voltage transformer used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current shall be at least 200 mA.

The overcurrent relay shall not trip when the output current is less than 100 mA.

The value of the test voltage shall be as follows:

- i) for the main circuit, and for the control and auxiliary circuits, in accordance with Table 19. The uncertainty of measurement of the test voltage shall not exceed $\pm 3\%$.
- ii) if an alternating test voltage cannot be applied, for example due to EMC filter components, a direct test voltage can be used having the value of Table 19, third column. The uncertainty of measurement of the test voltage shall not exceed $\pm 3\%$.

The test voltage applied shall be within $\pm 3\%$.

3) Application of test voltage

For the dielectric test between phases, all circuits between these phases can be disconnected for the test.

NOTE 9 The purpose of this test is to check the basic and supplementary insulation only.

For the dielectric test between phase and earth, all circuits shall be connected.

NOTE 10 The purpose of this test is to check both basic and supplementary insulation, and the ability to withstand temporary overvoltages.

The test voltage shall be applied to for 5 s in accordance with items b) 3) i), b) 3) ii) and b) 3) iii) above.

4) Acceptance criteria

During the test, no flashover, breakdown of insulation either internally (puncture) or externally (tracking) or any other manifestation of disruptive discharge shall occur. Any glow discharge shall be ignored. Components connected between phase and earth can be damaged during the tests but such failure shall not result in a condition that would lead to a hazardous situation.

NOTE 11 The voltage levels to earth are based on IEC 60664-1 under worst case conditions which generally do not occur in practice.

d) Power-frequency withstand verification after switching tests

1) General

The test should be performed on the contactor whilst it remains mounted for the switching tests. If this is not practicable, it can be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

2) Test voltage

The requirements of item c) 2) above shall apply except that the value of the test voltage shall be $2 U_e$ with a minimum of 1 000 V RMS or 1 415 V DC if an AC voltage test cannot be applied. The value of U_e referred to is that at which switching tests have been performed.

3) Application of test voltage

The requirements of item c) 3) above shall apply. The application of the metal foil, according to 9.3.3.4.1, item a), is not required.

4) Acceptance criteria

The requirements of item c) 4) above shall apply.

e) Verification of DC withstand voltage

Under consideration.

f) Verification of creepage distances

The shortest creepage distances between phases, between circuit conductors at different voltages and live and exposed conductive parts shall be measured. The measured creepage distance with respect to material group and pollution degree shall comply with the requirements of 8.2.3.5.

9.3.3.4.2 Routine tests

a) Impulse withstand voltage

The tests shall be performed in accordance with item b) of 9.3.3.4.1. The test voltage shall be not less than 30 % of the rated impulse withstand voltage (without altitude correction factor) or $2 U_i$ whichever is the higher.

b) Power-frequency withstand voltage**1) Test voltage**

The test apparatus shall be the same as that stated in item c) 2) of 9.3.3.4.1 except that the overcurrent trip should be set at 25 mA.

However, at the discretion of the manufacturer for safety reasons, test apparatus of a lower power or trip setting can be used, but the short-circuit current of the test apparatus shall be at least eight times the nominal trip setting of the overcurrent relay, for example for a transformer with a short-circuit current of 40 mA, the maximum trip setting of the overcurrent relay shall be $5 \text{ mA} \pm 1 \text{ mA}$.

NOTE 1 The capacitance of the contactor can be taken into account.

The RMS value of the test voltage shall be $2 U_e$ with a minimum of 1 000 V RMS.

NOTE 2 In the case of multiple values, U_e refers to the highest value marked on the contactor or given in the manufacturer's documentation.

2) Application of test voltage

The requirements of item c) 3) of 9.3.3.4.1 shall apply, except that the duration of the test voltage shall be 1 s only.

However, as an alternative, a simplified test procedure can be used if it is considered to subject the insulation to an equivalent dielectric stress.

3) Acceptance criteria

The overcurrent relay shall not trip.

c) Combined impulse voltage and power-frequency withstand voltage

The tests of items a) and b) above can be replaced by a single power-frequency withstand test where the peak value of the sinusoidal wave corresponds to the value stated in items a) or b), whichever is the higher.

d) In no case the application of the metal foil according to 9.3.3.4.1, item a) is required.

9.3.3.4.3 Sampling tests for verification of clearances**a) General**

These tests are intended to verify the maintaining of the design conformity regarding clearances and are only applicable to contactor with clearances smaller than those corresponding to Table 17, case A.

b) Test voltage

The test voltage shall be that corresponding to the rated impulse withstand voltage.

c) Application of test voltage

The requirements of item b) 3) of 9.3.3.4.1 shall apply, except that the metal foil shall not be applied to the actuator or the enclosure.

d) Acceptance criteria

No disruptive discharge shall occur.

9.3.3.4.4 Tests for contactor with protective separation

Tests for contactor with protective separation are given in Annex I.

Table 16 – Impulse test voltages and corresponding altitudes

Rated impulse withstand voltage U_{imp} kV	$U_{1,2/50}$ impulse kV				
	Sea level	200 m	500 m	1 000 m	2 000 m
0,33	0,36	0,36	0,35	0,34	0,33
0,5	0,54	0,54	0,53	0,52	0,5
0,8	0,95	0,9	0,9	0,85	0,8
1,5	1,8	1,7	1,7	1,6	1,5
2,5	2,9	2,8	2,8	2,7	2,5
4	4,9	4,8	4,7	4,4	4
6	7,4	7,2	7	6,7	6
8	9,8	9,6	9,3	9	8

Table 17 – Minimum clearances in air

Rated impulse withstand voltage U_{imp} kV	Minimum clearances mm							
	Case A Inhomogeneous-field conditions (see 3.5.31)				Case B Homogeneous-field ideal conditions (see 3.5.30)			
	Pollution degree				Pollution degree			
	1	2	3	4	1	2	3	4
0,33	0,01				0,01			
0,5	0,04	0,2			0,04	0,2		
0,8	0,1		0,8		0,1		0,8	1,6
1,5	0,5	0,5		1,6	0,3	0,3		
2,5	1,5	1,5	1,5		0,6	0,6		
4	3	3	3		1,2	1,2	1,2	
6	5,5	5,5	5,5	5,5	2	2	2	2
8	8	8	8	8	3	3	3	3

Table 18 – Minimum creepage distances

Rated insulation voltage of equipment or working voltage AC, RMS or DC V^e	Creepage distances for equipment subject to long-term stress														
	mm														
	Pollution degree			Pollution degree				Pollution degree				Pollution degree			
	1 ^f	2 ^f	1	2				3				4			
	Material group			Material group				Material group				Material group			
	b	c	b	I ^a	II	IIIa	IIIb	I	II	IIIa	IIIb	I	II	IIIa	IIIb
10	0,025	0,04	0,08	0,4	0,4	0,4		1	1	1		1,6	1,6	1,6	
12,5	0,025	0,04	0,09	0,42	0,42	0,42		1,05	1,05	1,05		1,6	1,6	1,6	
16	0,025	0,04	0,1	0,45	0,45	0,45		1,1	1,1	1,1		1,6	1,6	1,6	
20	0,025	0,04	0,11	0,48	0,48	0,48		1,2	1,2	1,2		1,6	1,6	1,6	
25	0,025	0,04	0,125	0,5	0,5	0,5		1,25	1,25	1,25		1,7	1,7	1,7	
32	0,025	0,04	0,14	0,53	0,53	0,53		1,3	1,3	1,3		1,8	1,8	1,8	
40	0,025	0,04	0,16	0,56	0,8	1,1		1,4	1,6	1,8		1,9	2,4	3	
50	0,025	0,04	0,18	0,6	0,85	1,2		1,5	1,7	1,9		2	2,5	3,2	
63	0,04	0,063	0,2	0,63	0,9	1,25		1,6	1,8	2		2,1	2,6	3,4	d
80	0,063	0,1	0,22	0,67	0,95	1,3		1,7	1,9	2,1		2,2	2,8	3,6	
100	0,1	0,16	0,25	0,71	1	1,4		1,8	2	2,2		2,4	3,0	3,8	
125	0,16	0,25	0,28	0,75	1,05	1,5		1,9	2,1	2,4		2,5	3,2	4	
160	0,25	0,4	0,32	0,8	1,1	1,6		2	2,2	2,5		3,2	4	5	
200	0,4	0,63	0,42	1	1,4	2		2,5	2,8	3,2		4	5	6,3	
250	0,56	1	0,56	1,25	1,8	2,5		3,2	3,6	4		5	6,3	8	
320	0,75	1,6	0,75	1,6	2,2	3,2		4	4,5	5		6,3	8	10	
400	1	2	1	2	2,8	4		5	5,6	6,3		8	10	12,5	
a Material group I or material groups II, IIIa, IIIb where likelihood to track is reduced due to the conditions of IEC 60664-1.															
b Material groups I, II, IIIa, IIIb.															
c Material groups I, II, IIIa.															
d Values of creepage distances in this area have not been established. Material group IIIb is in general not recommended for application in pollution degree 4.															
e As an exception, for rated insulation voltages 127, 208, 415 and 440 V, creepage distances corresponding to the lower values 125 V, 200 V, 400 V respectively can be used.															
f The values given in these two columns apply to creepage distances of printed wiring materials.															

Table 19 – Dielectric test voltage corresponding to the rated insulation voltage

Rated insulation voltage U_i V	AC test voltage RMS V	DC test voltage ^{a, b} V
$U_i \leq 60$	1 000	1 415
$60 < U_i \leq 300$	1 500	2 120
$300 < U_i \leq 440$	1 640	2 320
^a Test voltages based on 6.4.5, 5 th paragraph of IEC 60664-1:2020. ^b A direct current test voltage can be used only if an alternating test voltage cannot be applied. See also item c) 2) ii) of 9.3.3.4.1.		

9.3.3.5 Making and breaking capacities

9.3.3.5.1 General test conditions

Tests for verification of making and breaking capacities shall be made according to the general test conditions stated in 9.3.2.1.

Four-pole contactors shall be tested as three-pole contactors with the unused pole, which in the case of contactors provided with a neutral pole is the neutral pole, connected to the frame. One test on three adjacent poles is sufficient.

The tests shall be made under the operating conditions stated in Table 7 without failure (see 9.3.3.5.4, item b)).

The control supply voltage shall be 100 % of U_s for the test of utilization categories AC-7a, AC-7c and AC-7d. For the test of utilization category AC-7b, it shall be 110 % of U_s for half the number of operating cycles and 85 % of U_s for the other half.

Connections to the main circuit shall be similar to those intended to be used when the contactor is in service. If necessary, or for convenience, the control and auxiliary circuits, and in particular the coil of the contactor, can be supplied by an independent source. Such a source shall deliver the same kind of current and the same voltage as specified for service conditions.

9.3.3.5.2 Test circuit

a) Figure 11, Figure 12, Figure 13 and Figure 14 give diagrams of the circuits to be used for the tests concerning:

- single-pole contactors on single-phase AC (Figure 11);
- two-pole contactors on single-phase AC (Figure 12);
- three-pole contactors or three single-phase contactors on three-phase AC (Figure 13);
- four-pole contactors on three-phase four wire AC (Figure 14).

A detailed diagram of the circuit used for the test shall be given in the test report.

b) The prospective current at the supply terminals of the contactor shall be not less than 10 times the test current.

c) The test circuit comprises the supply source, the contactor D under test and the load circuit.

d) 1) Utilization categories AC-7a and AC-7b:

The load circuit shall consist of resistors and air-cored reactors in series. Air-cored reactors in any phase shall be shunted by resistors taking approximately 0,6 % of the current through the reactor.

However, where a transient recovery voltage is specified, instead of the 0,6 % shunt resistors, parallel resistors and capacitors shall be included across the load, the complete, load circuit being as shown in Figure 16.

2) Utilization category AC-7c:

The diagram of the circuit is given under

Figure 22. The prospective short-circuit current of the supply shall be between 3 kA and 4 kA at $\cos \varphi = 0,90 \pm 0,05$.

The load circuit shall consist of resistors and air-cored reactors in series and capacitors in parallel.

The line resistor R_1 consists in a twin-core cable of $2 \times 12,5$ m in length with wires cross-section appropriate to the rated current.

The load circuit consists of:

- a compensated capacitor value C_p of 10 μF ($-0 \mu\text{F}$; $+2 \mu\text{F}$) per A.

Ex: for 10 A, $C_p = 100 \mu\text{F}$; for 20 A, $C_p = 200 \mu\text{F}$.

The capacitors shall be connected with 2,5 mm² conductors having the shortest possible length;

- an inductor, X, and a resistor, R, adjusted to give to the load circuit (comprising C_p , R and X) the power factor and the test current according to Table 7 and Table 9.

3) Utilization category AC-7d:

The diagram of the circuit is given under Figure 26.

The calculations are based on the following parameters in order to have the required values for inrush current and I^2t :

- a prospective short-circuit current (RMS) of the supply of 3 kA at $\cos \phi = 0,9$ (lagging);
- a resistance R3 equal to 0,25 Ω and an inductance L equal to 20 μH simulating the twin-core cable in the test

The load shall be in accordance with Figure 26. The values for the maximum peak value and the maximum I^2t of the inrush current are given in Table 20.

NOTE 1 R2 is the total series resistance in the lamp circuit including the ESR (equivalent series resistance) value of the capacitor.

The values of R2 and C in load B shall be chosen in order to reach the values ($\pm 5 \%$) for I_{peak} and I^2t as given in Table 20 when the switching contact closes at $90^\circ \pm 5^\circ$ phase-angle.

The value of R4 shall be chosen to reach the rated power as given in Table 7 and Table 20.

The values of R2 and C given in Table 21 are for information only. The circuit shall be adjusted to reach the I_{peak} and I^2t values of Table 20.

Table 20 – Values for I_{peak} and I^2t depending on the type of distribution system

Rated power W	I_{peak} A	I^2t A ² s	I_{peak} A	I^2t A ² s
	Distribution system: 220/380, 230/400 240/415	Distribution system: 220/380, 230/400 240/415	Distribution system: 120/208 127/220	Distribution system: 120/208 127/220
15	22	0,08	69	0,56
22 ^a	31	0,18	90	1
30	41	0,3	109	1,9
45 ^a	58	0,6	140	3,5
60	73	1,2	162	5,9
100	108	2,8	200	11,5
150	142	5,5	231	18,5
200	170	9	248	24,5
250	192	13	255	30
300	209	16,5	260	35
350	223	20,5	262	39
400	235	24,5	263	43
520 ^a	250	29	280	53
600 ^a	260	32	290	59

NOTE 1 For values not given in the Table, the test values are determined by interpolation.

NOTE 2 Above values are in-line with IEC 60669-2-1.

^a Intermediate values for making and breaking capacity test when other existing values can't be used. These values are based on Figure BB.4 of IEC 60669-2-1:2021.

Table 21 – Calculated circuit parameters

Rated Power W	R2(Ω) 230 V	C (μF) 230 V	R2 (Ω) 120 V	C (μF) 120 V
15	13	20	1,36	70
22	9	33	0,9	105
30	6,5	40	0,65	140
45	4,5	68	0,33	220
60	3,25	80	0,28	280
100	1,9	125	0,17	445
150	1,25	180	0,11	640
200	0,95	240	0,10	830
250	0,8	310	0,10	1000
300	0,7	355	0,11	1250
350	0,64	420	0,13	1500
400	0,59	480	0,135	1660
520	0,29	590	0,135	1900
600	0,22	680	0,135	2200
NOTE For values not given in the table, the values are recalculated.				

e) The loads shall be adjusted to obtain, at the specified voltage:

- the value of current, power-factor and power frequency recovery voltage specified in Table 7;
- when specified, the oscillatory frequency of the transient recovery voltage and the value of the factor γ .

The factor γ is the ratio of the value U_1 of the highest peak of the transient recovery voltage to the instantaneous value U_2 , at the instant of current zero, of the component of the recovery voltage at power frequency (see Figure 15).

f) The test circuit shall be earthed at one unique point and the position of this point shall be stated in the test report.

g) All parts of the contactor normally earthed in service, including the enclosure or the screens, shall be insulated from earth and connected as indicated in Figure 11, Figure 12, Figure 13 or Figure 14.

This connection shall comprise a fusible element F consisting of a copper wire 0,8 mm in diameter and at least 50 mm long, or an equivalent fusible element, for the detection of the fault current.

The prospective fault current in the fusible-element circuit shall be $1\,500\text{ A} \pm 10\%$, except as stated in NOTE 3 and NOTE 4. If necessary, a resistor limiting the current to that value shall be used.

NOTE 2 A copper wire of 0,8 mm in diameter will melt at 1 500 A in approximately half a cycle at a frequency between 45 Hz to 67 Hz.

NOTE 3 The prospective fault current can be less than 1 500 A, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in NOTE 2.

NOTE 4 In the case of a supply having an artificial neutral, a lower prospective fault current can be accepted, subject to the agreement of the manufacturer, with a smaller diameter copper wire (see NOTE 5) corresponding to the same melting time as in NOTE 2.

NOTE 5 The relationship between the prospective fault current in the fusible element circuit and the diameter of the copper wire is in accordance with the Table 22 below:

Table 22 – relationship between the prospective fault current in the fusible element circuit and the diameter of the copper wire

Diameter of copper wire	Prospective fault current in the fusible element circuit
Mm	A
0,1	50
0,2	150
0,3	300
0,4	500
0,5	800
0,8	1 500

9.3.3.5.3 Characteristics of transient recovery voltage

The following requirements apply to contactors of utilization category AC-7b.

To simulate the conditions in circuits including individual motor loads (inductive loads), the oscillatory frequency of the transient recovery voltage of the load circuit shall be adjusted to the value:

$$f = 2\,000 \times I_c^{0,2} \times U_e^{-0,8} \pm 10\%$$

where

f is the oscillatory frequency, in kilohertz;

I_c is the breaking current, in amperes;

U_e is the rated operational voltage of the equipment, in volts.

The factor γ shall be adjusted to the value:

$$\gamma = 1,1 \pm 0,05.$$

The value of reactance necessary for the test can be obtained by coupling several reactors in parallel on condition that the transient recovery voltage can still be considered as having only one oscillatory frequency. This is generally the case when the reactors have practically the same time-constant.

The load terminals of the contactor shall be connected as closely as possible to the terminals of the adjusted load circuit. The adjustment should be made with these connections in place.

Adjustment of the transient recovery voltage shall be made on the whole load circuit and, in particular, the earth point shall not be moved between the adjustment and the test.

A procedure for adjusting the load circuit is given in Annex C.

9.3.3.5.4 Rated making and breaking capacities

a) Rated making and breaking capacities of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 7.

b) Behaviour of the contactor during and condition after the making and breaking capacity tests.

During the tests within the limits of the specified making and breaking capacities of 9.3.3.5 and the verification of conventional operational performance of 9.3.3.6.2, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.3.5.2) and no welding of the contacts.

After the tests, the dielectric properties of the contactor shall be verified by a dielectric test as specified in 9.3.3.4.1, item d).

The contacts shall operate when the contactor is switched by the applicable method of control.

9.3.3.6 Operational performance capability

9.3.3.6.1 General

Tests concerning the verification of conventional operational performance are intended to verify that a contactor is capable of fulfilling the requirements given in Table 9.

Connections to the main circuit shall be similar to those intended to be used when the contactor is in service.

The test circuit given in 9.3.3.5.2 is applicable and the load is to be tuned according to 9.3.3.5.3.

The control voltage shall be 100 % of the rated control supply voltage.

9.3.3.6.2 Conventional operational performance of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 9.

9.3.3.6.3 Behaviour of the contactor during and condition after the conventional operational performance tests

The requirement of 9.3.3.5.4, item b), should be fulfilled and the dielectric properties of the contactor shall be verified by a dielectric test as specified in 9.3.3.4.1, item d).

9.3.4 Performance under short-circuit conditions

9.3.4.1 General

This subclause specifies test conditions for verification of compliance with the requirements of 8.2.5. Specific requirements regarding test procedure, test sequence, condition of contactor after the test are given in 9.3.4.2 and 9.3.4.3.

9.3.4.2 General conditions for short-circuit tests

9.3.4.2.1 General requirements for short-circuit tests

The general requirements of 9.3.2.1 apply. The contactor shall be operated under the conditions specified in 8.2.1. It shall be verified that the contactor operates correctly on no-load when it is operated under the above conditions.

9.3.4.2.2 Test circuit

- a) Figure 17, Figure 18, Figure 19 and Figure 20 give diagrams of the circuits to be used for the tests concerning:

- single-pole contactors on single-phase AC (Figure 17);
- two-pole contactors on single-phase AC (Figure 18);
- three-pole contactors on three-phase AC (Figure 19);
- four-pole contactors on three-phase four wire AC (Figure 20).

A detailed diagram of the circuit used for the test shall be given in the test report.

- b) The supply S feeds a circuit including resistors R_1 , reactors X and the contactor D under test.

In all cases the supply shall have sufficient power to permit the verification of the characteristics given by the manufacturer.

The resistance and reactance of the test circuit shall be adjustable to satisfy the specified test conditions. The reactors X shall be air-cored. They shall be connected in series with the resistors R_1 , 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 the test circuits including large air-cored reactors are not representative of usual service conditions, the air-cored reactor in each phase shall be shunted by a resistor taking approximately 0,6 % of the current through the reactor.

- c) In each test circuit (Figure 17, Figure 18, Figure 19 and Figure 20), the resistors and reactances are inserted between the supply source S and the contactor D under test. The positions of the closing device A and the current sensing devices (I_1 , I_2 , I_3) can be different. The connection of the contactor under test to the test circuit shall be stated in the test report.

When tests are made with current less than the rated value, the additional impedances required shall normally be inserted on the load side of the contactor between it and the short-circuit; they can, however, be inserted on the line side, in which case this shall be stated in the test report.

The test circuit diagram shall conform to the figures, otherwise modifications shall be noted in the test report.

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

- d) All parts of the contactor normally earthed in service, including the enclosure or the screens, shall be insulated from earth and connected to a point, as indicated in Figure 17, Figure 18, Figure 19 and Figure 20.

This connection shall comprise a fusible element F consisting of a copper wire 0,8 mm in diameter and at least 50 mm long, or of an equivalent fusible element for the detection of the fault current.

The prospective fault current in the fusible-element circuit shall be $1\,500\text{ A} \pm 10\%$, except as stated in Note 2 and Note 3. If necessary, a resistor limiting the current to that value shall be used.

NOTE 1 A copper wire of 0,8 mm in diameter will melt at 1 500 A in approximately half a cycle at a frequency between 45 Hz to 67 Hz.

NOTE 2 The prospective fault current can be less than 1 500 A, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 3 In the case of a supply having an artificial neutral, a lower prospective fault current can be accepted, subject to the agreement of the manufacturer, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 4 The relationship between the prospective fault current in the fusible element circuit and the diameter of the copper wire is in accordance with the Table 22.

9.3.4.2.3 Power-factor of the test circuit

The power-factor of each phase of the test circuit should be determined according to an established method which shall be stated in the test report.

Two examples are given in Annex D.

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

The power-factor shall be in accordance with Table 23.

The difference between the mean value and the maximum and minimum values of the power-factors in the different phases shall remain within $\pm 0,05$.

Table 23 – Values of power-factors corresponding to test currents and ratio n between peak and RMS values of current

Test current A	Power-factor	n
$I \leq 1\,500$	0,95	1,41
$1\,500 < I \leq 3\,000$	0,9	1,42
$3\,000 < I \leq 4\,500$	0,8	1,47
$4\,500 < I \leq 6\,000$	0,7	1,53

9.3.4.2.4 Calibration of the test circuit

The calibration of the test circuit is carried out by placing temporary connections B of negligible impedance as close as reasonably possible to the terminals provided for connecting the equipment under test.

Resistors R_1 and reactors X are adjusted so as to obtain, at the applied voltage, a current equal to the rated short-circuit breaking capacity as well as the power-factor indicated in 9.3.4.2.3.

In order to determine the short-circuit making capacity of the contactor under test from the calibration oscillogram, it is necessary to calibrate the circuit so as to ensure that the prospective making current is achieved in one of the phases.

NOTE The applied voltage is the open circuit voltage necessary to produce the specified power frequency recovery voltage (but see also Note 1 of 9.3.2.2.3).

The test circuit is energized simultaneously in all poles and the current curve is recorded for a duration of at least 0,1 s.

9.3.4.2.5 Test procedure

After calibration of the test circuit in accordance with 9.3.4.2.4, the temporary connections are replaced by the contactor under test, and its connecting cables, if any.

The contactor and its associated SCPD shall be mounted and connected as in normal use. They shall be connected to the circuit using a maximum of 2,4 m of cable (corresponding to the operational current) for each main circuit.

Three phase tests are considered to cover single-phase applications.

9.3.4.2.6 Interpretation of records

a) *Determination of the applied voltage and power-frequency recovery voltage*

The applied voltage and the power-frequency recovery voltage are determined from the record corresponding to the break test made with the contactor under test and evaluated as indicated in Figure 21.

The voltage on the supply side shall be measured during the first complete cycle after arc extinction in all poles and after high frequency phenomena have subsided (see Figure 21).

b) *Determination of the prospective breaking current*

This determination is made by comparing the current curves recorded during the calibration of the circuit with those recorded during the break test of the contactor (see Figure 21).

The AC component of the prospective breaking current is taken as being equal to the RMS value of the AC component of the calibration current at the instant which corresponds to the separation of the arcing contacts (value corresponding to $A_2/2\sqrt{2}$ of Figure 21, item a)). The prospective breaking current shall be the average of the prospective currents in all phases; the prospective current in any phase shall not vary from the average by more than 10 % of the average.

c) *Determination of the prospective peak making current*

The prospective peak making current is determined from the calibration record and its value shall be taken as being that corresponding to A_1 of Figure 21, item a). In the case of a three-phase test it shall be taken as the highest of the three A_1 values obtained from the record.

NOTE For tests on single-pole contactors, the prospective peak making current determined from the calibration record can differ from the value of the actual making current corresponding to the test, depending on the instant of making.

9.3.4.3 Conditional short-circuit current

9.3.4.3.1 General

The contactor and the associated SCPD shall be subjected to the tests given in 9.3.4.3.2 and 9.3.4.3.3. The tests shall be so conducted that conditions of maximum I_e and of maximum U_e are covered.

For a magnetically operated contactor, the magnet shall be held closed by a separate electrical supply at the specified control voltage. The SCPD used shall be as stated in 8.2.5. If the SCPD is a circuit-breaker with an adjustable current setting, the test shall be made with the circuit-breaker adjusted to the maximum setting.

During the test, all openings of the enclosure shall be closed as in normal service and the door or cover secured by the means provided.

A new sample can be used for each operation of the test sequences at prospective currents I_r and I_q .

9.3.4.3.2 Test at the prospective current I_r

The circuit shall be adjusted to the prospective test current corresponding to the rated operational current I_e according to Table 24.

The contactor and the associated SCPD shall then be connected to the circuit. The following sequence of operations shall be performed:

- 1) One breaking operation of the SCPD shall be performed with SCPD and the contactor closed prior to the test.
- 2) One breaking operation of the SCPD shall be performed by closing the contactor on to the short-circuit.

Table 24 – Value of the prospective test current according to the rated operational current

Rated operational current I_e A	Prospective current I_r kA
$0 < I_e \leq 16$	1
$16 < I_e \leq 63$	3

The power factor shall be according to Table 23 of 9.3.4.2.3.

9.3.4.3.3 Test at the rated conditional short-circuit I_q

This test is done if the current I_q is higher than the current I_r .

The circuit shall be adjusted to the prospective short-circuit I_q equal to the rated conditional short-circuit current.

If the SCPD is a fuse and the test current is within the current-limiting range of the fuse then, if possible, the fuse shall be selected to permit the maximum let through peak current I_p and I^2t .

The contactor and the associated SCPD shall then be connected to the circuit.

The following sequence of operations shall be performed:

- 1) One breaking operation of the SCPD shall be performed with SCPD and the contactor closed prior to the test.
- 2) One breaking operation of the SCPD shall be performed by closing the contactor on to the short-circuit.

9.3.4.3.4 Results to be obtained

The contactor shall be considered to have passed the tests at the prospective current I_r and, where applicable, the prospective current I_q if the following conditions are met:

- A The fault current has been successfully interrupted by the SCPD and the fuse or fuse element or solid connection between the enclosure and supply shall not have melted.
- B The door or cover of the enclosure has not been blown open, and it is possible to open the door or cover. Deformation of enclosure is considered acceptable provided that the degree of protection by the enclosure is not less than IP2X.
- C There is no damage to the conductors or terminals and no conductor has been separated from the terminals.
- D There is no cracking or breaking of an insulating base to the extent that the integrity of mounting of a live part is impaired.
- E There has been no discharge of parts beyond the enclosure. Damage to the contactor is acceptable and the contactor can be unsuitable for further use.

9.3.5 Overload current withstand capability

For the test, the contactor shall be mounted, wired and operated as specified in 9.3.2.

All poles of the contactor are simultaneously subjected to one test with the overload current and duration values stated in 8.2.4.4. The test is performed at any convenient voltage and it starts with the contactor at room temperature.

After the test, the contactor shall be substantially in the same condition as before the test. This is verified by visual inspection.

NOTE The I^2t value (Joule integral) calculated from this test cannot be used to estimate the performance of the contactor under short-circuit conditions.

9.3.6 Routine tests

9.3.6.1 General

Routine tests are tests to which each individual contactor is subjected during or after manufacture to ascertain whether it complies with the stated requirements.

Routine tests shall be carried out under the same or equivalent conditions to those specified for type tests in the relevant parts of 9.1.2. However, the limits of operation in 9.3.3.2 can be verified at the prevailing ambient air temperature with a correction if needed.

9.3.6.2 Operation and operating limits

Tests are carried out to verify operation within the limits specified in 8.2.1.2. In these tests it is not necessary to reach thermal equilibrium.

9.3.6.3 Dielectric tests

Subclause 9.3.3.4.2 applies.

9.4 Tests for EMC

9.4.1 General

No tests are required for equipment not incorporating electronic circuits (see 8.3.1).

The test sample shall be in the open or closed position, whichever is the worse, and shall be supplied with the rated control circuit supply voltage.

9.4.2 Immunity

9.4.2.1 General

The tests of Table 25 are required.

If, during the EMC tests, conductors are to be connected to the test sample, the cross-section and the type of the conductors are optional but shall be in accordance with the manufacturer's literature.

Where a range of contactors comprise similar control electronics, within similar frame sizes, it is only necessary to test a single representative sample.

The product shall perform according to the performance criteria given in Table 26.

After the tests, the operating limits of 9.3.3.2 shall be verified at ambient temperature.

Table 25 – Tests for EMC – Immunity

Type of test	Reference test standard	Minimum test level required	Performance criterion
Electrostatic discharges	IEC 61000-4-2	Air discharge 8 kV Contact discharge 4 kV	B
Radio-frequency electromagnetic field	IEC 61000-4-3	80 Hz to 1 000 MHz – 3 V/m 1,4 GHz to 6 GHz – 3V/m 80 % AM (1 kHz)	A
Fast transient	IEC 61000-4-4	+1 kV Tr/Th 5/50 ns Repetition frequency 100 kHz	B
Surge	IEC 61000-4-5	1,2/50 (8/20) Tr/Td μ s 2 kV (line-to-earth) 1 kV (line-to-line)	B
Radio-frequency common mode	IEC 61000-4-6	0,15 MHz to 80 MHz 3 V 80 % AM (1 kHz)	A
Power-frequency magnetic field	IEC 61095	Covered by 9.3.4 Short-circuit test	/
Voltage dips ^a	for $I_e \leq 16$ A IEC 61000-4-11	0 % of the rated control supply voltage U_s during 0,5 cycle	B
	for $I_e > 16$ A IEC 61000-4-34	0 % of the rated control supply voltage U_s during 1 cycle	B
		70 % of the rated control supply voltage U_s during 25/30 cycles (50/60 Hz)	C
Voltage interruptions ^a		0 % of the rated control supply voltage U_s during 250/300 cycles (50/60 Hz)	C

^a This equipment is inherently sensitive to voltage dips and short time interruptions on the control supply; it shall react within the limits of 8.2.1.2 and this is verified by the operating limits tests given in 9.3.3.2.

Table 26 – Specific acceptance criteria for immunity tests

Acceptance criteria			
Item	A	B	C
During the test referring to this criterion	the contactor shall remain in the expected position	contacts position can change self-recoverable	contacts position can change (not self-recoverable)

9.4.2.2 Electrostatic discharge

The point to which discharges shall be applied is selected by an exploration of the accessible surfaces of the contactor, when installed as for normal use.

9.4.2.3 Surge

Where three-phase equipment employs an identical circuit configuration for each phase then tests are required on only one phase.

9.4.3 Emission

9.4.3.1 Conducted radio-frequency emission tests

A description of the test, the test method and the test set-up are given in CISPR 14-1:2020, 5.1, 5.2 and 5.4.

The emission shall not exceed the levels given in Table 27.

Table 27 – Terminal disturbance voltage limits for conducted radio-frequency emission (for mains ports)

Frequency band MHz	Limits dB(μV)
0,15 to 0,5	66 to 56 quasi-peak 56 to 46 average
0,5 to 5,0	56 quasi-peak 46 average
5 to 30	60 quasi-peak 50 average
NOTE Limits are in accordance with CISPR 14-1 for mains ports Table 5.	

9.4.3.2 Radiated radio-frequency emission tests

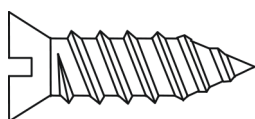
A description of the test, the test method and the test set-up are given in CISPR 14-1:2020, 5.1, 5.2 and 5.4.

Tests are required where the control and auxiliary circuits contain components with fundamental switching frequencies greater than 9 kHz, for example switch-mode power supplies, etc.

The emission shall not exceed the levels given in Table 28.

Table 28 – Radiated emission test limits

Frequency range MHz	Limits ^a Quasi-peak dB (μV)	
	at 10 m	at 3 m
30 to 230	30	40
230 to 1 000	37	47
^a Tests can be carried out at 3 m distance only to small equipment (equipment, either positioned on a tabletop or standing on the floor which, including its cables fits in a cylindrical test volume of 1,2 m in diameter and 1,5 m above the ground plane).		



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Figure 1 – Thread-forming tapping screw

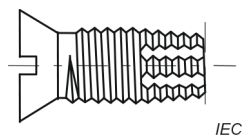


Figure 2 – Thread-cutting tapping screw

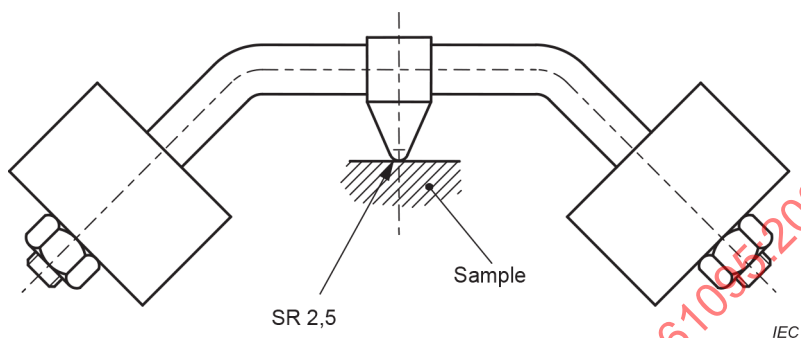


Figure 3 – Ball-pressure test apparatus (see 9.2.2.3.1)

Dimensions in millimetres

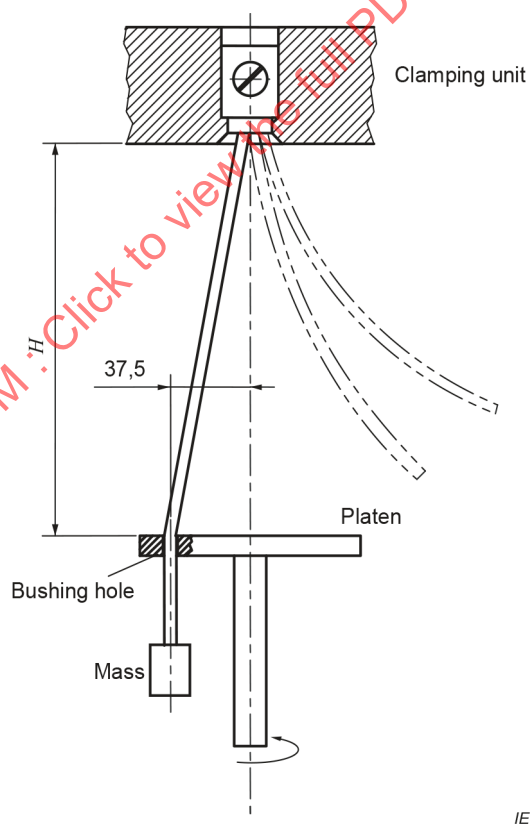


Figure 4 – Test equipment for flexion test (see 9.2.5.4)

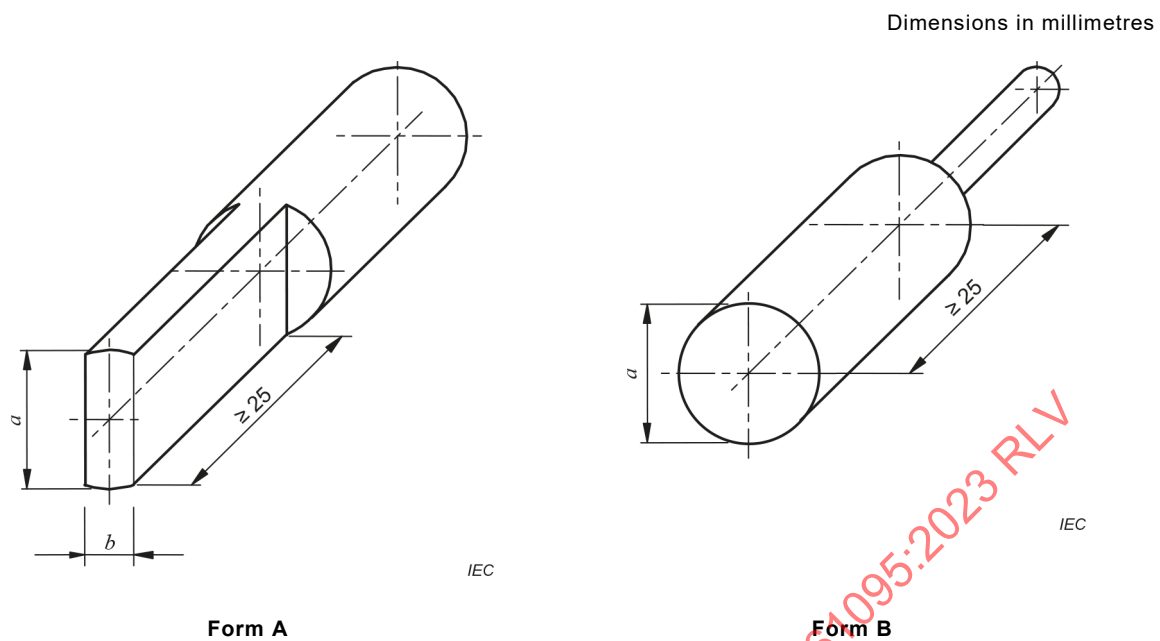
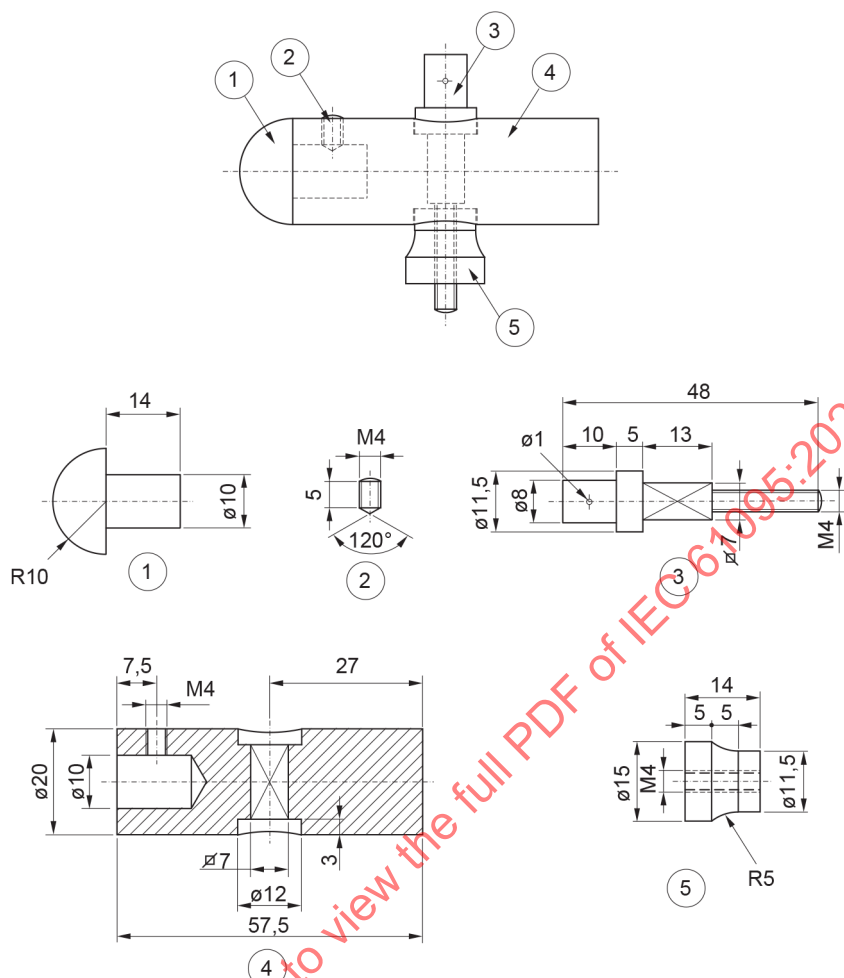


Figure 5 – Gauges of form A and form B (see 9.2.5.6)

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Dimensions in millimetres



IEC

Key:

1 Polyamide

2, 3, 4, 5 Steel Fe 360

Figure 6 – Pendulum for mechanical impact test apparatus (striking element)
 (see 9.2.6.2.1)

Dimensions in millimetres

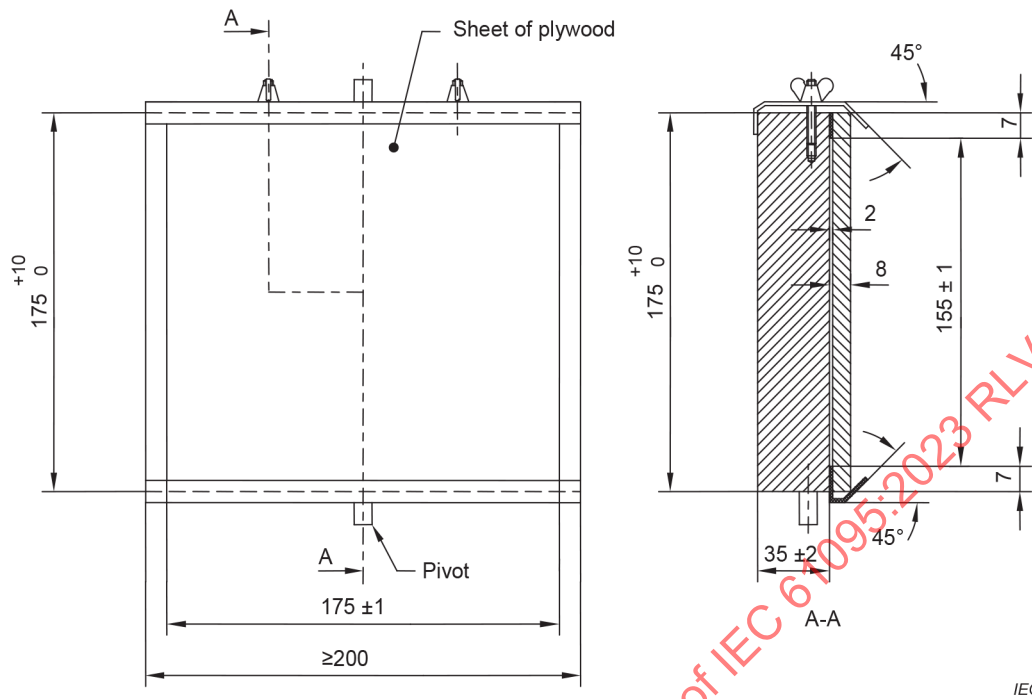


Figure 7 – Mounting support for sample for mechanical impact test
(see 9.2.6.2.1)

Dimensions in millimetres

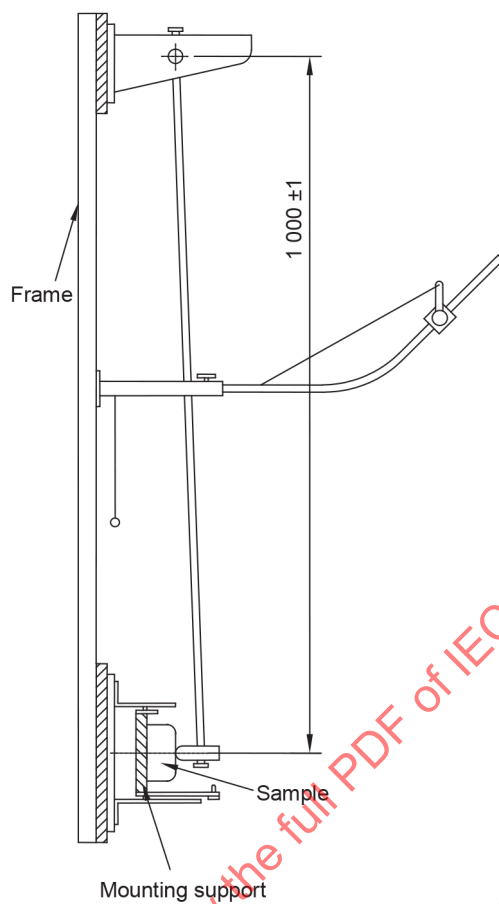
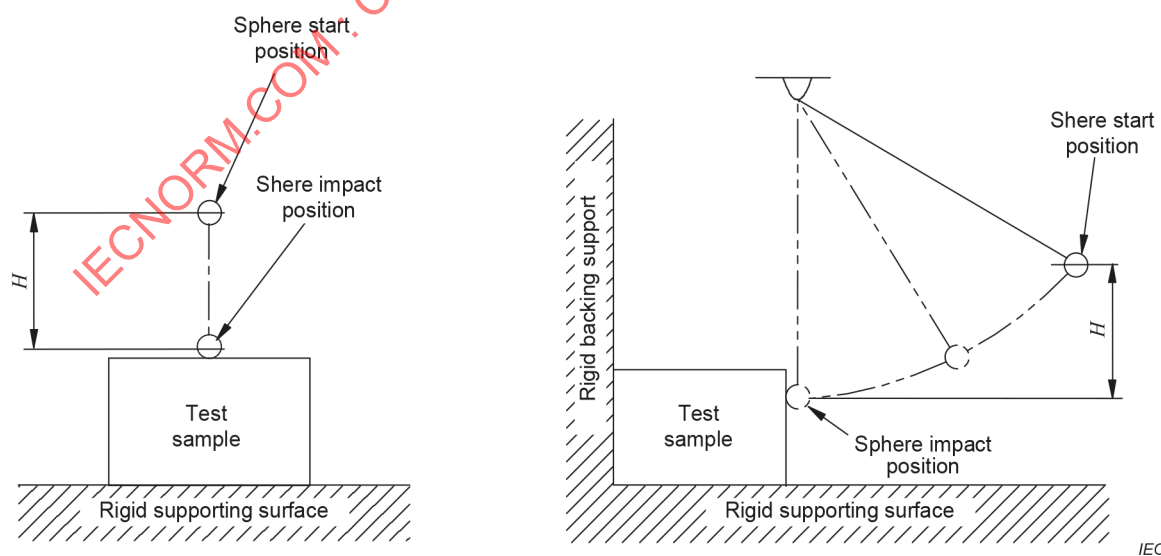


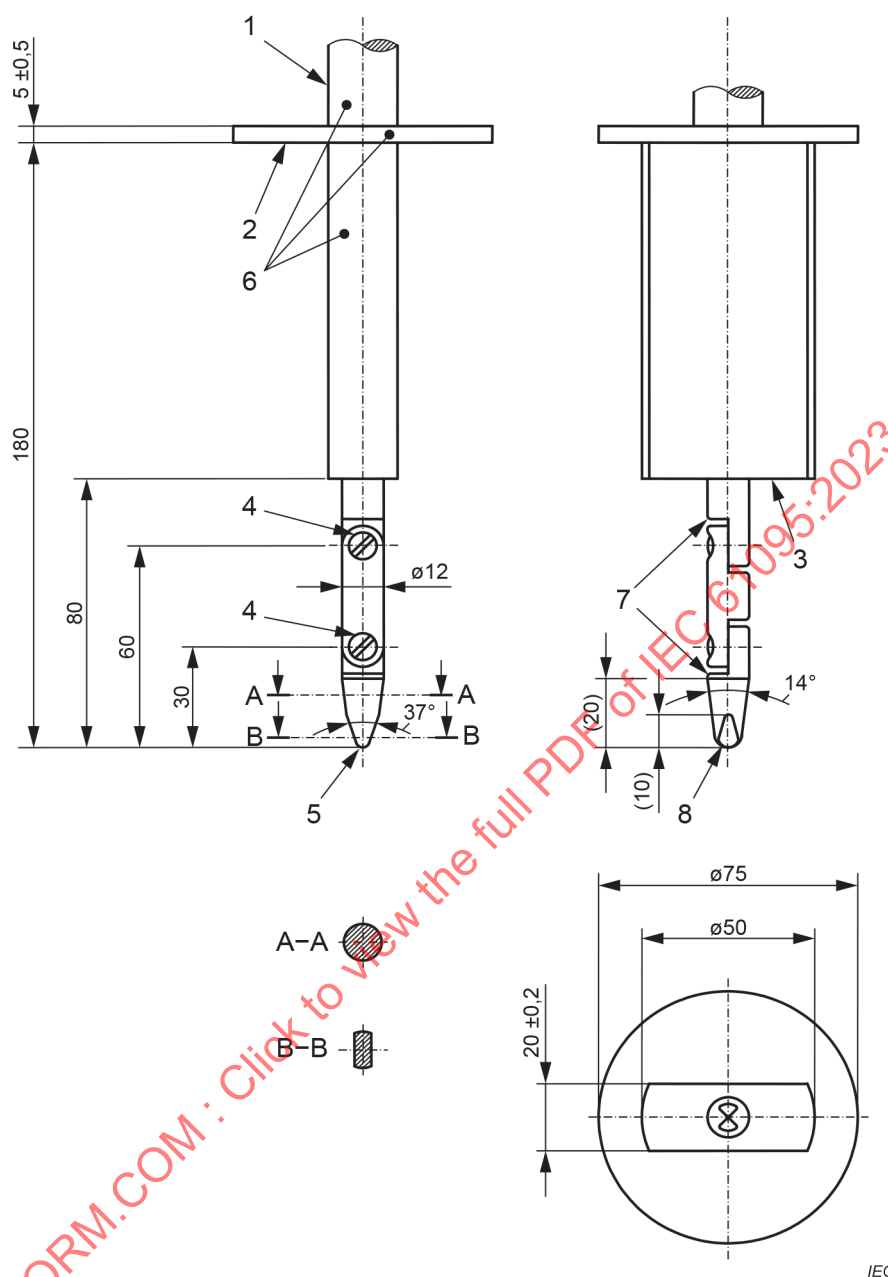
Figure 8 – Pendulum hammer test apparatus (see 9.2.6.2.1)

NOTE $H = 1\,300\text{ mm}$.

For the ball pendulum impact test, the sphere shall contact the test sample when the cord is in the vertical position as shown.

Figure 9 – Sphere test apparatus (see 9.2.6.2.2)

Dimensions in millimetres



Key:

1 handle	2 guard	3 stop face
4 joints	5 R2 ± 0,05 Cylindrica	6 insulating material
7 chamfer all edges	8 R4 ± 0,05 Spherical	

Material: metal, except where otherwise specified

Linear dimensions in millimetres

Tolerances on dimensions without specific tolerance:

on angles: 0/-10'

on linear dimensions:

up to 25 mm: 0/-0,05

over 25 mm: ±0,2

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

Figure 10 – Jointed test finger (according to IEC 60529:1989, Figure 1)

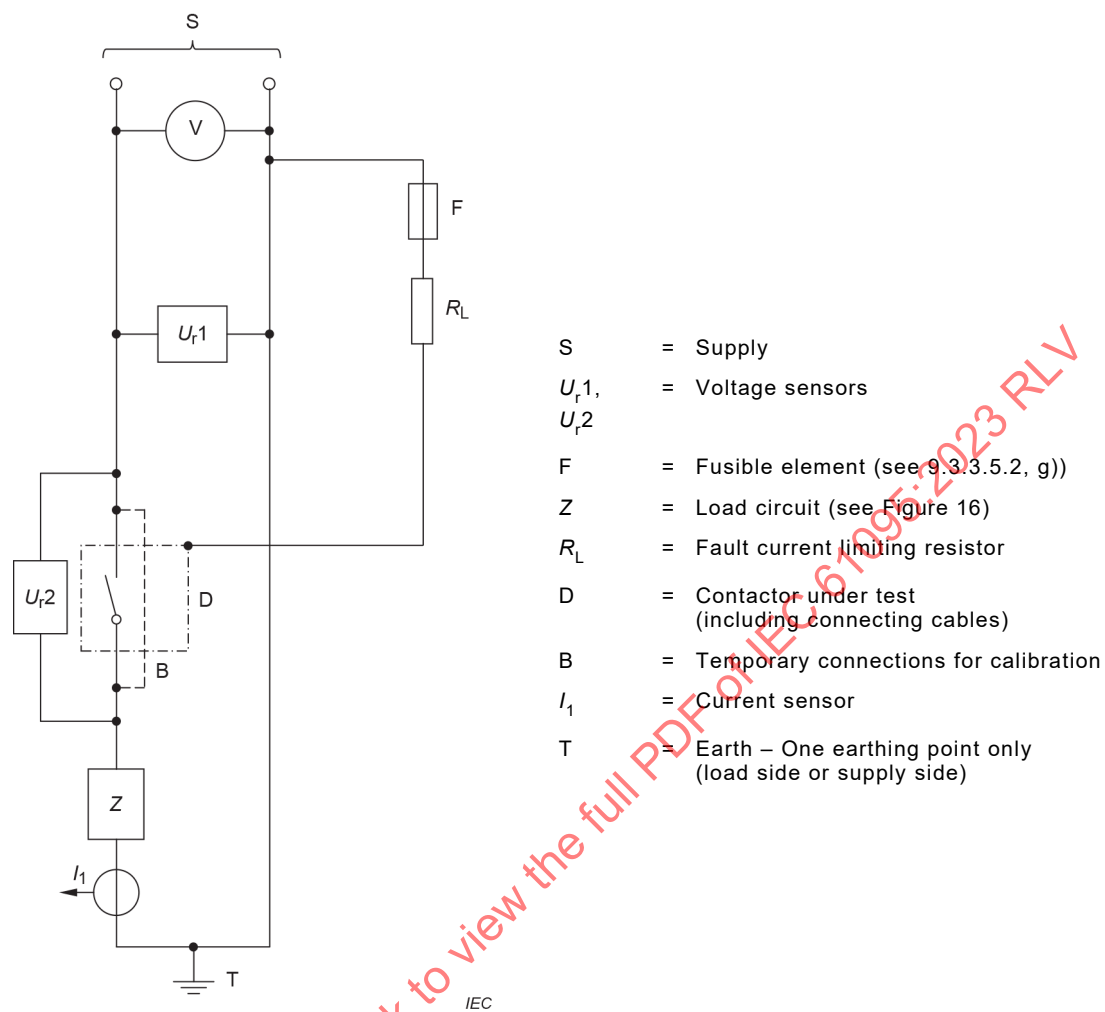
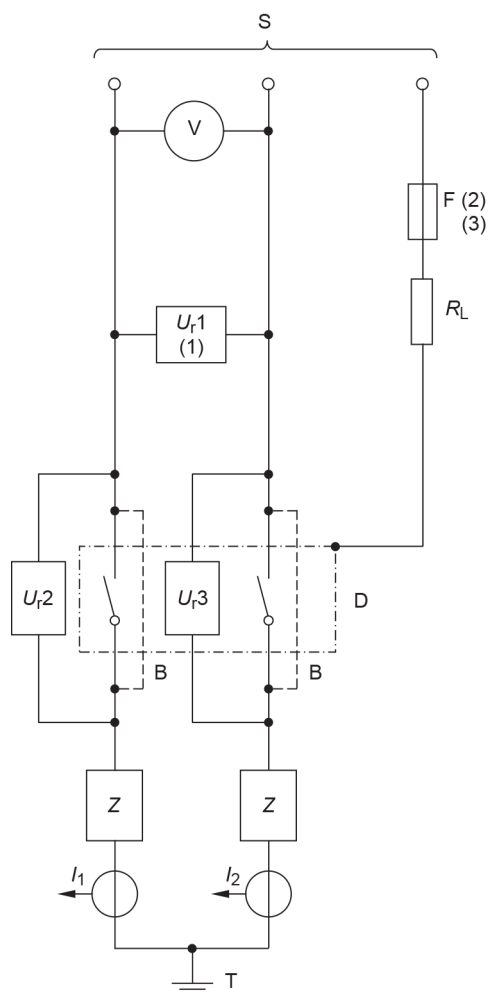


Figure 11 – Diagram of the test circuit for the verification of making and breaking capacities of a single-pole contactor on single-phase AC



S	=	Supply
U_{r1}, U_{r2}, U_{r3}	=	Voltage sensors
V	=	Voltage measuring device
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (see 9.3.3.5.2. g))
Z	=	Load circuit (see Figure 16)
R_L	=	Fault current limiting resistor
D	=	Contactor under test (including connecting cables)
B	=	Temporary connections for calibration
I_1, I_2	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)

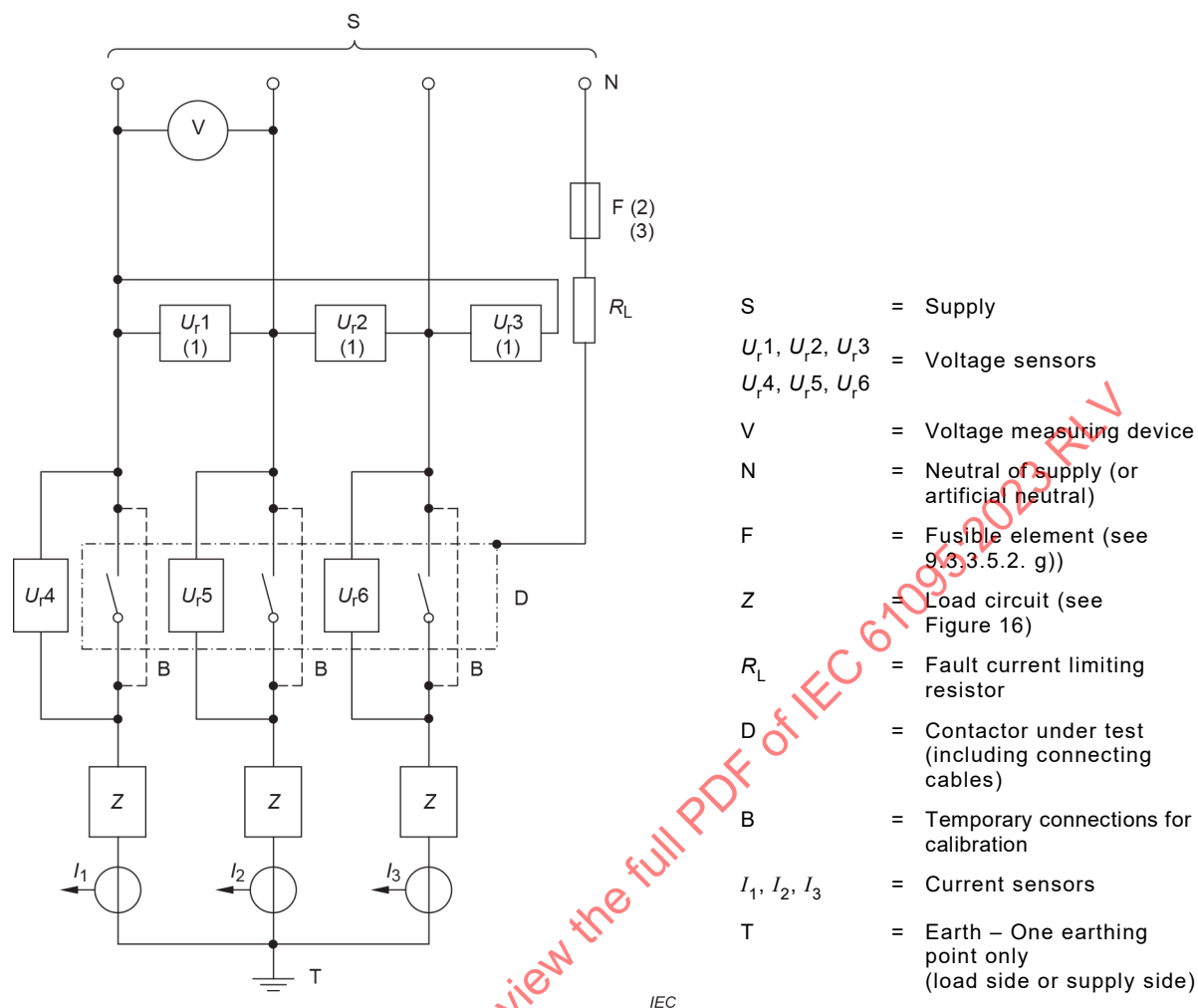
NOTE 1 U_{r1} can, alternatively, be connected between phase and neutral.

In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 2 In the USA and Canada, F shall be connected:

- to one phase of the supply for equipment marked with a single value of U_e
- to the neutral for equipment marked with a twin voltage for U_e (see Note 1 of 6.2).

Figure 12 – Diagram of the test circuit for the verification of making and breaking capacities of a two-pole contactor on single-phase AC



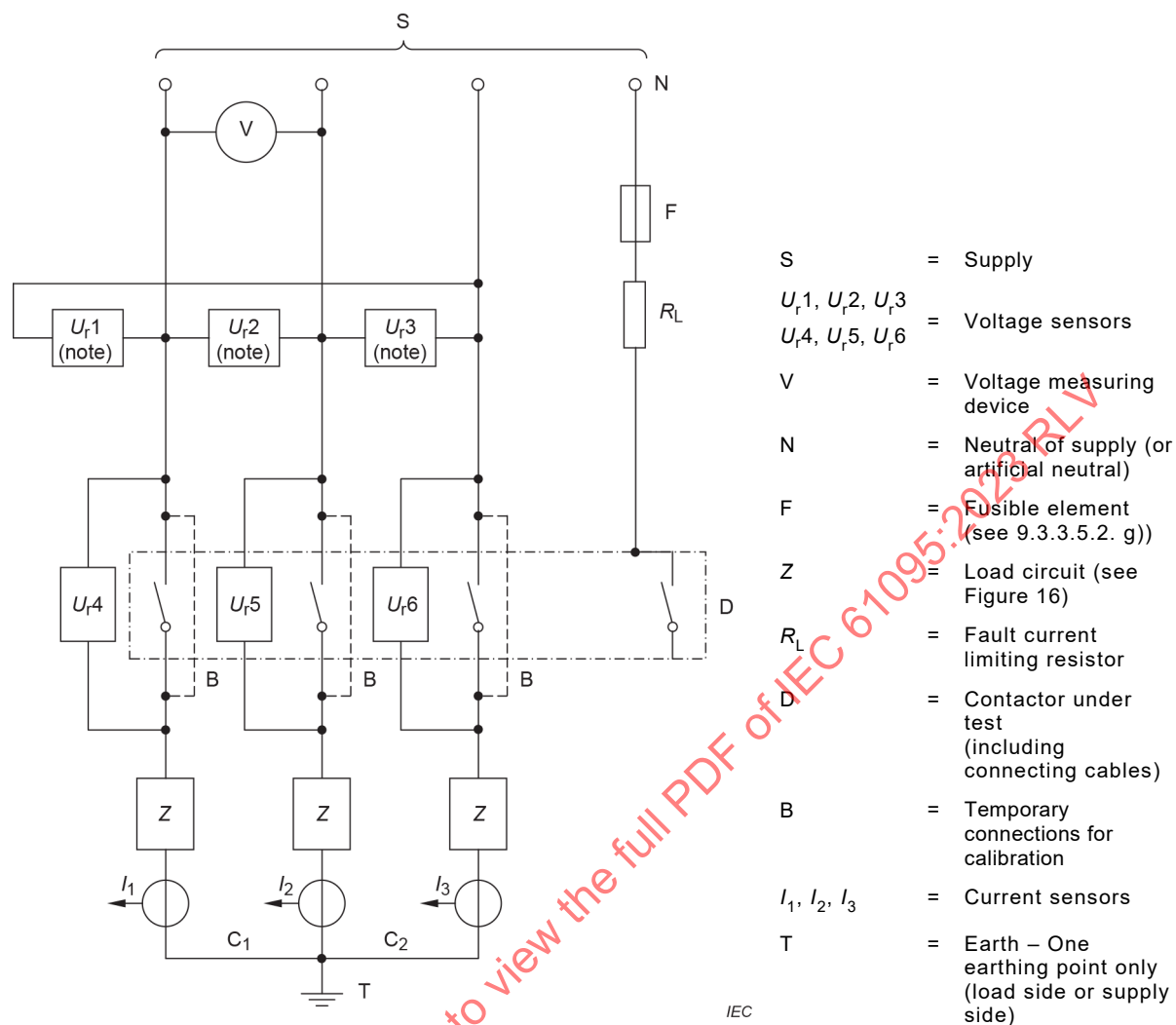
NOTE 1 U_r1, U_r2, U_r3 can, alternatively, be connected between phase and neutral.

In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 2 In the USA and Canada, F shall be connected:

- to one phase of the supply for equipment marked with a single value of U_e .
- to the neutral for equipment marked with a twin voltage for U_e (see Note 1 of 6.2).

Figure 13 – Diagram of the test circuit for the verification of making and breaking capacities of a three-pole contactor



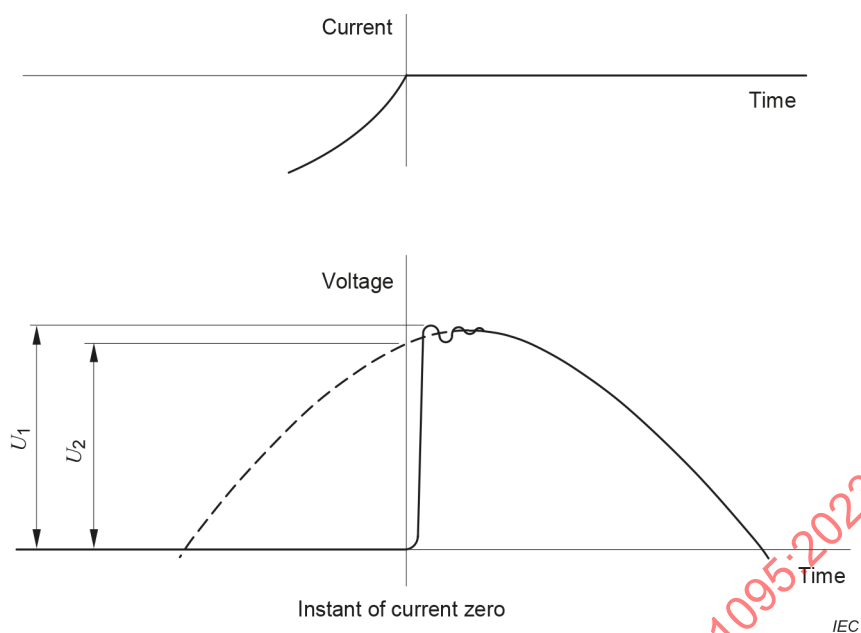
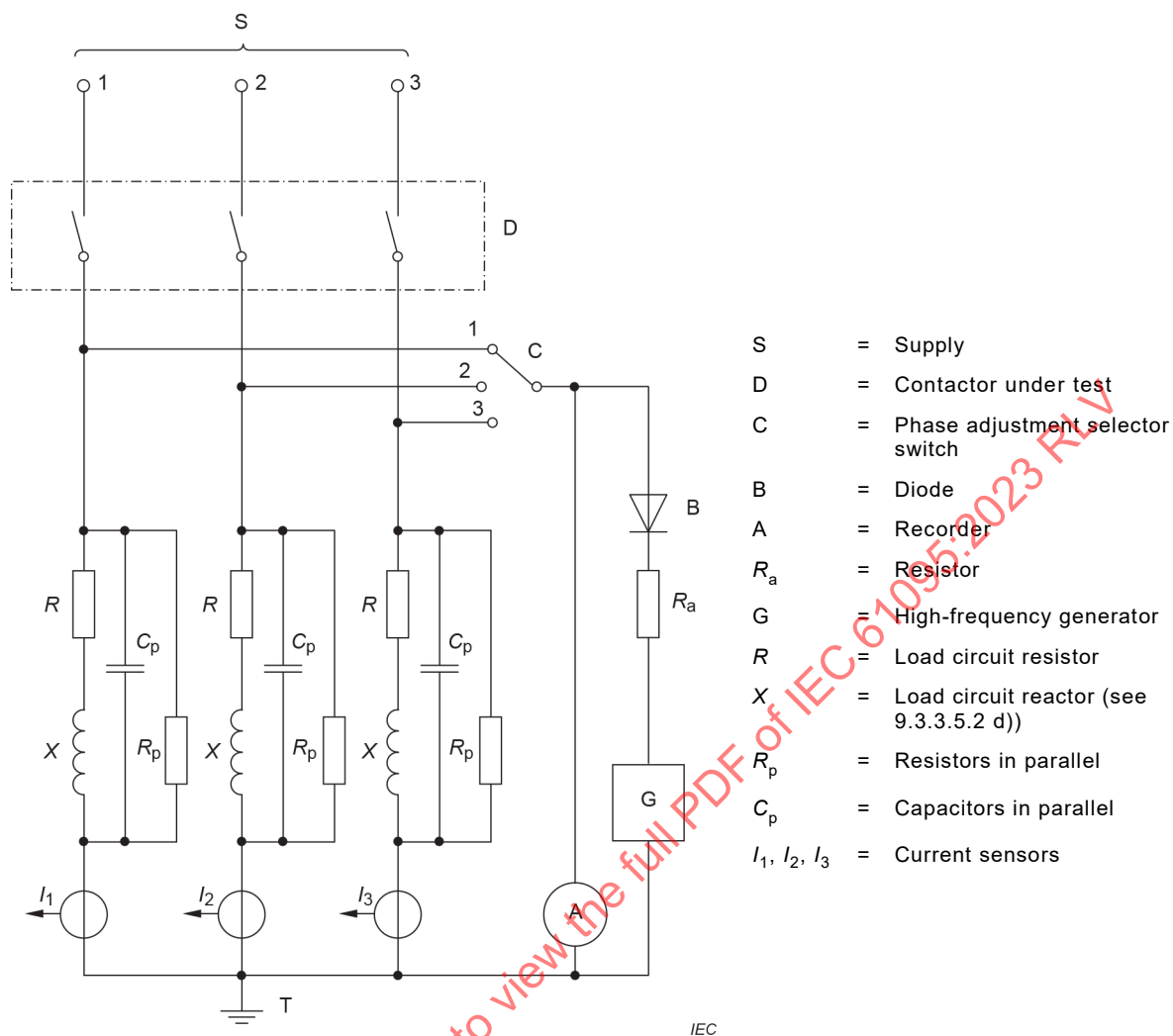
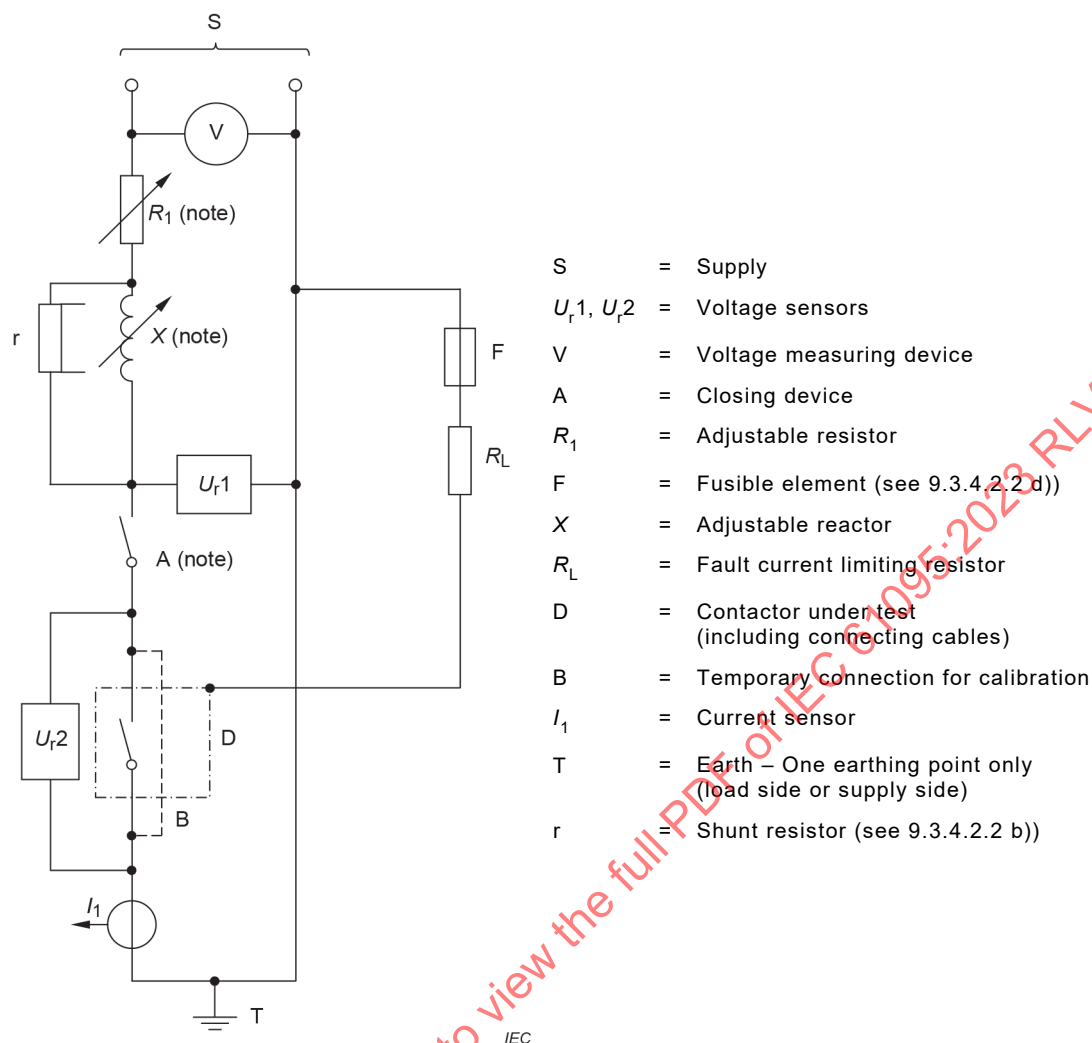


Figure 15 – Schematic illustration of the recovery voltage across contacts of the first phase to clear (see 9.3.3.5.2, e)) under ideal conditions



The relative positions of the high-frequency generator (G) and of the diode (B) shall be as shown.

Figure 16 – Diagram of a load circuit adjustment method



NOTE Adjustable loads X and R_1 can be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

Figure 17 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a single-pole contactor on single-phase AC

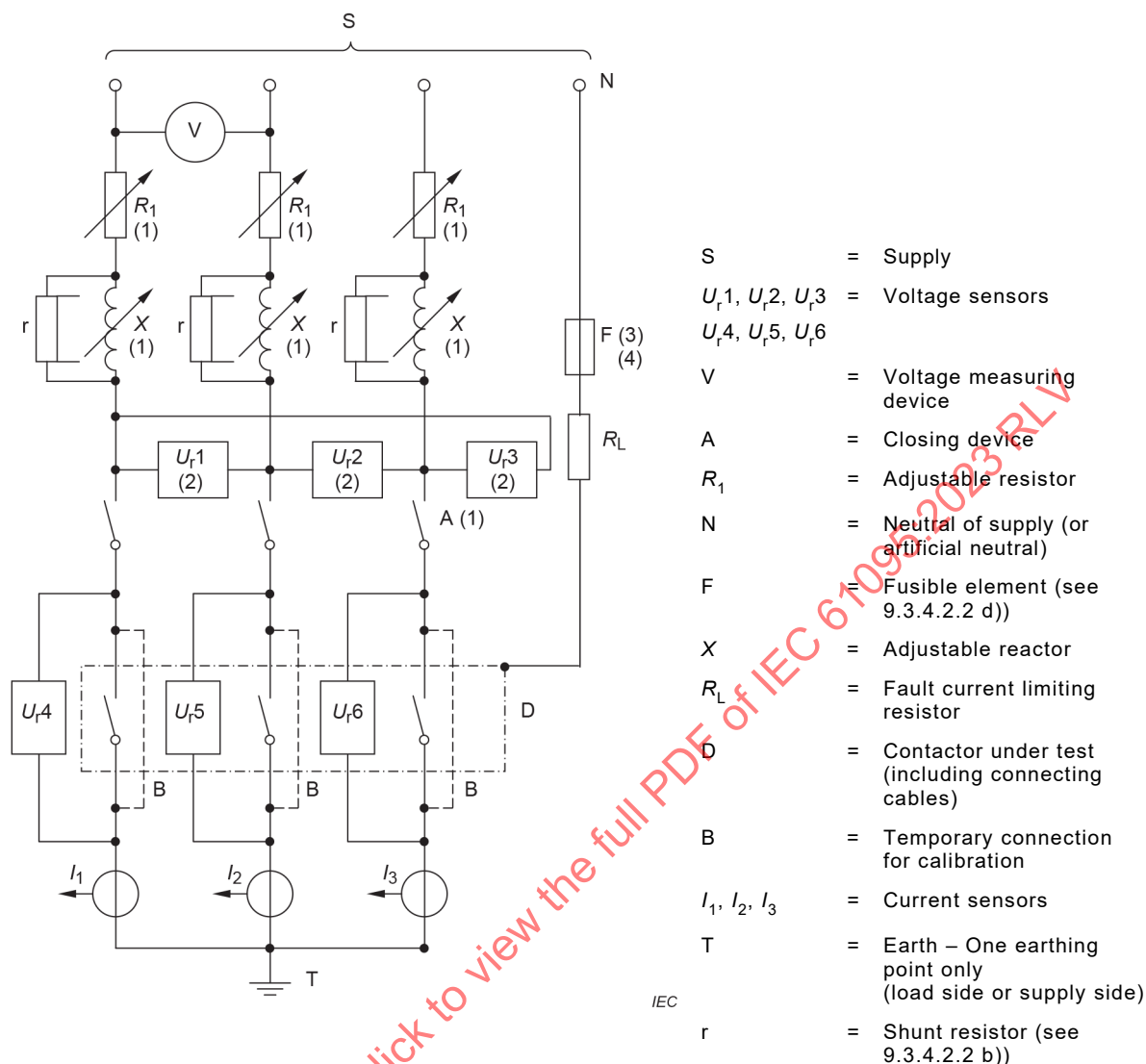


NOTE 2 U_r1 can, alternatively, be connected between phase and neutral.

NOTE 3 In the USA and Canada, F shall be connected:

- to one phase of the supply for equipment marked with a single value of U_e ,
- to the neutral for equipment marked with a twin voltage for U_e (see NOTE 1 to 6.2).

Figure 18 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a two-pole contactor on single-phase AC



NOTE 1 Adjustable loads X and R_1 can be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

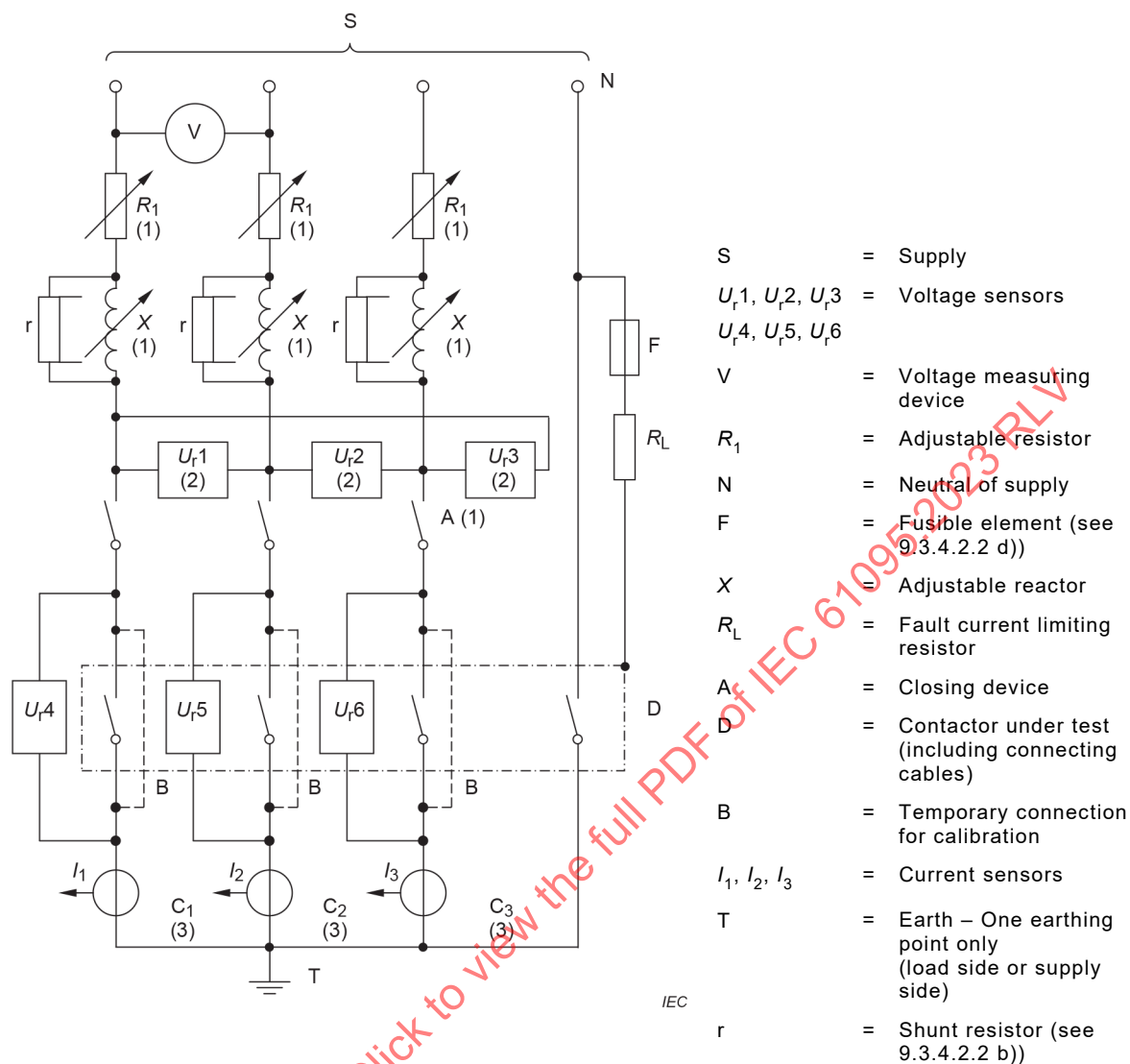
NOTE 2 U_{r1}, U_{r2}, U_{r3} can, alternatively, be connected between phase and neutral.

In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 3 In the USA and Canada, F shall be connected:

- to one phase of the supply for equipment marked with a single value of U_e
- to the neutral for equipment marked with a twin voltage for U_e (see NOTE 1 to 6.2).

Figure 19 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a three-pole contactor

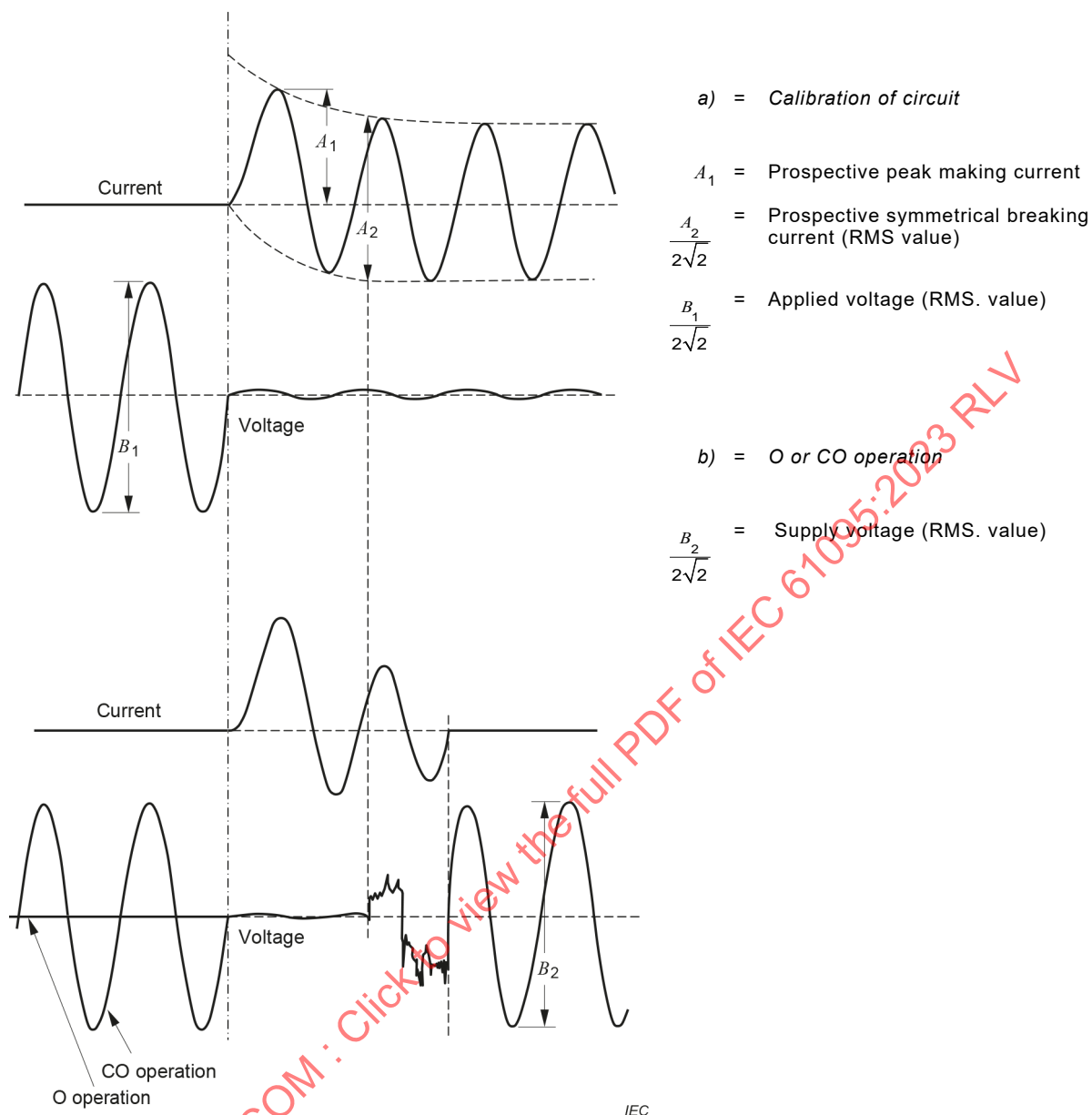


NOTE 1 Adjustable loads X and R_1 can be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

NOTE 2 U_{r1}, U_{r2}, U_{r3} can, alternatively, be connected between phase and neutral.

NOTE 3 If an additional test is applicable between the neutral pole and the adjacent pole, the connections C_1 and C_2 are omitted.

Figure 20 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a four-pole contactor



Making capacity (peak value) = A_1^*

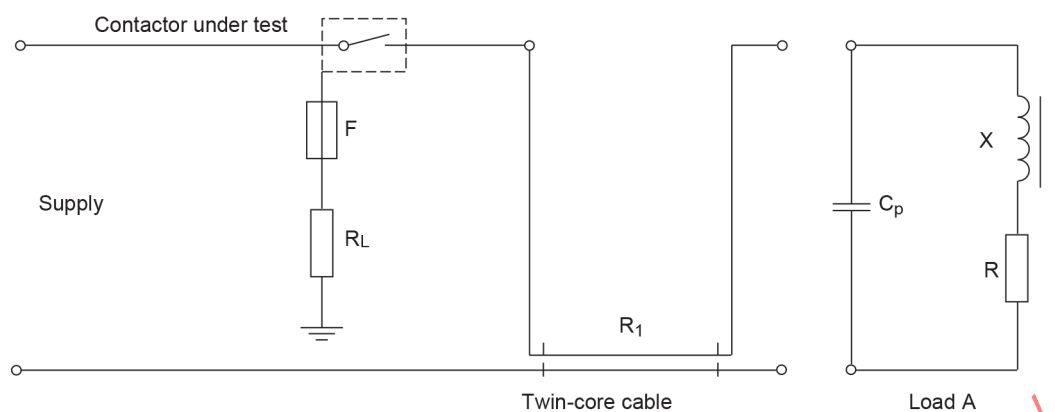
Breaking capacity (RMS value) = $\frac{A_2^*}{2\sqrt{2}}$

NOTE 1 The amplitude of the voltage trace, after initiation of the test current, varies according to the relative positions of the closing device, the adjustable impedances, the voltage sensors and according to the test circuit diagram.

NOTE 2 It is assumed that the instant of making is the same for calibration and test.

* See 9.3.4.2.6 b).

Figure 21 – Example of short-circuit making and breaking test record in the case of a single-pole contactor on single-phase AC



Key

F = Fuse element (see 9.3.3.5.2 g)

R_L = Fault current limiting resistor

R₁ = Twin-core cable resistor

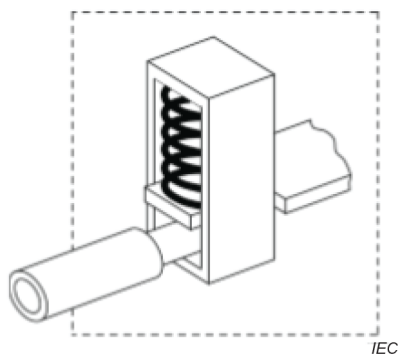
R = Resistor of load circuit

X = Inductor

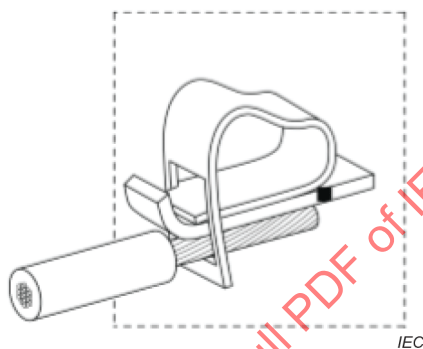
C_p = Capacitor

Figure 22 – Diagram of the test circuit for making and breaking verification for utilization category AC-7c

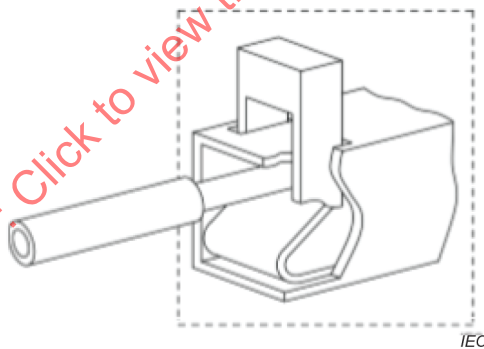
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(a) Screwless-type terminal with indirect pressure



(b) Screwless-type terminal with direct pressure



(c) Screwless-type terminal with actuating element

Figure 23 – Example of screwless-type clamping units

Dimensions in millimetres

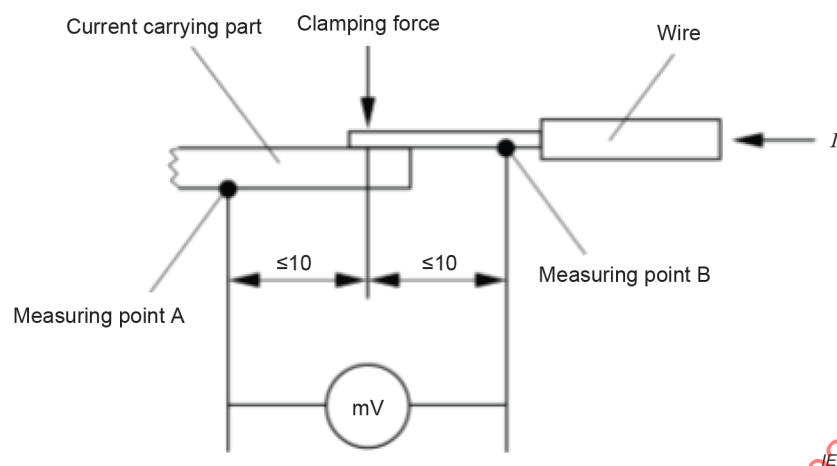


Figure 24 – Voltage drop measurement at contact point of the clamping terminal

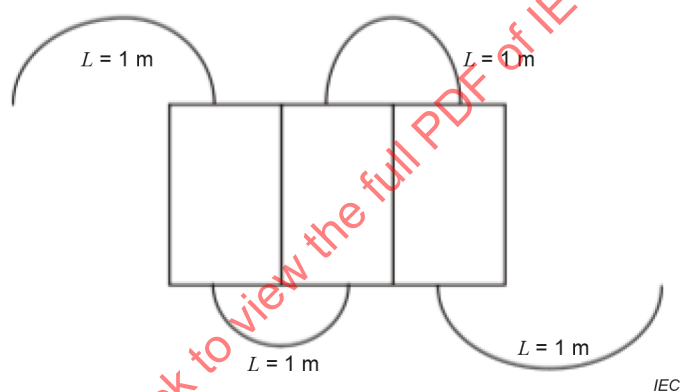
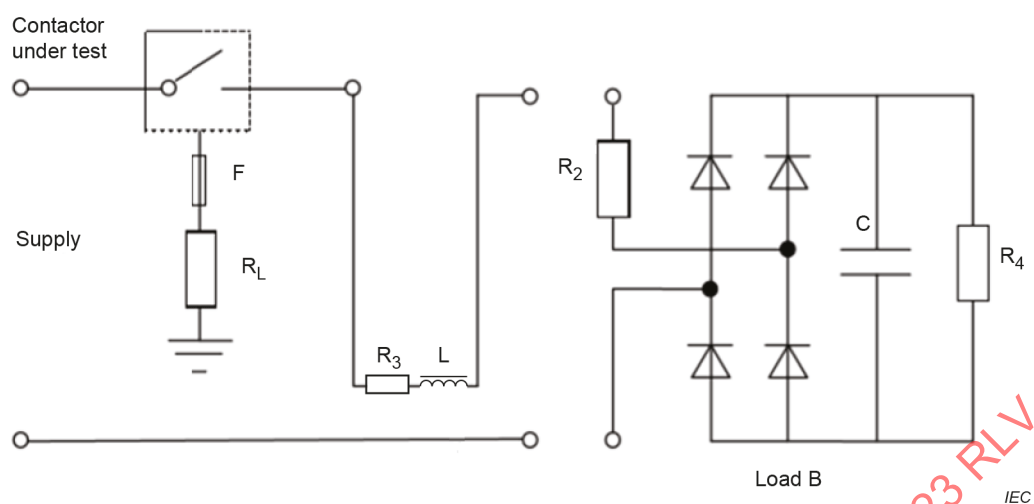


Figure 25 – Connecting samples for ageing test for screwless-type clamping units

**Key**

F = Fuse element (see 9.3.3.5.2 g)

R_L = Fault current limiting resistor

R_3 = Resistor simulating twin-core cable

L = Inductance simulating twin-core cable

R_2, R_4 = Resistors of load circuit

C = Capacitor

Figure 26 – Diagram of the test circuit for making and breaking verification for utilization category AC-7d

Annex A (normative)

Terminal marking and distinctive number

A.1 General

The purpose of identifying terminals of contactors is to provide information regarding the function of each terminal, or its location with respect to other terminals, or for other use.

A.2 Terminal marking of impedances (alphanumeric)

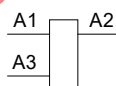
A.2.1 Coils

A.2.1.1 The two terminals of a coil for an electromagnetically operated drive shall be marked by A1 and A2.

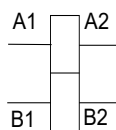


A.2.1.2 For a coil with tapplings, the terminals of the tapplings are marked in sequential order A3, A4, etc.

EXAMPLE



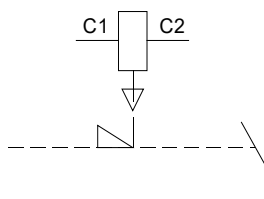
A.2.1.3 For a coil having two windings, the terminals of the first winding shall be marked A1, A2 and of the second winding B1, B2.



A.2.2 Electromagnetic releases

A.2.2.1 Shunt release

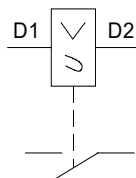
The two terminals of a shunt release shall be marked C1 and C2.



NOTE For a device with two shunt releases (for example with different ratings), the terminals of the second release are marked preferably C3 and C4.

A.2.2.2 Under-voltage release

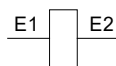
The two terminals of a coil intended to be used exclusively as an under-voltage release shall be marked D1 and D2.



NOTE For a device with two shunt releases (for example with different ratings), the terminals of the second release are marked preferably D3 and D4.

A.2.3 Interlocking electromagnets

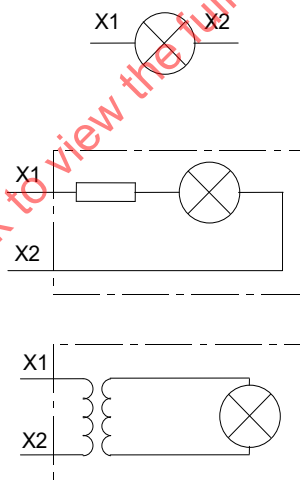
The two terminals of an interlocking electromagnet shall be marked E1 and E2.



A.2.4 Indicating light devices

The two terminals of an indicating light device shall be marked X1 and X2.

EXAMPLE



NOTE The term "indicating light devices" includes any incorporated resistor or transformer.

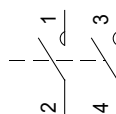
A.3 Terminal marking of contact elements for contactors with two positions (numerical)

A.3.1 Contact elements for main circuits (main contact elements)

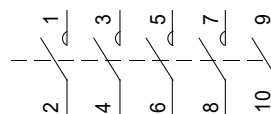
The terminals of main switching elements are identified by single figure numbers.

Each terminal marked by an odd number is associated with that terminal marked by the following even number.

EXAMPLES



Two main contact elements



Five main contact elements

When a contactor has more than five main contact elements, alphanumerical marking shall be chosen, according to IEC 60445.

A.3.2 Contact elements for auxiliary circuit (auxiliary contact elements)

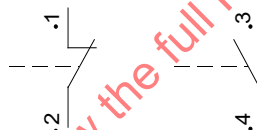
A.3.2.1 General

The terminals of auxiliary contact elements are identified by two-figure numbers:

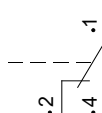
- the figure of the units is a function number;
- the figure of the tens is a sequence number.

A.3.2.2 Function number

A.3.2.2.1 Function numbers 1 and 2 are allocated to break-contact elements and functions 3 and 4 to make-contact elements.



The terminals of change-over contact elements are marked by the function numbers 1, 2 and 4.

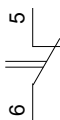


NOTE The definitions of break-contact element and make-contact element are given in IEC 60050-441.

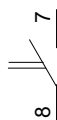
A.3.2.2.2 Auxiliary contact elements with special functions, such as time-delayed auxiliary contact elements, are identified by the function numbers 5 and 6, 7 and 8 for break-contact elements and make-contact elements respectively.

EXAMPLES

Break-contact delayed on closing



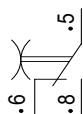
Make-contact delayed on closing



The terminals of change-over contact elements with special functions are marked by the function numbers 5, 6 and 8.

EXAMPLE

Change-over contact delayed in both directions

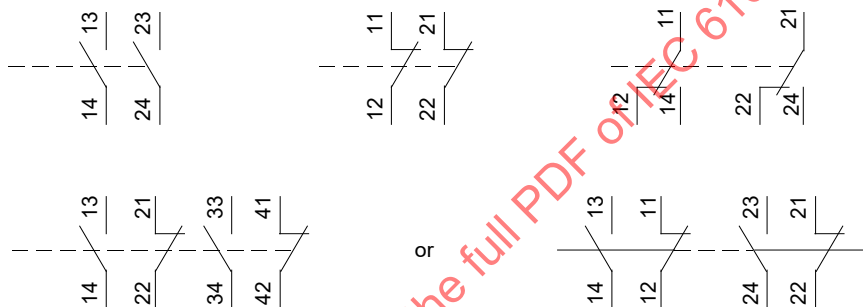


A.3.2.3 Sequence number

A.3.2.3.1 Terminals belonging to the same contact elements are marked with the same sequence numbers.

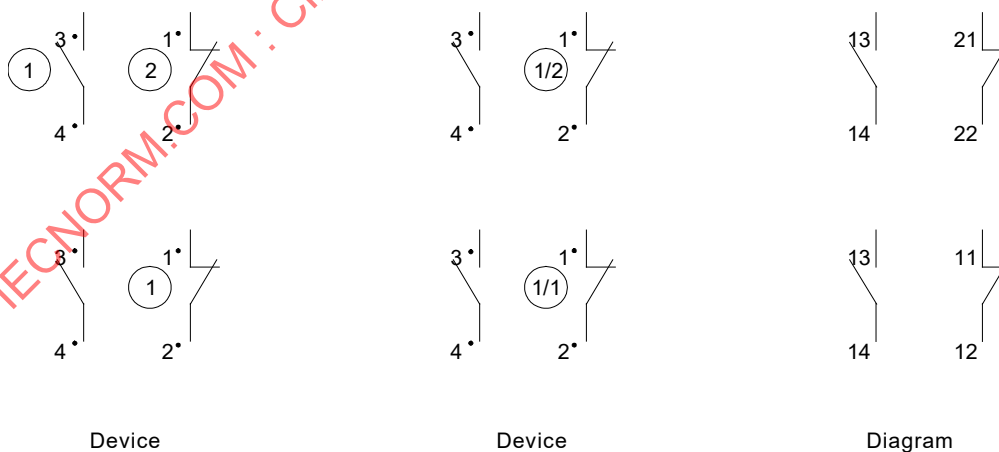
All contact elements having the same function shall have different sequence numbers.

EXAMPLES



A.3.2.3.2 The sequence number can be omitted from the terminals only if additional information provided by the manufacturer or the user clearly gives such a number.

EXAMPLES



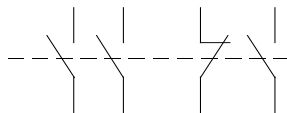
NOTE The dots shown in the examples of A.3.2 are merely used to show the relationship and are not necessarily used in practice.

A.4 Distinctive number

A device with a fixed number of make-contact elements and break-contact elements can be allocated a two-figure distinctive number.

The first figure indicates the number of make-contact elements and the second figure the number of break-contact elements.

Distinctive number 31



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Annex B (normative)

Test sequences and number of samples

B.1 Test sequences

The tests are made according to Table B.1, where the tests in each sequence are carried out in the order indicated.

Table B.1 – Test sequences

Test sequences	Subclauses	Tests or inspections
A	9.3.3.3	Temperature-rise
	9.3.3.2	Operating limits
	9.3.3.5	Making and breaking capacities
B	9.3.3.4	Dielectric properties ^a
	9.3.3.6	Operational performance capability
C	9.2.2.2	Test of resistance to humidity
	9.3.5	Ability to withstand overload currents
	9.2.2.5	Test of resistance to rusting
D	9.2.7	Test of durability of marking
	9.2.6	Test of resistance to impact
	9.3.3.4	Verification of clearances when necessary and verification of creepage distances
E	9.2.5	Mechanical properties of terminals
	9.2.3	Test on screws or nuts other than those on terminals which are intended to be operated during installation or maintenance
	9.2.2.3	Test of resistance to heat
	9.2.2.4	Tests of resistance to abnormal heat and fire
	9.2.2.6	Test of resistance to tracking ^b
F	9.2.2.1	Test of resistance to ageing
	9.2.4	Verification of the degrees of protection of enclosed contactors
G	9.3.4	Performance under short-circuit conditions
H	9.2.8	Breakdown of components, if applicable
I	9.4	Tests for EMC, if applicable
^a Dielectric withstand test only, without measurement of clearances and creepage distances.		
^b In case where no tests on specimen of insulating materials are available.		

B.2 Number of samples

The number of samples to be submitted to the different test sequences are those indicated in the following Table B.2. Contactors in clean, new condition shall be used for each sequence, unless under specific agreement

The samples required for a test sequence are submitted to all the tests of this test sequence and the requirements are met if all the tests are satisfied.

If only one of the samples does not satisfy a test in a given test sequence due to an assembly or manufacturing fault, which is not representative of the design, that test and any preceding ones which can have influenced the results of the test, shall be repeated on another full set of samples. Requirements are met if all the repeated tests are satisfied.

Table B.2 – Number of samples to be tested

Test sequences	Number of samples
A	3
B	3
C	1
D	1
E	1
F	1
G	4 ^a
H	/ ^b
I	3 ^c
^a One sample can be used for each operation if necessary (see 9.3.4.3). ^b Number of samples defined by the analysis ^c A set of three new samples may be used for each EMC test	

Annex C (normative)

Description of a method for adjusting the load circuit

To adjust the load circuit to obtain the characteristics prescribed in 9.3.3.5.3 several methods can be applicable in practice. One of them is described below.

The principle is illustrated in Figure 16.

The oscillatory frequency f of the transient recovery voltage and the value of the factor γ are essentially determined by the natural frequency and the damping of the load circuit. Since these values are independent of the voltage and frequency applied to the circuit, the adjustment can be made by energizing the load circuit from an AC power supply, the voltage and frequency of which can be different from those of the supply source utilized for the test of the contactor. The circuit is interrupted at a current zero by a diode, and the oscillations of the recovery voltage are observed on the screen of a cathode-ray oscilloscope, the sweep of which is synchronized with the frequency of the power supply (see Figure C.1).

To permit reliable measurements to be made, the load circuit is energized by means of a high-frequency generator G giving a voltage suitable for the diode. The frequency of the generator is chosen equal to:

- a) 2 kHz for test currents up to and including 1 000 A;
- b) 4 kHz for test currents higher than 1 000 A.

Connected in series with the generator are:

- a dropping resistor having a resistance value R_a high with respect to the load circuit impedance ($R_a \geq 10 Z$, where $Z = \sqrt{R^2 + (\omega L)^2}$ and where ω is $2\pi \times 2\,000\text{ s}^{-1}$ or $2\pi \times 4\,000\text{ s}^{-1}$ for cases a) and b) respectively;
- an instantaneously blocking switching diode B; switching diodes commonly used in computers such as diffused junction silicon switching diodes of not over 1 A forward rated current are suitable for this application.

Due to the value of frequency of the generator G, the load circuit is practically purely inductive and, at the instant of current zero, the applied voltage across the load circuit will be at its peak value. To ensure that the components of the load circuit are suitable, it shall be checked on the screen that the curve of the transient voltage at its initiation (point A in Figure C.1) has a practically horizontal tangent.

The actual value of the factor γ is the ratio U_{11}/U_{12} ; U_{11} is read on the screen, U_{12} is read between the ordinate of point A and the ordinate of the trace when the load circuit is no longer energized by the generator (see Figure C.1).

When observing the transient voltage in the load circuit with no resistor R_p or capacitor C_p in parallel, one reads on the screen the natural oscillatory frequency of the load circuit. Care should be taken that the capacitance of the oscilloscope or of its connecting leads does not influence the resonant frequency of the load circuit.

If that natural frequency exceeds the upper limit of the required value f , the suitable values of frequency and factor γ can be obtained by connecting in parallel capacitors C_p and resistors R_p of appropriate values. The resistors R_p shall be practically non-inductive.

It is recommended that, as a first step, each of the three phases of the load circuit be adjusted separately. The adjustment is then completed by successively connecting, in each possible combination, the high-frequency generator to one phase in series with the other two in parallel as shown in Figure 16; the adjustment is refined if necessary so that the specified values of f and γ are obtained in each combination.

NOTE 1 A higher value of frequency obtained from the generator G facilitates the observation on the screen and improves the resolution.

NOTE 2 Other methods of determining frequency and factor γ (such as the impression of a square-wave current on the load circuit) can also be used.

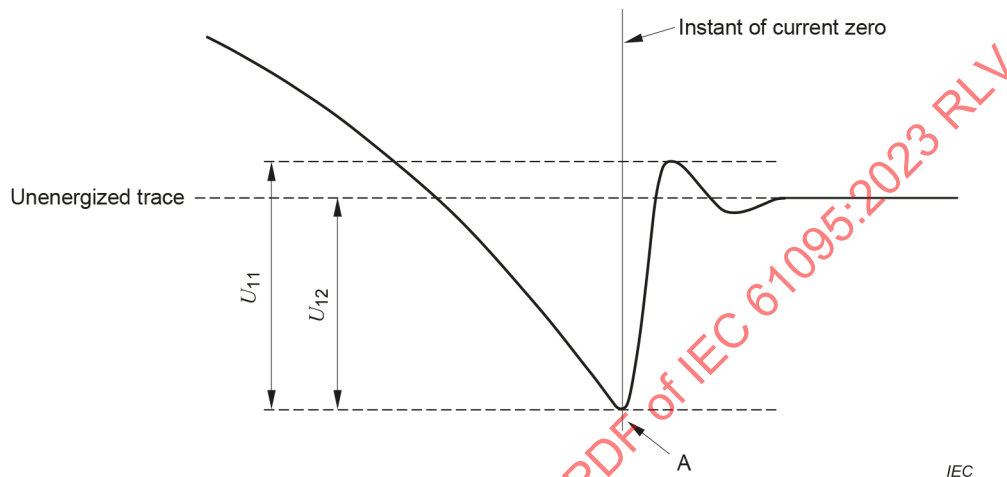


Figure C.1 – Determination of the actual value of the factor γ

Annex D (normative)

Determination of short-circuit power-factor

D.1 General

There is no method by which the short-circuit power-factor can be determined with precision, but for the purpose of this document, the determination of the power-factor of the test circuit can be made by one of the following methods.

NOTE Other methods for determining the short-circuit power-factor are under consideration.

D.2 Method I – Determination from DC component

The angle φ can be determined from the curve of the DC component of the asymmetrical current wave between the instant of the short-circuit and the instant of contact separation as follows:

- 1) To determine the time-constant L/R from the formula for the DC component.

The formula for the DC component is:

$$i_d = I_{do} e^{-Rt/L}$$

where

i_d is the value of the DC component at the instant t ;

I_{do} is the value of the DC 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 Napierian logarithms.

The time-constant L/R can be determined by:

- a) measuring the value of I_{do} at the instant of short-circuit and the value of i_d at another instant t before contact separation,
- b) determining the value of $e^{-Rt/L}$ by dividing i_d by I_{do} ,
- c) determining the value of $-\chi$ corresponding to the ratio i_d/I_{do} , from a table of values of e^{-x} .

The value χ represents Rt/L , from which R/L is obtained.

- 2) To determine the angle φ from: $\varphi = \arctan(\omega L/R)$

where ω is 2π times the actual frequency.

This method should not be used when the currents are measured by current transformers, except if suitable precautions are taken to eliminate errors due to:

- the time-constant of the transformer and its burden in relation to that of the primary circuit;
- magnetic saturation which can result from the transient flux conditions combined with possible remanence.

D.3 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 can 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.

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Annex E (normative)

Measurement of creepage distances and clearances

E.1 Basic principles

The widths X of grooves specified in Figure E.2 to Figure E.12 basically apply to all examples as a function of pollution degree as given in Table E.1:

Table E.1 – Minimum values of width of grooves according to the pollution degrees

Pollution degrees	Minimum values of width X of grooves mm
1	0,25
2	1,0
3	1,5
4	2,5

If the associated clearance is less than 3 mm, the minimum groove width can be reduced to one-third of this clearance.

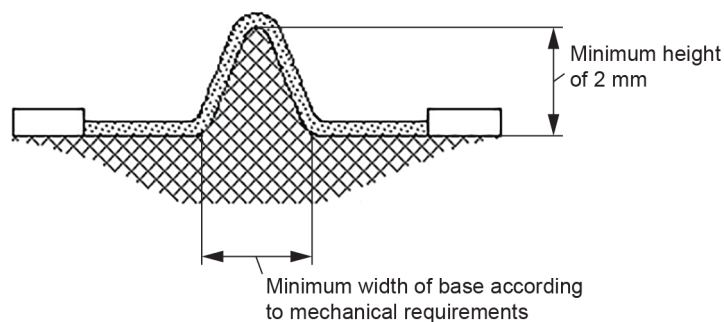
The methods of measuring creepage distances and clearances are indicated in the following Figure E.2 to Figure E.12. These examples do not differentiate between gaps and grooves or between types of insulation.

Furthermore:

- any corner is assumed to be bridged with an insulating link of X mm width moved into the most unfavourable position (see Figure E.4);
- when the distance across the top of a groove is X mm or more, a creepage distance is measured along the contours of the groove (see Figure E.3);
- creepage distances and clearances measured between parts moving in relation to each other are measured when these parts are in their most unfavourable positions.

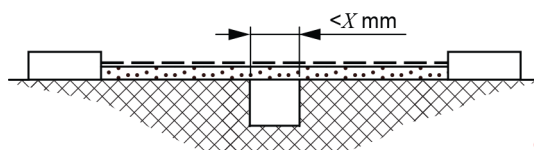
E.2 Use of ribs

Because of their influence on contamination and their better drying-out effect, ribs decrease considerably the formation of leakage current. Creepage distances can therefore be reduced to 0,8 times the required value, provided the minimum height of the ribs is 2 mm.



IEC

Figure E.1 – Measurement of ribs

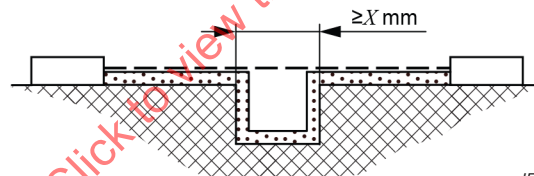


IEC

Condition: This creepage distance path includes a parallel- or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

Figure E.2 – Creepage distance example 1

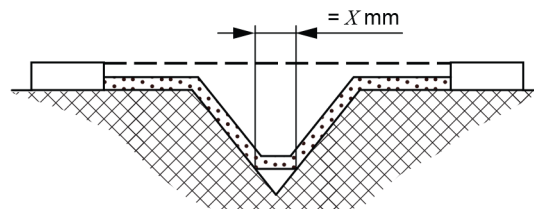


IEC

Condition: This creepage distance path includes a parallel-sided groove of any depth and a width equal to or more than X mm.

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

Figure E.3 – Creepage distance example 2



IEC

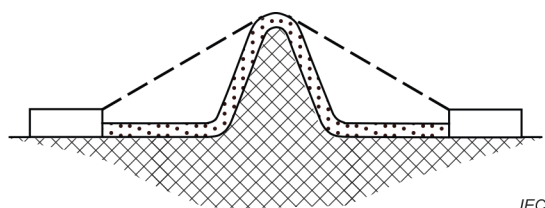
Condition: This creepage distance path includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

Figure E.4 – Creepage distance example 3

----- Clearance

----- Creepage distance



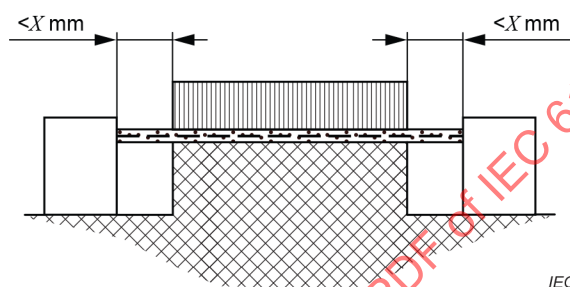
IEC

Condition: This creepage distance path includes a rib.

Rule:

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

Figure E.5 – Creepage distance example 4



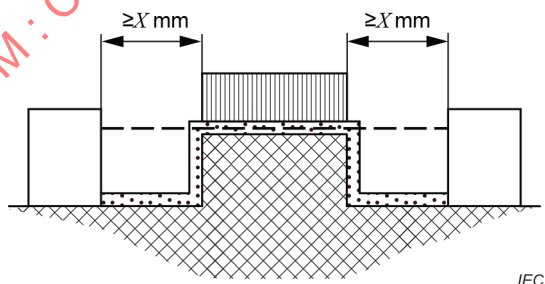
IEC

Condition: This creepage distance path includes an uncemented joint with grooves less than X mm wide on each side.

Rule:

Creepage distance and clearance path is the "line-of-sight" distance shown.

Figure E.6 – Creepage distance example 5



IEC

Condition: This creepage distance path includes an uncemented joint with grooves equal to or more than X mm wide on each side.

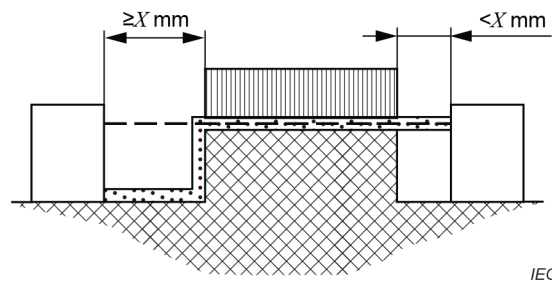
Rule:

Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the grooves.

Figure E.7 – Creepage distance example 6

— — — — — Clearance

..... Creepage distance

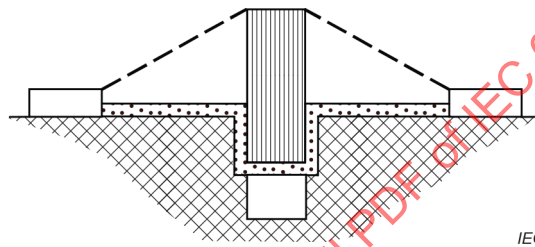


Condition: This creepage distance path includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule:

Clearance and creepage distance paths are as shown.

Figure E.8 – distance example 7

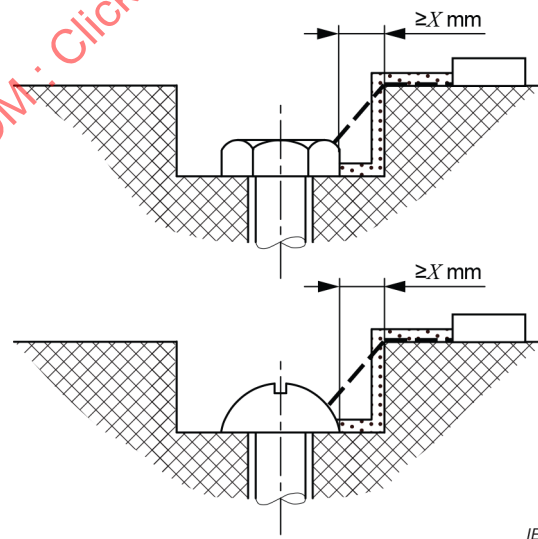


Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

Rule:

Clearance is the shortest direct air path over the top of the barrier.

Figure E.9 – Creepage distance example 8



Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

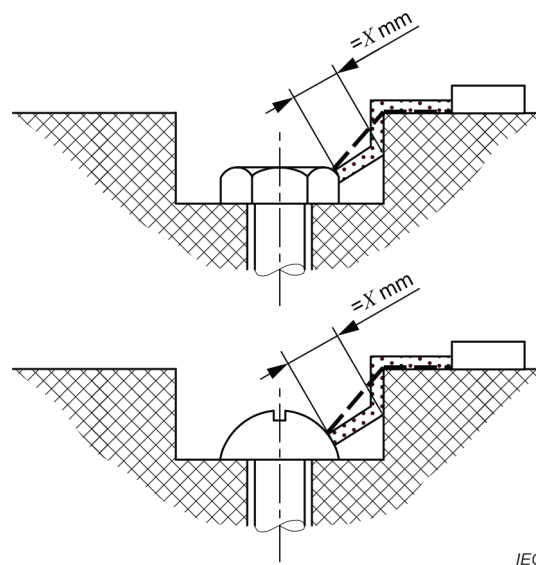
Rule:

Clearance and creepage distance paths are as shown.

Figure E.10 – Creepage distance example 9

— — — — — Clearance

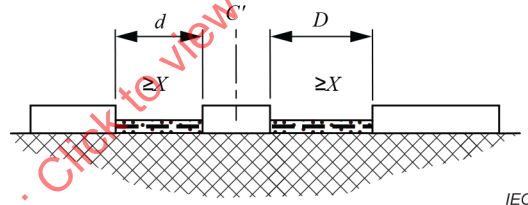
..... Creepage distance



Condition: Gap between head of screw and wall of recess too narrow to be taken into account.

Rule: Measurement of creepage distance is from screw to wall when the distance is equal to X mm.

Figure E.11 – Creepage distance example 10



Clearance is the distance = $d + D$

Creepage distance is also = $d + D$

Figure E.12 – Creepage distance example 11

----- Clearance

..... Creepage distance

Annex F

(normative)

Correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of a contactor

This annex is intended to give the necessary information concerning the choice of a contactor for use in a circuit within an electrical system or part thereof.

Table F.1 provides examples of the correlation between supply system voltages and the corresponding rated impulse withstand voltage of a contactor.

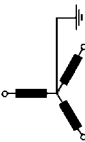
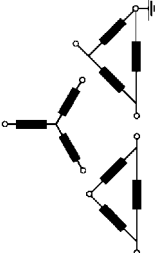
The values of rated impulse withstand voltage given in Table F.1 are based on the performance characteristics of surge arresters.

It should also be recognized that control of overvoltages with respect to the values in Table F.1 can also be achieved by conditions in the supply system such as the existence of a suitable impedance or cable feed.

In such cases where the control of overvoltages is achieved by means other than surge arresters, guidance for the correlation between the nominal supply system voltage and the equipment rated impulse withstand voltage is given in IEC 60364-4-44.

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Table F.1 – Correspondence between the nominal voltage of the supply system and the contactor rated impulse withstand voltage, in case of overvoltage protection by surge-arresters according to IEC 60099-1^a

Maximum value of rated operational voltage to earth	Nominal voltage of the supply system ($\leq$ rated insulation voltage of the equipment)				Preferred values of rated impulse withstand voltage (1,2/50 μ s) at 2 000 m kV			
	 AC RMS V	 AC RMS V	 AC RMS or DC V	 AC RMS or DC V	Overvoltage category			
					IV	III	II	I
50	–	–	12,5, 24, 25 30, 42, 48	60-30	1,5	0,8	0,5	0,33
100	66/115	66	60	–	2,5	1,5	0,8	0,5
150	120/208 127/220	115, 120 127	110, 120	220-110, 240-120	4	2,5	1,5	0,8
300	220/380, 230/400 240/415, 260/440 277/480	220, 230 240, 260 277	220	440-220	6	4	2,5	1,5

^a This publication was withdrawn.

^a This publication was withdrawn.

Annex G (normative)

Hot wire ignition test

G.1 Five samples of each material shall be tested. The samples shall be 150 mm long by 13 mm wide and of uniform thickness representing the thinnest section of the part.

Edges shall be free from burrs, fins, etc.

G.2 A 250 mm $\pm$ 5 mm length of nichrome wire (80 % nickel, 20 % chromium, iron free) approximately 0,5 mm diameter and having a cold resistance of approximately 5,28 Ω /m shall be used. The wire shall be connected in a straight length to a variable source of power which is adjusted to cause a power dissipation of 0,26 W/mm in the wire for a period of 8 s to 12 s. After cooling, the wire shall be wrapped around a sample to form five complete turns spaced 6 mm apart.

G.3 The wrapped sample shall be supported in a horizontal position and the ends of the wire connected to the variable power source which is again adjusted to dissipate 0,26 W/mm in the wire (see Figure G.1).

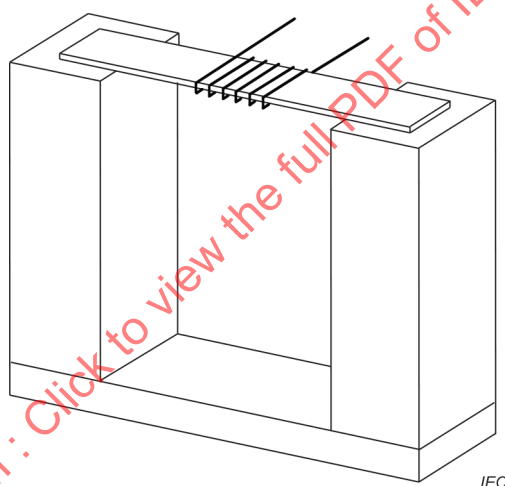


Figure G.1 – Test fixture for hot wire ignition test

G.4 Start the test by energizing the circuit so that a current is passed through the heater wire yielding a linear power density of 0,26 W/mm.

G.5 Continue heating until the test specimen ignites. When ignition occurs, shut off power and record time to ignite. Discontinue the test if ignition does not occur within 120 s.

For specimens that melt through the wire without ignition, discontinue the test when the specimen is no longer in intimate contact with all five turns of the heater wire.

G.6 The test shall be repeated on the remaining samples.

G.7 The hot wire ignition time of the material shall be recorded as the average ignition time of the specimens tested.

Annex H (normative)

Degrees of protection of enclosed contactor

H.0 Guide to the use of Annex H

Where an IP code is stated by the manufacturer for a contactor with integral enclosure or for an enclosed contactor, the requirements of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013 apply with the following.

NOTE To understand the IP code, graphical representation of IP ratings can be seen on IEC website at: <https://www.iec.ch/ip-ratings>.

Clauses and subclauses of IEC 60529 applicable to a contactor with integral enclosure and to an enclosed contactor are explicitly detailed in this annex.

Clause and subclause numbers of this annex are sometimes discontinuous because they correspond to those of IEC 60529.

H.1 Scope and object

This annex applies to the degrees of protection of a contactor with integral enclosure and of an enclosed contactor at rated voltages not exceeding 440 V AC hereafter referred to as "device".

Clause 1 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999 apply with the additional requirements of this annex.

H.3 Terms and definitions

Clause 3 of IEC 60529:1989 applies except that "enclosure" (3.1) is replaced by the following, Note 1 and Note 2 remaining as they are.

"A part providing a specified degree of protection of device against certain external influences and a specified degree of protection against approach to or contact with live parts and moving parts."

[IEC 60050-441:1984, 441-13-01, modified — The definition was slightly modified.]

NOTE This definition given in 3.1.16 of this document is similar to IEC 60050-441:1984, 441-13-01 which applies to assemblies.

H.4 Designation

Clause 4 of IEC 60529:1989 applies except for letters H, M, S and W.

H.5 Degrees of protection against access to hazardous parts and against ingress of solid foreign objects indicated by the first characteristic numeral

Clause 5 of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013 apply.

H.6 Degrees of protection against ingress of water indicated by the second characteristic numeral

Clause 6 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 apply.

H.7 Degrees of protection against access to hazardous parts indicated by the additional letter

Clause 7 of IEC 60529:1989 applies.

H.8 Supplementary letters

Clause 8 of IEC 60529:1989 applies except for letters H, M and S.

H.9 Examples of designations with IP Code

Clause 9 of IEC 60529:1989 applies.

H.10 Marking

Clause 10 of IEC 60529:1989 applies with the following addition.

If the IP Code is designated for one mounting position only, it shall be indicated by the symbol of ISO 7000-0623 (2014-06) placed next to the IP Code specifying this position of the device, e.g. vertical:



H.11 General requirements for tests

H.11.1 Subclause 11.1 of IEC 60529:1989 applies

H.11.2 Subclause 11.2 of IEC 60529:1989 applies with the following additions

All tests are made in the unenergized state.

Certain devices (e.g. exposed faces of push-buttons) can be verified by inspection.

The temperature of the test sample shall not deviate from the actual ambient temperature by more than 5 K.

Where device is mounted in an empty enclosure which already has an IP Code (see 11.5 of IEC 60529:1989) the following requirements apply.

- a) For IP1X to IP4X and additional letters A to D.

This shall be verified by inspection and compliance with the enclosure manufacturer's instructions.

- b) For IP6X dust test.

This shall be verified by inspection and compliance with the enclosure manufacturer's instructions.

- c) For IP5X dust test and IPX1 to IPX8 water tests.

Testing of the enclosed device is only required where the ingress of dust or water can impair the operation of the device.

IP5X dust and IPX1 to IPX8 water tests allow the ingress of a certain amount of dust and water provided that there are no harmful effects. Every internal device configuration should, therefore, be separately considered.

H.11.3 Subclause 11.3 of IEC 60529:1989 applies with the following addition

Drain and ventilating holes are treated as normal openings.

H.11.4 Subclause 11.4 of IEC 60529:1989 applies

H.11.5 Where an empty enclosure is used as a component of an enclosed device, 11.5 of IEC 60529:1989 applies

H.12 Tests for protection against access to hazardous parts indicated by the first characteristic numeral

Clause 12 of IEC 60529:1989 applies except for 12.3.2.

H.13 Tests for protection against ingress of solid foreign objects indicated by the first characteristic numeral

Clause 13 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999 apply except for:

H.13.4 Dust test for first characteristic numerals 5 and 6

The following text to be added:

Enclosed device having a degree of protection IP5X shall be tested according to category 2 of 13.4 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999.

Enclosed device having a degree of protection IP6X shall be tested according to category 1 of 13.4 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999.

NOTE For enclosed device according to this document, a degree of protection IP5X is generally deemed satisfactory.

H.13.5.2 Acceptance conditions for first characteristic numeral 5

The following text to be added:

Where dust deposits could raise doubts as to the correct functioning and safety of device, a preconditioning and a dielectric test shall be conducted as follows:

The preconditioning, after the dust test, shall be verified by test Cab: damp heat, steady state, according to IEC 60068-2-78, under the following test conditions.

The device shall be prepared so that the dust deposits are subject to the test by leaving open the lid and/or removing parts, where possible without the aid of tool.

Before being placed in the test chamber the device shall be stored at room temperature for at least 4 h before the test.

The test duration shall be 24 consecutive hours.

After this period, the device is to be removed from the test chamber within 15 min and submitted to a power-frequency dielectric test for 1 min, the value being $2 U_e$ max with a minimum of 1 000 V. The application of the test voltage and the acceptance criteria shall be as specified in 9.3.3.4, item b) 3) and item b) 4).

H.14 Tests for protection against water indicated by the second characteristic numeral

H.14.1 Subclause 14.1 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 apply

H.14.2 Subclause 14.2 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 apply

H.14.3 Subclause 14.3 of IEC 60529:1989 and IEC 60529:1989/AMD2:2013 apply with the following addition

The device is then submitted to a power-frequency dielectric test for 1 min, the value being $2 U_e$ max. with a minimum of 1 000 V. The application of the test voltage and the acceptance criteria shall be as specified in 9.3.3.4.1, item b) 3) and item b) 4).

H.15 Tests for protection against access to hazardous parts indicated by the additional letter

Clause 15 of IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013 apply.

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Annex I (normative)

Requirements and tests for equipment with protective separation

I.1 General

This annex applies to a device one or more circuits of which being able to be used in SELV (PELV) circuit (the device by itself cannot be Class III, see 7.5 of IEC 61140:2016).

The purpose of this annex is to harmonize as far as practicable all rules and requirements applicable to low voltage switchgear and controlgear having a protective separation between parts intended to be used in SELV (PELV) circuits and others, in order to obtain uniformity of requirements and tests and to avoid the need for testing to different standards.

I.2 Terms and definitions

I.2.1

functional insulation

insulation between conductive parts which is necessary only for the proper functioning of the equipment

I.2.2

basic insulation

insulation of hazardous live parts which provides basic protection against electric shock

Note 1 to entry: The term basic insulation does not apply to insulation used exclusively for functional purposes. (See I.2.1)

I.2.3

supplementary insulation

independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation

I.2.4

double insulation

insulation comprising both basic insulation and supplementary insulation

I.2.5

reinforced insulation

insulation of hazardous live parts which provides a degree of protection against electric shock equivalent to double insulation

Note 1 to entry: Reinforced insulation can comprise several layers which cannot be tested singly as basic or supplementary insulation.

I.2.6

protective separation

<electrically> separation of one electric circuit from another by means of:

- double insulation, or
- basic insulation and electrically protective screening, or
- reinforced insulation

[SOURCE: IEC 60050-195:2021, 195-06-19, modified — Replacement of “basic protection and fault protection” with “double insulation, or basic insulation and electrically protective screening, or reinforced insulation”.]

I.2.7

SELV circuit

electrical circuit in which the voltage cannot exceed ELV:

- under normal conditions, and
- under single-fault conditions, including earth faults in other circuits

Note 1 to entry: Definition adapted from the definition of SELV system given in 3.26.1 of IEC 61140:2016.

I.2.8

PELV circuit

electrical circuit in which the voltage cannot exceed ELV:

- under normal conditions, and
- under single-fault conditions, except earth faults in other circuits

Note 1 to entry: Definition adapted from the definition of PELV system given in 3.26.2 of IEC 61140:2016.

I.2.9

limitation of steady-state touch current and charge

protection against electric shock by circuit or equipment design such that under normal and fault conditions the steady-state touch current and charge are limited to non-hazardous levels

I.2.10

protective impedance device

component or assembly of components the impedance and construction of which are such as to ensure that steady-state touch current and charge are limited to non-hazardous levels

I.3 Requirements

I.3.1 General

The only method considered in this document to achieve the protective separation is based on double (or reinforced) insulation between SELV (PELV) circuit(s) and other circuits. If any component is connected between the separated circuits, that component shall comply with the requirements for protective impedance devices according to 5.3.4 of IEC 61140:2016 (see Figure I.1).

The effects of electrical arcs normally produced in the breaking chambers of switchgears and controlgears on insulation are deemed to be taken into account in the dimensioning of creepage distances and no specific verification is required.

Partial discharge effects are not taken into consideration.

I.3.2 Dielectric requirements

I.3.2.1 Creepages

It shall be verified that the creepage distances between SELV (PELV) circuit and other circuits are equal or higher than twice those given for basic insulation in Table 18 and corresponding to the voltage of the circuit having the highest rated voltage value.

NOTE This requirement follows the principles given in IEC 60664-1.

The creepage distances shall be verified in accordance with I.4.2.1.

I.3.2.2 Clearances

The clearances between SELV (PELV) circuit and other circuits of the device shall be dimensioned to withstand the rated impulse voltage as determined in accordance with Annex F relevant to the basic insulation for the specific utilisation class but one step higher in the series value (or a value equal to 160 % of the voltage value required for the basic insulation) following the principles given in 5.2.5 of IEC 60664-1:2007. The test conditions are given in I.4.2.2.

I.3.3 Construction requirements

Construction measures should be taken regarding:

- materials employed regarding aging;
- thermal stresses or mechanical risks of failure which will impair insulation between circuits;
- risks of electrical contact between different circuits in case of accidental disconnection of wiring.

Subclause I.4.3 gives examples of constructional risks which have to be taken into consideration.

I.4 Tests

I.4.1 General

These tests are normally conducted as type tests. Where the constructional design cannot ensure without doubt that the insulation intended for protective separation cannot be impaired by the effects of product conditions, the manufacturer can also conduct all or parts of these tests as routine tests.

Tests verification shall be made between the SELV (PELV) circuit and each other circuits, such as main circuit, control and auxiliary circuits.

Tests shall be done in all operating conditions of the device: open, close, trip positions.

I.4.2 Dielectric tests

I.4.2.1 Creepages verification

Conditions of measuring are those given in 9.3.3.4 and Annex E.

I.4.2.2 Clearances verification

I.4.2.2.1 Condition of the device for test

Tests shall be made on devices mounted as for service, including internal wiring and in a clean and dry condition.

I.4.2.2.2 Application of the test voltage

For each circuit of the device under test, external terminals shall be connected together.

I.4.2.2.3 Impulse test voltage

It shall be an impulse test voltage having a 1,2/50 μ s wave form as described in 9.3.3.4, the value of which being chosen as defined in I.3.2.2.

I.4.2.2.4 Test

Clearances are verified by application of the test voltage of I.4.2.2.3. The test shall be conducted for a minimum of five impulses of each polarity with an interval of at least 1 s between pulses in accordance with in 9.3.3.4.1.

Application of test voltage can be avoided where clearances are equal or higher than those given in Table 17 for the determined test voltage value.

I.4.2.2.5 Results to be obtained

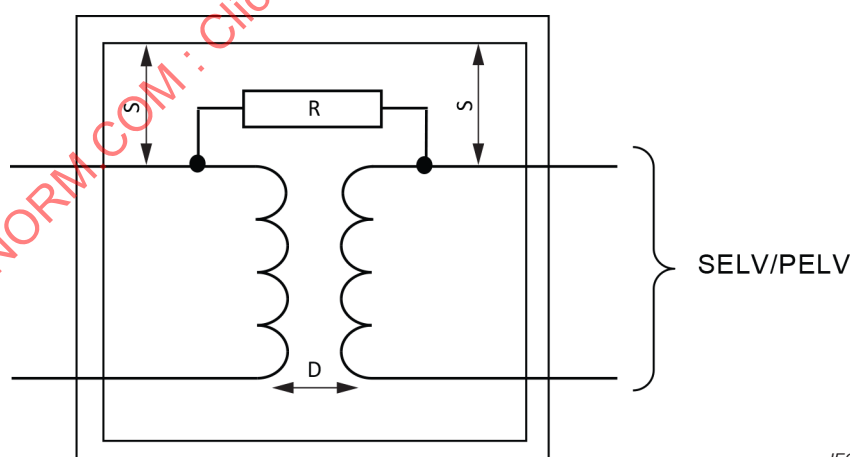
When the voltage is applied, the test is considered to have been passed if there is no puncture or flashover.

I.4.3 Examples of constructional measures

Measures should be taken that a single mechanical fault – e.g. a bent solder pin, a detached soldering point or a broken winding (coil), a loosened and fallen screw – should not have the result of impairing the insulation to such a degree that it no longer fulfils the requirements of the basic insulation; the design, however, should not consider that two or more of these events will appear simultaneously.

Examples of constructional measures:

- sufficient mechanical stability;
- mechanical barriers;
- employment of captive screws;
- impregnation or casting of components;
- inserting pins into an insulating sleeve;
- to avoid sharp-edges in the vicinity of conductors.



IEC

Key

D double (or reinforced) insulation between circuits (including SELV/PELV circuit)

R component complying with protective impedance devices requirements

S basic insulation

Figure I.1 – Example of application with component connected between separated circuits

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¹ This publication was withdrawn.

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CONTACTEURS ÉLECTROMÉCANIQUES POUR USAGES DOMESTIQUES ET ANALOGUES

AVANT-PROPOS

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L'IEC 61095 a été établie par le sous-comité 121A: Appareillage à basse tension, du comité d'études 121 de l'IEC: Appareillages et ensembles d'appareillages basse tension, en collaboration avec le sous-comité 23E: Disjoncteurs et appareillage similaire pour usage domestique, du comité d'études 23 de l'IEC: Petit appareillage. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2009. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) ajout des exigences relatives aux bornes sans vis;
- b) ajout des exigences relatives à la commande des lampes à LED. Les contacteurs pour applications domestiques et analogues peuvent être utilisés pour commander les charges d'éclairage, qui utilisent de plus en plus la technologie de lampe à LED. Création d'une catégorie spécifique pour les contacteurs: AC-7d. Des exigences et des essais ont été ajoutés pour couvrir cette évolution du marché, notamment en ce qui concerne la fermeture et la coupure et le fonctionnement conventionnel en service;
- c) ajout des exigences relatives aux contacteurs qui comportent un électroaimant commandé électroniquement. Les contacteurs domestiques qui comportent un électroaimant commandé électroniquement sont disponibles sur le marché depuis des années. Pour couvrir pleinement les appareils de ce types, des exigences et des essais ont été ajoutés, qui traitent notamment des limites de fonctionnement, du comportement en conditions anormales, du claquage des composants, des essais CEM, etc.
- d) concernant les logiciels intégrés, de plus en plus de contacteurs contiennent des circuits électroniques avec un logiciel intégré. Une référence est fournie à titre de guide pour la conception des logiciels.

Le texte de ce document est issu des documents suivants:

Projet	Rapport de vote
121A/566/FDIS	121A/573/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

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- reconduit,
- supprimé, ou
- révisé.

INTRODUCTION

Le présent document spécifie les exigences applicables aux contacteurs pour usages domestiques et analogues, y compris les contacteurs destinés à la commande du réseau de distribution dans les bâtiments.

Les contacteurs destinés à de tels usages sont soumis à des exigences particulières, notamment des séquences d'essais et des plans d'échantillonnage particuliers dans le but de faciliter les essais.

Les courants d'emploi et les tensions d'emploi des contacteurs conformes au présent document sont limités aux valeurs appropriées aux applications envisagées. Ces contacteurs sont destinés à être utilisés dans des circuits dont le courant de défaut en court-circuit présumé a une valeur limitée à laquelle ils sont coordonnés avec un dispositif approprié de protection contre les courts-circuits afin d'assurer une coordination adéquate.

Le présent document définit en un seul document la catégorie d'emploi spécifique pour une application définie et précise les exigences correspondantes. Il s'aligne dans la mesure du possible sur les exigences de l'IEC 60947-4-1.

Le présent document s'applique également aux contacteurs qui sont des composants d'un appareil, sauf indication contraire dans la norme relative à cet appareil.

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CONTACTEURS ÉLECTROMÉCANIQUES POUR USAGES DOMESTIQUES ET ANALOGUES

1 Domaine d'application

Le présent document s'applique aux contacteurs électromécaniques à air pour usages domestiques et analogues dont les contacts principaux sont destinés à être reliés à des circuits dont la tension assignée ne dépasse pas 440 V en courant alternatif (entre phases) et dont les courants assignés d'emploi sont inférieurs ou égaux à 63 A pour la catégorie d'emploi AC-7a et à 32 A pour les catégories d'emploi AC-7b, AC-7c et AC-7d (exprimés en puissance assignée), et le courant assigné de court-circuit conditionnel est inférieur ou égal à 6 kA.

NOTE Aujourd'hui, la plupart des fabricants de lampes à LED fournit les informations en Watt. Ainsi, la caractéristique du contacteur principal pour la catégorie d'emploi AC-7d est exprimée en Watt afin d'être directement applicable à la charge de lampe à LED correspondante.

Des exigences spécifiques s'appliquent aux contacteurs équipés de bornes sans vis.

Le présent document ne s'applique pas aux:

- contacteurs conformes à l'IEC 60947-4-1;
- contacteurs à semiconducteurs;
- contacteurs conçus pour des applications spéciales;
- contacts auxiliaires des contacteurs. Ces contacteurs sont traités dans l'IEC 60947-5-1.

Le présent document établit:

- 1) les caractéristiques des contacteurs;
- 2) les conditions auxquelles doivent satisfaire les contacteurs concernant:
 - a) leur fonctionnement et leur tenue;
 - b) leurs propriétés diélectriques;
 - c) les degrés de protection procurés par leurs enveloppes, le cas échéant;
 - d) leur construction;
 - e) leurs caractéristiques de compatibilité électromagnétique;
- 3) les essais destinés à vérifier si ces conditions sont remplies, ainsi que les méthodes à adopter pour ces essais;
- 4) les séquences d'essais et le nombre d'échantillons;
- 5) les informations à fournir avec les contacteurs ou dans la documentation du fabricant.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60028:1925, *Spécification internationale d'un cuivre-type recuit*

IEC 60068-2-78:2012, *Essais d'environnement – Partie 2-78: Essais – Essai Cab: Chaleur humide, essai continu*

IEC 60073:2002, *Principes fondamentaux et de sécurité pour l'interface homme-machine, le marquage et l'identification – Principes de codage pour les indicateurs et les organes de commande*

IEC 60085:2007, *Isolation électrique – Évaluation et désignation thermiques*

IEC 60112:2020, *Méthode de détermination des indices de résistance et de tenue au cheminement des matériaux isolants solides*

IEC 60417, *Symboles graphiques utilisables sur le matériel*, disponible à l'adresse <https://www.graphical-symbols.info/equipment>

IEC 60445:2021, *Principes fondamentaux et de sécurité pour les interfaces homme-machines, le marquage et l'identification – Identification des bornes de matériels, des extrémités de conducteurs et des conducteurs*

IEC 60447:2004, *Principes fondamentaux et de sécurité pour l'interface homme-machine, le marquage et l'identification – Principes de manœuvre*

IEC 60529:1989, *Degrés de protection procurés par les enveloppes (Code IP)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 60664-1:2020, *Coordination de l'isolement des matériels dans les réseaux d'énergie électrique à basse tension – Partie 1: Principes, exigences et essais*

IEC 60695-2-10:2021, *Essais relatifs aux risques du feu – Partie 2-10: Essais au fil incandescent/chauffant – Appareillage et méthode commune d'essai*

IEC 60695-2-11:2021, *Essais relatifs aux risques du feu – Partie 2-11: Essais au fil incandescent/chauffant – Méthode d'essai d'inflammabilité pour produits finis (GWEPT)*

IEC 60695-11-10:2013, *Essais relatifs aux risques du feu – Partie 11-10: Flammes d'essai – Méthodes d'essai horizontale et verticale à la flamme de 50 W*

IEC 60947-4-1:2018, *Appareillage à basse tension – Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques*

IEC 60947-5-1:2016, *Appareillage à basse tension – Partie 5-1: Appareils et éléments de commutation pour circuits de commande – Appareils électromécaniques pour circuits de commande*

IEC 61000-4-2, *Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques*

IEC 61000-4-3, *Compatibilité électromagnétique (CEM) – Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques*

IEC 61000-4-4, *Compatibilité électromagnétique (CEM) – Partie 4-4: Techniques d'essai et de mesure – Essais d'immunité aux transitoires électriques rapides en salves*

IEC 61000-4-5, *Compatibilité électromagnétique (CEM) – Partie 4-5: Techniques d'essai et de mesure – Essai d'immunité aux ondes de choc*

IEC 61000-4-6, *Compatibilité électromagnétique (CEM) – Partie 4-6: Techniques d'essai et de mesure – Immunité aux perturbations conduites, induites par les champs radioélectriques*

IEC 61000-4-11, *Compatibilité électromagnétique (CEM) – Partie 4-11: Techniques d'essai et de mesure – Essais d'immunité aux creux de tension, coupures brèves et variations de tension pour les appareils à courant d'entrée inférieur ou égal à 16 A par phase*

IEC 61000-4-34, *Compatibilité électromagnétique (CEM) – Partie 4-34: Techniques d'essai et de mesure - Essais d'immunité aux creux de tension, coupures brèves et variations de tension pour matériel ayant un courant appelé de plus de 16 A par phase*

IEC 61140:2016, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61180:2016, *Techniques des essais à haute tension pour matériels à basse tension – Définitions, exigences et modalités relatives aux essais, matériel d'essai*

CISPR 14-1:2020, *Compatibilité électromagnétique – Exigences relatives aux appareils électrodomestiques, aux outils électriques et aux appareils analogues – Partie 1: Émission*

ISO 7000:2019, *Symboles graphiques utilisables sur le matériel – Symboles enregistrés*

ISO 2039-2:1987, *Plastiques – Détermination de la dureté – Partie 2: Dureté Rockwell*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <https://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <https://www.iso.org/obp>

3.1 Termes généraux

3.1.1

surintensité

courant supérieur au courant assigné

[SOURCE: IEC 60050-441:1984, 441-11-06]

3.1.2

court-circuit

chemin conducteur accidentel ou intentionnel entre deux parties conductrices ou plus forçant les différences de potentiel électrique entre ces parties conductrices à être nulles ou proches de zéro

[SOURCE: IEC 60050-151:2001, 151-12-04]

3.1.3

courant de court-circuit

surintensité résultant d'un court-circuit dû à un défaut ou à un branchement incorrect dans un circuit électrique

[SOURCE: IEC 60050-441:1984, 441-11-07]

3.1.4

surcharge

conditions de fonctionnement d'un circuit électriquement sain, qui provoquent une surintensité

[SOURCE: IEC 60050-441:1984, 441-11-08]

3.1.5

courant de surcharge

surintensité qui se produit dans un circuit électriquement sain

3.1.6

température de l'air ambiant

température déterminée dans des conditions prescrites de l'air qui entoure la totalité de l'appareil de connexion ou du fusible

Note 1 à l'article: Pour des appareils de connexion ou des fusibles installés à l'intérieur d'une enveloppe, c'est la température de l'air à l'extérieur de l'enveloppe.

[SOURCE: IEC 60050-441:1984, 441-11-13]

3.1.7

partie conductrice

partie capable de conduire du courant, bien qu'elle ne soit pas nécessairement utilisée pour conduire du courant en service normal

[SOURCE: IEC 60050-441:1984, 441-11-09]

3.1.8

masse

partie conductrice accessible

partie conductrice, susceptible d'être touchée directement, qui n'est pas normalement sous tension mais qui peut le devenir en cas de défaut

Note 1 à l'article: Les masses caractéristiques sont les parois des enveloppes, les poignées de commande, etc.

[SOURCE: IEC 60050-441:1984, 441-11-10]

3.1.9

choc électrique

effet physiologique résultant du passage d'un courant électrique à travers le corps humain ou celui d'un animal

[SOURCE: IEC 60050-826:2022, 826-12-01]

3.1.10

partie active

conducteur ou partie conductrice destiné à être sous tension en service normal, y compris le conducteur de neutre, mais par convention, excepté le conducteur PEN, le conducteur PEM ou le conducteur PEL

Note 1 à l'article: Cette notion n'implique pas nécessairement un risque de choc électrique.

[SOURCE: IEC 60050-826:2022, 826-12-08, modifié – Reformulation de la définition et ajout d'une Note 1 à l'article.]

3.1.11

conducteur de protection (identification: PE)
conducteur prévu à des fins de sécurité

EXEMPLE Protection contre les chocs électriques.

Note 1 à l'article: Dans une installation électrique, le conducteur identifié PE est normalement aussi considéré comme conducteur de mise à la terre de protection.

[SOURCE: IEC 60050-826:2022, 826-13-22, modifié – Reformulation de la définition, ajout d'un nouvel exemple et d'une nouvelle Note 1 à l'article.]

3.1.12

conducteur (de) neutre

conducteur relié électriquement au point neutre et pouvant contribuer à la distribution de l'énergie électrique

[SOURCE: IEC 60050-826:2021, 826-14-07]

3.1.13

conducteur PEN

conducteur assurant à la fois les fonctions de conducteur de mise à la terre de protection et de conducteur de neutre

[SOURCE: IEC 60050-826:2022, 826-13-25]

3.1.14

conducteur PEM

conducteur assurant les fonctions de conducteur de mise à la terre de protection et de conducteur de point milieu

[SOURCE: IEC 60050-826:2022, 826-13-26]

3.1.15

conducteur PEL

conducteur assurant à la fois les fonctions de conducteur de mise à la terre de protection et de conducteur de ligne

[SOURCE: IEC 60050-826:2022, 826-13-27]

3.1.16

enveloppe

partie qui procure un degré de protection spécifié du matériel contre certaines influences externes et un degré de protection spécifié contre l'approche ou le contact des parties actives et des pièces en mouvement

Note 1 à l'article: Cette définition est similaire à celle de l'IEC 60050-441:1984, 441-13-01, qui s'applique aux ensembles.

[SOURCE: IEC 60050-441:1984, 441-13-01, modifié – Reformulation de la définition et nouvelle Note 1 à l'article.]

3.1.17

enveloppe intégrée

enveloppe qui fait partie intégrante du matériel

3.1.18

catégorie d'emploi

<appareil de connexion ou un fusible> ensemble de prescriptions spécifiées relatives aux conditions dans lesquelles l'appareil de connexion ou le fusible doit remplir son office, choisies pour représenter un groupe caractéristique d'applications pratiques

Note 1 à l'article: Les prescriptions spécifiées peuvent concerner, par exemple, les valeurs des pouvoirs de fermeture, s'il y a lieu, les valeurs des pouvoirs de coupure et d'autres caractéristiques, les circuits associés et les conditions correspondantes d'emploi et de comportement.

[SOURCE: IEC 60050-441:1984, 441-17-19]

3.2 Appareils de connexion

3.2.1

appareil de connexion

appareil destiné à établir ou à interrompre le courant dans un ou plusieurs circuits électriques

Note 1 à l'article: Un appareil de connexion peut effectuer l'une de ces manœuvres ou les deux.

[SOURCE: IEC 60050-441:1984, 441-14-01, modifié – Ajout d'une Note 1 à l'article.]

3.2.2

appareil mécanique de connexion

appareil de connexion destiné à fermer et à ouvrir un ou plusieurs circuits électriques au moyen de contacts séparables

Note 1 à l'article: Tout appareil mécanique de connexion peut être désigné en fonction du milieu dans lequel ses contacts s'ouvrent et se ferment, par exemple: air, SF₆, huile.

[SOURCE: IEC 60050-441:1984, 441-14-02]

3.2.3

appareil de connexion à semiconducteur

appareil de connexion conçu pour établir et/ou interrompre le courant dans un circuit électrique au moyen de la commande de la conductivité d'un semiconducteur

Note 1 à l'article: Cette définition diffère de celle de l'IEC 60050-441:1984, 441-14-03, car un appareil de connexion à semiconducteur est également conçu pour interrompre le courant.

[SOURCE: IEC 60050-441:1984, 441-14-03, modifié – Ajout de "et/ou interrompre" et d'une nouvelle Note 1 à l'article.]

3.2.4

fusible

coupe-circuit à fusibles

appareil dont la fonction est d'ouvrir par la fusion d'un ou de plusieurs de ses éléments conçus et calibrés à cet effet le circuit dans lequel il est inséré en coupant le courant lorsque celui-ci dépasse pendant un temps suffisant une valeur donnée

Note 1 à l'article: Le fusible comprend toutes les parties qui constituent l'appareil complet.

[SOURCE: IEC 60050-441:1984, 441-18-01]

3.2.5

disjoncteur

appareil mécanique de connexion capable d'établir, de supporter et d'interrompre des courants dans les conditions normales du circuit, ainsi que d'établir, de supporter pendant une durée spécifiée et d'interrompre des courants dans des conditions anormales spécifiées du circuit telles que celles du court-circuit

[SOURCE: IEC 60050-441:1984, 441-14-20]

3.2.6

contacteur mécanique

contacteur

appareil mécanique de connexion ayant une seule position de repos, commandé autrement qu'à la main, capable d'établir, de supporter et d'interrompre des courants dans les conditions normales du circuit, y compris les conditions de surcharge en service

Note 1 à l'article: L'expression "commandé autrement qu'à la main" signifie que l'appareil est destiné à être commandé et maintenu en position de fonctionnement à partir d'une ou de plusieurs sources d'énergie extérieures.

Note 2 à l'article: Un contacteur pour usages domestiques peut comporter un organe de commande manuelle afin d'améliorer sa manœuvre. Dans certains pays, les contacteurs peuvent être commandés par un signal émis par le distributeur d'énergie pendant les heures creuses. Un utilisateur final peut ouvrir ou fermer manuellement le contacteur si nécessaire.

Note 3 à l'article: Un contacteur est généralement prévu pour fonctionner fréquemment.

[SOURCE: IEC 60050-441:1984, 441-14-33, modifié – Ajout de Notes à l'article.]

3.2.7

contacteur électromagnétique

contacteur pour lequel l'effort nécessaire à la fermeture des contacts principaux normalement ouverts ou à l'ouverture des contacts principaux normalement fermés est fourni par un électroaimant

Note 1 à l'article: L'électroaimant peut être commandé électroniquement.

3.2.8

électroaimant commandé électroniquement

électroaimant dans lequel la bobine est commandée par un circuit qui comporte des éléments électroniques actifs

3.2.9

contacteur à accrochage

contacteur muni d'un dispositif d'accrochage empêchant ses éléments mobiles de retourner à leur position de repos quand on cesse d'actionner le dispositif de commande

Note 1 à l'article: L'accrochage et le déclencheur d'accrochage peuvent être mécaniques, électromagnétiques, pneumatiques, etc.

Note 2 à l'article: Du fait de son accrochage, le contacteur à accrochage possède en fait une seconde position de repos et, conformément au 3.2.6, il n'est pas à proprement parler un contacteur. Cependant, étant donné que le contacteur à accrochage, tant par son utilisation que par sa conception, se rapproche davantage d'un contacteur en général que de toute autre sorte d'appareil de connexion, on admet qu'il réponde aux spécifications des contacteurs dans la mesure du possible.

[SOURCE: IEC 60050-441:1984, 441-14-34]

3.2.10

contacteur à semiconducteurs (contacteur statique)

dispositif qui assure la fonction d'un contacteur en utilisant un appareil de connexion à semiconducteurs

Note 1 à l'article: Un contacteur à semiconducteur peut aussi comporter des appareils mécaniques de connexion.

3.2.11

auxiliaire automatique de commande

auxiliaire de commande non manuel, actionné à la suite de conditions spécifiées d'une grandeur d'action

Note 1 à l'article: La grandeur d'action peut être la pression, la température, la vitesse, le niveau d'un liquide, le temps écoulé, etc.

[SOURCE: IEC 60050-441:1984, 441-14-48]

3.2.12

bouton-poussoir

auxiliaire de commande muni d'un organe de commande destiné à être actionné par l'effort exercé par une partie du corps humain, généralement le doigt ou la paume de la main, et possédant une énergie de rappel accumulée (ressort)

[SOURCE: IEC 60050-441:1984, 441-14-53]

3.2.13

dispositif de protection contre les courts-circuits DPCC

dispositif destiné à protéger un circuit ou des parties d'un circuit contre les courants de court-circuit par l'interruption de ceux-ci

3.2.14

parafoudre

appareil prévu pour protéger le matériel électrique contre les surtensions transitoires élevées et pour limiter la durée et souvent l'amplitude du courant de suite

[SOURCE: IEC 60050-614:2016, 614-03-51, modifié – Ajout de "pour protéger le matériel électrique contre les surtensions transitoires élevées et".]

3.3 Parties des appareils de connexion

3.3.1

pôle

<appareil de connexion> élément constituant d'un appareil de connexion associé exclusivement à un chemin conducteur électriquement séparé appartenant à son circuit principal, cet élément ne comprenant pas les éléments constituant assurant la fixation et le fonctionnement d'ensemble de tous les pôles

Note 1 à l'article: Un appareil de connexion est appelé unipolaire s'il n'a qu'un pôle. S'il a plus d'un pôle, il peut être appelé multipolaire (bipolaire, tripolaire, etc.) à condition que les pôles soient ou puissent être liés entre eux de façon qu'ils fonctionnent ensemble.

[SOURCE: IEC 60050-441:1984, 441-15-01]

3.3.2**circuit principal**

<appareil de connexion> ensemble de pièces conductrices d'un appareil de connexion insérées dans le circuit qu'il a pour fonction de fermer ou d'ouvrir

[SOURCE: IEC 60050-441:1984, 441-15-02]

3.3.3**circuit de commande**

<appareil de connexion> ensemble de pièces conductrices d'un appareil de connexion, autres que celles du circuit principal, insérées dans un circuit utilisé pour commander la manœuvre de fermeture ou la manœuvre d'ouverture ou les deux manœuvres de l'appareil

[SOURCE: IEC 60050-441:1984, 441-15-03]

3.3.4**circuit auxiliaire**

<appareil de connexion> ensemble de pièces conductrices d'un appareil de connexion destinées à être insérées dans un circuit autre que le circuit principal et les circuits de commande de l'appareil

Note 1 à l'article: Certains circuits auxiliaires remplissent des fonctions supplémentaires telles que la signalisation, le verrouillage, etc., et, à ce titre, ils peuvent faire partie du circuit de commande d'un autre appareil de connexion.

[SOURCE: IEC 60050-441:1984, 441-15-04]

3.3.5**contact**

<appareil mécanique de connexion> pièces conductrices destinées à établir la continuité d'un circuit lorsqu'elles se touchent et qui, par leur mouvement relatif pendant la manœuvre, ouvrent et ferment un circuit ou, dans le cas de contacts pivotants ou glissants, maintiennent la continuité du circuit

[SOURCE: IEC 60050-441:1984, 441-15-05]

3.3.6**contact****pièce de contact**

une des pièces conductrices formant un contact

[SOURCE: IEC 60050-441:1984, 441-15-06]

3.3.7**contact principal**

contact inséré dans le circuit principal d'un appareil mécanique de connexion, prévu pour supporter, dans la position de fermeture, le courant du circuit principal

[SOURCE: IEC 60050-441:1984, 441-15-07]

3.3.8**contact auxiliaire**

contact inséré dans un circuit auxiliaire et manœuvré mécaniquement par l'appareil de connexion

[SOURCE: IEC 60050-441:1984, 441-15-10]

3.3.9

interrupteur auxiliaire

<appareil mécanique de connexion> interrupteur comprenant un ou plusieurs contacts auxiliaires et/ou de commande, manœuvré mécaniquement par un appareil de connexion

[SOURCE: IEC 60050-441:1984, 441-15-11]

3.3.10

contact à fermeture

contact "a"

contact de commande ou auxiliaire qui est fermé lorsque les contacts principaux de l'appareil mécanique de connexion sont fermés et qui est ouvert lorsque ces contacts sont ouverts

[SOURCE: IEC 60050-441:1984, 441-15-12]

3.3.11

contact à ouverture

contact "b"

contact de commande ou auxiliaire qui est ouvert lorsque les contacts principaux de l'appareil mécanique de connexion sont fermés et qui est fermé lorsque ces contacts sont ouverts

[SOURCE: IEC 60050-441:1984, 441-15-13]

3.3.12

déclencheur

<appareil mécanique de connexion> dispositif raccordé mécaniquement à un appareil mécanique de connexion dont il libère les organes de retenue et qui permet l'ouverture ou la fermeture de l'appareil

Note 1 à l'article: La manœuvre d'un déclencheur peut être instantanée, différée, etc.

[SOURCE: IEC 60050-441:1984, 441-15-17]

3.3.13

mécanisme transmetteur

<appareil mécanique de connexion> ensemble des organes de manœuvre d'un appareil mécanique de connexion qui transmet l'effort de manœuvre aux pièces de contact

Note 1 à l'article: Les organes de manœuvre d'un mécanisme transmetteur peuvent être mécaniques, électromagnétiques, hydrauliques, pneumatiques, thermiques, etc.

3.3.14

organe de commande

partie du mécanisme transmetteur à laquelle un effort extérieur de manœuvre est appliqué

Note 1 à l'article: L'organe de commande peut prendre la forme d'une poignée, d'un bouton, d'un bouton-poussoir, d'une roulette, d'un plongeur, etc.

[SOURCE: IEC 60050-441:1984, 441-15-22]

3.3.15

indicateur de position

partie d'un appareil mécanique de connexion qui indique les positions de celui-ci, par exemple: position d'ouverture, position de fermeture, ou, le cas échéant, position de mise à la terre

[SOURCE: IEC 60050-441:1984, 441-15-25]

3.3.16**borne**

partie conductrice d'un appareil destinée à la connexion électrique des circuits extérieurs

3.3.17**borne à vis**

borne pour la connexion et la déconnexion de conducteurs ou pour l'interconnexion de plusieurs conducteurs, la connexion étant réalisée directement ou indirectement au moyen de vis ou d'écrous de tous types

3.3.18**borne sans vis**

borne pour la connexion et la déconnexion de conducteurs ou pour l'interconnexion de plusieurs conducteurs, la connexion étant réalisée directement ou indirectement au moyen de ressorts, pièces formant coin, excentriques ou coniques, etc.

3.3.19**borne universelle**

borne pour la connexion et la déconnexion de tous les types de conducteurs (massifs, câblés et souples)

[SOURCE: IEC 60998-2-2:2002, 3.101.1, modifié – "(rigides et souples)" a été remplacé par "(massifs, câblés et souples)".]

3.3.20**borne non universelle**

borne pour la connexion et la déconnexion d'un certain type de conducteur seulement (conducteurs massifs seulement ou conducteurs massifs et câblés seulement, par exemple)

[SOURCE: IEC 60998-2-2:2002, 3.101.2, modifié – "rigides [massifs ou câblés]" a été remplacé par "massifs et câblés".]

3.3.21**borne pousse-fil**

borne non universelle dans laquelle la connexion est réalisée en introduisant un conducteur massif ou câblé

[SOURCE: IEC 60998-2-2:2002, 3.101.3, modifié – "rigide (massif ou câblé)" a été remplacé par "massif ou câblé".]

3.3.22**vis autotaraudeuse par déformation**

vis autotaraudeuse dont le filetage est continu

Note 1 à l'article: Ce filetage n'est pas destiné à enlever du matériau de la cavité.

Note 2 à l'article: Un exemple de vis autotaraudeuse par déformation est représenté à la Figure 1.

3.3.23**vis autotaraudeuse à découpe**

vis autotaraudeuse dont le filetage n'est pas continu

Note 1 à l'article: Ce filetage est destiné à enlever du matériau de la cavité.

Note 2 à l'article: Un exemple de vis autotaraudeuse à découpe est représenté à la Figure 2.

3.3.24**organe de serrage**

partie d'une borne nécessaire pour le serrage mécanique et la connexion électrique du ou des conducteurs

3.3.25

conducteur non préparé

conducteur dont l'extrémité coupée a été dénudée pour être insérée dans une borne

Note 1 à l'article: Un conducteur dont la forme a été disposée de manière à être introduite dans une borne ou dont les torons sont torsadés pour consolider son extrémité est considéré comme un conducteur non préparé.

3.3.26

conducteur préparé

conducteur dont l'extrémité dénudée est munie d'un accessoire tel que manchon ou cosse ou raccord de câbles

[SOURCE: IEC 60050-442:1998, 442-01-27]

3.3.27

âme massive

âme constituée d'un fil unique

Note 1 à l'article: L'âme massive peut être circulaire ou profilée.

Note 2 à l'article: Une âme massive est définie comme une âme de classe 1 dans l'IEC 60228 ou, selon l'IEC TR 60344, par sa dimension équivalente dans le système AWG/kcmil.

[SOURCE: IEC 60050-461:2008, 461-01-06, modifié – La Note 2 à l'article a été ajoutée.]

3.3.28

conducteur câblé

conducteur constitué d'un ensemble de fils, dont certains ou tous sont enroulés en hélice

Note 1 à l'article: Un conducteur câblé est défini comme un conducteur de classe 2 dans l'IEC 60228 ou, selon l'IEC TR 60344, par sa dimension équivalente dans le système AWG/kcmil.

[SOURCE: IEC 60050-151:2001, 151-12-36, modifié – La Note 1 à l'article a été ajoutée.]

3.3.29

âme rigide

conducteur massif ou toronné constitué de fils présentant un diamètre tel ou assemblés de façon à ne pas pouvoir être utilisés dans un câble souple

[SOURCE: IEC 60947-1:2020, 3.5.31]

3.3.30

âme souple

âme câblée constituée de fils suffisamment fins et assemblés de façon à pouvoir être utilisés dans un câble souple

Note 1 à l'article: Une âme souple est définie comme un conducteur de classe 5 ou 6 dans l'IEC 60228 ou, selon l'IEC TR 60344, par sa dimension équivalente dans le système AWG/kcmil.

[SOURCE: IEC 60050-461:2008, 461-01-11, modifié – La Note 1 à l'article a été ajoutée.]

3.4 Manœuvre des appareils de connexion

3.4.1

manœuvre

<appareil mécanique de connexion> passage d'un ou de plusieurs contacts mobiles d'une position à une position adjacente

Note 1 à l'article: Par exemple, pour un disjoncteur, ce pourra être une manœuvre de fermeture ou une manœuvre d'ouverture.

Note 2 à l'article: Si une distinction est nécessaire, on emploiera les mots manœuvre électrique (par exemple: établissement ou coupure) et manœuvre mécanique (par exemple: fermeture ou ouverture).

[SOURCE: IEC 60050-441:1984, 441-16-01]

3.4.2

cycle de manœuvres

<appareil mécanique de connexion> suite de manœuvres d'une position à une autre avec retour à la première position en passant par toutes les autres positions, s'il en existe

[SOURCE: IEC 60050-441:1984, 441-16-02]

3.4.3

séquence de manœuvres

<appareil mécanique de connexion> suite de manœuvres spécifiées effectuées à des intervalles de temps spécifiés

[SOURCE: IEC 60050-441:1984, 441-16-03]

3.4.4

manœuvre de fermeture

<appareil mécanique de connexion> manœuvre par laquelle on fait passer l'appareil de la position d'ouverture à la position de fermeture

[SOURCE: IEC 60050-441:1984, 441-16-08]

3.4.5

manœuvre d'ouverture

<appareil mécanique de connexion> manœuvre par laquelle on fait passer l'appareil de la position de fermeture à la position d'ouverture

[SOURCE: IEC 60050-441:1984, 441-16-09]

3.4.6

position de fermeture

<appareil mécanique de connexion> position dans laquelle la continuité prédéterminée du circuit principal de l'appareil est assurée

[SOURCE: IEC 60050-441:1984, 441-16-22]

3.4.7

position d'ouverture

<appareil mécanique de connexion> position dans laquelle les exigences prédéterminées de tension de tenue diélectrique entre contacts ouverts sont assurées dans le circuit principal de l'appareil

Note 1 à l'article: Cette définition diffère de celle de l'IEC 60050-441:1984, 441-16-23 afin de satisfaire aux exigences concernant les propriétés diélectriques.

[SOURCE: IEC 60050-441:1984, 441-16-23, modifié – Remplacement de "la distance prédéterminée d'isolement entre contacts ouverts est assurée" par "les exigences prédéterminées de tension de tenue diélectrique entre contacts ouverts sont assurées".]

3.4.8

position de repos

<contacteur> position que prennent les organes mobiles du contacteur quand son électroaimant ou son dispositif à air comprimé n'est pas alimenté

[SOURCE: IEC 60050-441:1984, 441-16-24]

3.4.9

marche par à-coups

commande caractérisée par une série de fermetures brèves et fréquentes du circuit d'un moteur ou d'un électroaimant, en vue d'obtenir de petits déplacements de l'organe entraîné

3.4.10

inversion de marche

arrêt ou inversion rapide du sens de rotation d'un moteur par permutation des connexions d'alimentation du moteur pendant que celui-ci tourne

3.5 Grandeurs caractéristiques

3.5.1

valeur nominale

valeur de dénomination

valeur d'une grandeur, utilisée pour dénommer et identifier un composant, un dispositif, un matériel ou un système

Note 1 à l'article: La valeur nominale est généralement une valeur arrondie.

[SOURCE: IEC 60050-151:2001, 151-16-09]

3.5.2

valeur limite

dans une spécification d'un composant, dispositif, matériel ou système, la plus grande ou la plus petite valeur admissible d'une grandeur

[SOURCE: IEC 60050-151:2001, 151-16-10]

3.5.3

valeur assignée

valeur d'une grandeur, utilisée à des fins de spécification, correspondant à un ensemble spécifié de conditions de fonctionnement d'un composant, dispositif, matériel ou système

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.5.4

caractéristiques assignées

ensemble des valeurs assignées et des conditions de fonctionnement

[SOURCE: IEC 60050-151:2001, 151-16-11]

3.5.5

courant présumé

<d'un circuit et relatif à un appareil de connexion ou à un fusible> courant qui circulerait dans le circuit si chaque pôle de l'appareil de connexion ou le fusible était remplacé par un conducteur d'impédance négligeable

Note 1 à l'article: La méthode à employer pour évaluer et pour exprimer le courant présumé est spécifiée dans les publications particulières.

[SOURCE: IEC 60050-441:1984, 441-17-01]

3.5.6

valeur de crête du courant présumé

valeur de crête d'un courant présumé pendant la période transitoire qui suit son établissement

Note 1 à l'article: La définition implique que le courant est établi par un appareil de connexion idéal, c'est-à-dire passant instantanément d'une impédance infinie à une impédance nulle. Pour un circuit ayant plusieurs voies, par exemple un circuit polyphasé, il est entendu en outre que le courant est établi simultanément dans tous les pôles même si on ne considère que le courant dans un seul pôle.

[SOURCE: IEC 60050-441:1984, 441-17-02]

3.5.7

valeur maximale de crête du courant présumé

<circuit à courant alternatif> valeur de crête du courant présumé quand l'établissement du courant a lieu à l'instant qui conduit à la plus grande valeur possible

Note 1 à l'article: Pour un appareil multipolaire dans un circuit polyphasé, la valeur maximale de crête du courant présumé ne se rapporte qu'à un seul pôle.

[SOURCE: IEC 60050-441:1984, 441-17-04]

3.5.8

courant coupé

<appareil de connexion ou fusible> courant dans un pôle d'un appareil de connexion ou dans un fusible évalué à l'instant de l'amorçage de l'arc au cours d'une coupure

Note 1 à l'article: En courant alternatif, ce courant est exprimé par la valeur efficace symétrique de la composante alternative.

[SOURCE: IEC 60050-441:1984, 441-17-07, modifié – Ajout d'une nouvelle Note 1 à l'article.]

3.5.9

pouvoir de coupure

<appareil de connexion ou fusible> valeur de courant présumé qu'un appareil de connexion ou un fusible est capable d'interrompre sous une tension fixée dans des conditions prescrites d'emploi et de comportement

Note 1 à l'article: La tension à fixer et les conditions à prescrire sont précisées dans la norme de matériel correspondante.

Note 2 à l'article: En courant alternatif, ce courant est exprimé par la valeur efficace symétrique de la composante alternative.

Note 3 à l'article: Pour le pouvoir de coupure en court-circuit, voir 3.5.11.

[SOURCE: IEC 60050-441:1984, 441-17-08, modifié – Ajout des Notes 2 et 3 à l'article.]

3.5.10

pouvoir de fermeture

<appareil de connexion> valeur du courant présumé établi qu'un appareil de connexion est capable d'établir sous une tension donnée et dans des conditions prescrites d'emploi et de comportement

Note 1 à l'article: La tension à fixer et les conditions à prescrire sont précisées dans la norme de matériel correspondante.

Note 2 à l'article: Pour le pouvoir de fermeture en court-circuit, voir 3.5.12.

[SOURCE: IEC 60050-441:1984, 441-17-09, modifié – Ajout d'une nouvelle Note 2 à l'article.]

3.5.11

pouvoir de coupure en court-circuit

pouvoir de coupure pour lequel les conditions prescrites comprennent un court-circuit aux bornes de l'appareil de connexion

[SOURCE: IEC 60050-441:1984, 441-17-11]

3.5.12

pouvoir de fermeture en court-circuit

pouvoir de fermeture pour lequel les conditions prescrites comprennent un court-circuit aux bornes de l'appareil de connexion

[SOURCE: IEC 60050-441:1984, 441-17-10]

3.5.13

intégrale de Joule

I^2t

intégrale du carré du courant pour un intervalle de temps donné:

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

[SOURCE: IEC 60050-441:1984, 441-18-23, modifié – Suppression des Notes à l'article.]

3.5.14

courant coupé limité

valeur instantanée maximale du courant atteinte au cours de la coupure effectuée par un appareil de connexion ou un fusible

Note 1 à l'article: Cette notion est d'importance particulière si l'appareil de connexion ou le fusible fonctionne de telle manière que la valeur de crête du courant présumé du circuit n'est pas atteinte.

[SOURCE: IEC 60050-441:1984, 441-17-12]

3.5.15

tension appliquée

<appareil de connexion> tension qui existe entre les bornes d'un pôle d'un appareil de connexion immédiatement avant l'établissement du courant

Note 1 à l'article: Cette définition s'applique à un appareil unipolaire. Pour un appareil multipolaire, il s'agit de la tension entre phases aux bornes d'alimentation de l'appareil.

[SOURCE: IEC 60050-441:1984, 441-17-24, modifié – Nouvelle Note 1 à l'article.]

3.5.16**tension de rétablissement**

tension qui apparaît entre les bornes d'un pôle d'un appareil de connexion ou d'un fusible après l'interruption du courant

Note 1 à l'article: Cette tension peut être considérée durant deux intervalles de temps consécutifs, l'un durant lequel existe une tension transitoire, suivi par un second intervalle durant lequel la tension de rétablissement à fréquence industrielle ou en régime établi existe seule.

Note 2 à l'article: Cette définition s'applique à un appareil unipolaire. Pour un appareil multipolaire, il s'agit de la tension entre phases aux bornes d'alimentation de l'appareil.

[SOURCE: IEC 60050-441:1984, 441-17-25, modifié – Nouvelle Note 2 à l'article.]

3.5.17**tension transitoire de rétablissement****TTR**

tension de rétablissement pendant le temps où elle présente un caractère transitoire appréciable

Note 1 à l'article: La tension transitoire peut être oscillatoire ou non oscillatoire ou être une combinaison de celles-ci selon les caractéristiques du circuit, de l'appareil de connexion ou du fusible. Elle tient compte de la variation du potentiel du point neutre du circuit polyphasé.

[SOURCE: IEC 60050-441:1984, 441-17-26, modifié – Remplacement dans la note de "et de l'appareil de connexion" par "de l'appareil de connexion ou du fusible".]

3.5.18**tension de rétablissement à fréquence industrielle**

tension de rétablissement après la disparition des phénomènes transitoires de tension

[SOURCE: IEC 60050-441:1984, 441-17-27]

3.5.19**tension de rétablissement en courant continu en régime établi**

tension de rétablissement dans un circuit à courant continu après la disparition des phénomènes transitoires de tension, exprimée par sa valeur moyenne s'il y a des ondulations

[SOURCE: IEC 60050-441:1984, 441-17-28]

3.5.20**distance d'isolement**

distance entre deux parties conductrices le long d'un fil tendu suivant le plus court trajet possible entre ces deux parties conductrices

[SOURCE: IEC 60050-441:1984, 441-17-31]

3.5.21**ligne de fuite**

distance la plus courte le long de la surface d'un matériau isolant entre deux parties conductrices

Note 1 à l'article: Un joint entre deux pièces en matériau isolant est considéré comme faisant partie de la surface.

3.5.22**tension locale**

valeur efficace la plus élevée de la tension en courant alternatif ou valeur la plus élevée de la tension en courant continu qui peut apparaître (localement) à travers n'importe quelle isolation à la tension assignée d'alimentation, les surtensions transitoires n'étant pas prises en compte, en circuit ouvert ou dans les conditions normales de fonctionnement

3.5.23

tension de tenue aux chocs

valeur de crête la plus élevée d'une tension de choc, de la forme et de la polarité prescrites, qui ne provoque pas de claquage dans les conditions d'essai spécifiées

3.5.24

tension de tenue à fréquence industrielle

valeur efficace d'une tension sinusoïdale à fréquence industrielle qui ne provoque pas de claquage dans les conditions d'essai spécifiées

3.5.25

pollution

tout apport de matériau étranger solide, liquide ou gazeux (gaz ionisés) qui peut modifier la rigidité diélectrique ou la résistivité superficielle

3.5.26

degré de pollution

<conditions d'environnement> nombre conventionnel fondé sur la quantité de poussières conductrices ou hygroscopiques, de gaz ionisés ou de sels, et sur l'humidité relative et sa fréquence d'apparition se traduisant par l'absorption ou la condensation d'humidité, ayant pour effet de diminuer la rigidité diélectrique et/ou la résistivité superficielle

Note 1 à l'article: Le degré de pollution du microenvironnement auquel est exposé un matériel peut être différent de celui du macroenvironnement dans lequel est situé le matériel en raison de la protection procurée par une enveloppe ou un chauffage interne qui empêche l'absorption ou la condensation de l'humidité.

Note 2 à l'article: Dans le cadre du présent document, le degré de pollution est celui du microenvironnement.

3.5.27

microenvironnement

<distances d'isolement ou lignes de fuite> conditions ambiantes à proximité immédiate des distances d'isolement ou des lignes de fuite à l'étude

Note 1 à l'article: L'effet sur l'isolation est déterminé par le microenvironnement des lignes de fuite ou des distances d'isolement, et non pas par l'environnement du matériel. Le microenvironnement peut être meilleur ou pire que l'environnement du matériel. Il comprend tous les facteurs qui ont une incidence sur l'isolation, comme les conditions climatiques et électromagnétiques, la production de pollution, etc.

3.5.28

catégorie de surtension

<dans un circuit ou dans un système électrique> nombre conventionnel fondé sur la limitation (ou la maîtrise) des valeurs des surtensions transitoires présumées apparaissant dans un circuit (ou dans un système électrique présentant plusieurs tensions nominales) et qui dépend des moyens employés pour agir sur ces surtensions

Note 1 à l'article: Dans un système électrique, le passage d'une catégorie de surtension à une catégorie inférieure est réalisé à l'aide de moyens appropriés conformes aux exigences d'interface, comme un dispositif de protection contre les surtensions ou des impédances montées en série et/ou en parallèle capables de dissiper, d'absorber ou de détourner l'énergie dans le courant de surcharge correspondant, afin d'abaisser la valeur des surtensions transitoires à celle qui correspond à la catégorie de surtension inférieure souhaitée.

3.5.29

coordination de l'isolement

correspondance des caractéristiques d'isolement du matériel électrique, d'une part avec les surtensions attendues et avec les caractéristiques des dispositifs de protection contre les surtensions et, d'autre part, avec le microenvironnement attendu et les moyens de protection contre la pollution

3.5.30**champ homogène****champ uniforme**

champ électrique dont le gradient de tension est essentiellement constant entre les électrodes, tel que celui existant entre deux sphères dont le rayon de chacune est plus grand que la distance qui les sépare

3.5.31**champ hétérogène****champ non uniforme**

champ électrique dont le gradient de tension entre les électrodes n'est pas essentiellement constant

3.5.32**cheminement**

formation progressive de chemins conducteurs à la surface ou dans un isolant solide, sous l'effet combiné des contraintes électriques et de la contamination électrolytique de cette surface

3.5.33**indice de résistance au cheminement****IRC**

valeur numérique de la tension maximale en volts pour laquelle un matériau supporte le dépôt de 50 gouttes d'une solution d'essai, sans cheminement

Note 1 à l'article: La valeur de chaque tension d'essai et celle de l'IRC sont divisibles par 25.

Note 2 à l'article: Cette définition est fondée sur le 3.5 de l'IEC 60112:2020.

4 Classification

Le 5.2 fournit toutes les données qui peuvent servir de critères de classification.

5 Caractéristiques des contacteurs**5.1 Récapitulatif des caractéristiques**

Les caractéristiques doivent être indiquées comme suit, s'il y a lieu:

- type de contacteur (voir 5.2);
- valeurs assignées et valeurs limites des circuits principaux (voir 5.3);
- catégorie d'emploi (voir 5.4);
- circuits de commande (voir 5.5);
- circuits auxiliaires (voir 5.6);
- coordination avec les dispositifs de protection contre les courts-circuits (voir 5.7).

5.2 Type de contacteur**5.2.1 Généralités**

Les informations suivantes doivent être indiquées (voir aussi l'Article 6):

5.2.2 Nombre de pôles**5.2.3 Mode de commande**

- automatique (par auxiliaire automatique de commande ou commande séquentielle);
- non automatique (par commande manuelle ou par boutons-poussoirs, par exemple);
- semi-automatique (c'est-à-dire en partie automatique, en partie non automatique).

5.3 Valeurs assignées et valeurs limites des circuits principaux

5.3.1 Généralités

Les valeurs assignées établies pour un contacteur doivent être indiquées conformément aux 5.3.2 à 5.4 et au 5.7.

5.3.2 Tensions assignées

5.3.2.1 Généralités

Un contacteur est défini par les tensions assignées données du 5.3.2.2 au 5.3.2.4.

5.3.2.2 Tension assignée d'emploi (U_e)

Une tension assignée d'emploi d'un contacteur est une valeur de tension qui, combinée à un courant assigné d'emploi, détermine l'application du contacteur, et à laquelle se rapportent les essais correspondants et la catégorie d'emploi.

Pour un contacteur unipolaire, la tension assignée d'emploi s'exprime généralement par la tension aux bornes du pôle.

Pour un contacteur multipolaire, elle s'exprime généralement par la tension entre phases.

NOTE 1 Un contacteur peut être caractérisé par un certain nombre de valeurs combinées de tensions assignées d'emploi et de puissances ou courants assignés d'emploi correspondant à différents services et différentes catégories d'emploi.

NOTE 2 Un contacteur peut être caractérisé par un certain nombre de tensions assignées d'emploi et de pouvoirs de fermeture et de coupure correspondant à différents services et différentes catégories d'emploi.

NOTE 3 L'attention est attirée sur le fait que la tension d'emploi peut être différente de la tension locale (voir 3.5.22) à l'intérieur d'un contacteur.

5.3.2.3 Tension d'isolement assignée (U_i)

La tension assignée d'isolement d'un contacteur est la valeur de tension à laquelle se réfèrent les essais diélectriques et les lignes de fuite.

En aucun cas, la valeur la plus élevée de la tension assignée d'emploi ne doit dépasser celle de la tension assignée d'isolement.

NOTE Dans le cas des contacteurs pour lesquels aucune tension assignée d'isolement n'est spécifiée, la valeur la plus élevée de la tension assignée d'emploi est considérée comme étant la tension assignée d'isolement.

5.3.2.4 Tension assignée de tenue aux chocs (U_{imp})

Valeur de crête d'une tension de choc, de la forme et de la polarité prescrites, que peut supporter le contacteur sans claquage dans les conditions d'essai spécifiées et à laquelle se réfèrent les valeurs des distances d'isolement.

La tension assignée de tenue aux chocs d'un contacteur doit être supérieure ou égale aux valeurs fixées pour les surtensions transitoires apparaissant dans le circuit, où est placé le matériel.

NOTE Les valeurs préférentielles de la tension assignée de tenue aux chocs sont indiquées dans le Tableau 16.

5.3.3 Courants ou puissances

5.3.3.1 Généralités

Un contacteur est défini par les courants donnés du 5.3.3.2 au 5.3.3.4.

5.3.3.2 Courant thermique conventionnel à l'air libre (I_{th})

Le courant thermique conventionnel à l'air libre est la valeur maximale du courant d'essai à utiliser pour les essais d'échauffement d'un contacteur sans enveloppe à l'air libre (voir 9.3.3.3).

La valeur du courant thermique conventionnel à l'air libre doit être au moins égale à la valeur maximale du courant assigné d'emploi (voir 5.3.3.4) du contacteur sans enveloppe, en service de 8 h (voir 5.3.5.2).

L'air libre est l'air présent à l'intérieur dans les conditions normales, raisonnablement exempt de courants d'air et de rayonnements externes.

NOTE 1 Ce courant n'est pas une caractéristique assignée et n'est pas obligatoirement marqué sur le contacteur.

NOTE 2 Un contacteur sans enveloppe est un contacteur fourni par le fabricant sans enveloppe ou un contacteur fourni par le fabricant avec une enveloppe intégrée qui n'est pas destinée normalement à être la seule enveloppe de protection du contacteur. Un contacteur sans enveloppe est caractérisé par le code IP00.

5.3.3.3 Courant thermique conventionnel sous enveloppe (I_{the})

Le courant thermique conventionnel sous enveloppe d'un contacteur est la valeur du courant fixée par le fabricant, qui doit être utilisée pour les essais d'échauffement du contacteur lorsqu'il est monté dans une enveloppe spécifiée. Ces essais doivent être conformes au 9.3.3.3 et sont obligatoires si les catalogues du fabricant décrivent le contacteur comme un contacteur sous enveloppe normalement destiné à être utilisé avec une ou plusieurs enveloppes d'un type et de taille spécifiés (voir Note 2 du 5.3.3.2).

La valeur du courant thermique conventionnel sous enveloppe doit être au moins égale à la valeur maximale du courant assigné d'emploi (voir 5.3.3.4) du contacteur sous enveloppe en service de 8 h (voir 5.3.5.2).

Si le contacteur est normalement destiné à être utilisé dans des enveloppes non spécifiées, cet essai n'est pas obligatoire si l'essai au courant thermique conventionnel à l'air libre (I_{th}) a été effectué. Dans ce cas, le fabricant doit être en mesure de fournir des recommandations relatives à la valeur du courant thermique sous enveloppe ou au facteur de déclassement.

NOTE 1 Ce courant n'est pas une caractéristique assignée et n'est pas obligatoirement marqué sur le contacteur.

NOTE 2 Un contacteur sous enveloppe est un contacteur normalement destiné à être utilisé avec un type et une taille d'enveloppe spécifiés, ou avec plusieurs types d'enveloppes.

5.3.3.4 Courants assignés d'emploi (I_e) ou puissances assignées

Un courant assigné d'emploi d'un contacteur est défini par le fabricant et tient compte de la tension assignée d'emploi (voir 5.3.2.2), du courant thermique conventionnel à l'air libre ou sous enveloppe, de la fréquence assignée (voir 5.3.4), du service assigné (voir 5.3.5), de la catégorie d'emploi (voir 5.4) et du type d'enveloppe de protection, le cas échéant.

Dans le cas d'un contacteur destiné à la commande directe de moteurs distincts ou de lampes à LED distinctes, l'indication d'un courant assigné d'emploi peut être remplacée ou complétée par celle de la puissance assignée maximale, à la tension assignée d'emploi concernée, de la charge pour laquelle le contacteur est prévu. Le fabricant doit être en mesure de préciser la relation présumée entre le courant d'emploi et la puissance.

5.3.4 Fréquence assignée

Fréquence d'alimentation pour laquelle est conçu un contacteur et à laquelle correspondent les autres valeurs caractéristiques.

NOTE Un même contacteur peut avoir plusieurs fréquences assignées ou une plage de fréquences assignées.

5.3.5 Services assignés

5.3.5.1 Généralités

Les services assignés considérés comme normaux sont donnés du 5.3.5.2 au 5.3.5.5.

5.3.5.2 Service de 8 heures (service continu)

Service dans lequel les contacts principaux d'un contacteur restent fermés tout en transportant un courant permanent pendant une durée suffisamment longue pour permettre au contacteur d'atteindre l'équilibre thermique, la durée étant inférieure ou égale à 8 h sans interruption.

NOTE 1 Ce service est le service de référence à partir duquel les courants thermiques conventionnels I_{th} et I_{the} du contacteur sont déterminés.

NOTE 2 Une interruption est la coupure du courant par la manœuvre du contacteur.

5.3.5.3 Service intermittent périodique ou service intermittent

Service avec des durées de fonctionnement en charge pendant lesquelles les contacts principaux d'un contacteur restent fermés, et dont la relation avec les durées sans charge est définie, chacune de ces durées étant trop courte pour permettre au contacteur d'atteindre l'équilibre thermique.

Le service intermittent est caractérisé par la valeur du courant, par la durée de passage du courant et par le facteur de marche, qui est le rapport entre la durée du passage du courant et la durée totale, et qui est souvent exprimé par un pourcentage.

Selon le nombre de cycles de manœuvres qu'ils doivent être capables d'effectuer par heure, les contacteurs sont répartis entre les classes préférentielles suivantes:

– classe	1:	1	cycle de manœuvres par heure;
– classe	3:	3	cycles de manœuvres par heure;
– classe	12:	12	cycles de manœuvres par heure;
– classe	30:	30	cycles de manœuvres par heure;
– classe	120:	120	cycles de manœuvres par heure;
– classe	300:	300	cycles de manœuvres par heure;
– classe	1 200:	1 200	cycles de manœuvres par heure.

Un contacteur destiné au service intermittent peut être désigné par les caractéristiques du service intermittent.

EXEMPLE Un service intermittent comprenant le passage d'un courant de 32 A pendant 2 min par période de 5 min peut être défini: 32 A, classe 12, 40 %.

5.3.5.4 Service temporaire

Service dans lequel les contacts principaux d'un contacteur restent fermés pendant des durées qui ne sont pas suffisamment longues pour permettre au contacteur d'atteindre l'équilibre thermique, les durées de fonctionnement en charge étant séparées par des durées sans charge d'une durée suffisante pour égaliser la température du contacteur avec celle du milieu refroidissant.

5.3.5.5 Service périodique

Service dans lequel le fonctionnement à charge constante ou variable est périodique.

5.3.6 Caractéristiques en conditions normales de charge et de surcharge

5.3.6.1 Généralités

Le présent paragraphe fournit les exigences générales relatives aux caractéristiques assignées en conditions normales de charge et de surcharge.

Les exigences détaillées sont fournies au 8.2.4.

5.3.6.2 Aptitude à supporter les courants de surcharge occasionnés par le démarrage de moteurs

Un contacteur destiné à connecter des moteurs doit pouvoir supporter les contraintes thermiques occasionnées par le démarrage et l'accélération d'un moteur à sa vitesse normale et par les surcharges de fonctionnement.

Les exigences pour remplir ces conditions sont spécifiées au 8.2.4.4.

5.3.6.3 Pouvoir assigné de fermeture

Les exigences concernant les différentes catégories d'emploi (voir 5.4) sont spécifiées au 8.2.4.2. Les pouvoirs assignés de fermeture et de coupure ne sont valables que lorsque le contacteur fonctionne selon les exigences spécifiées au 8.2.1.1 et au 8.2.1.2.

5.3.6.4 Pouvoir assigné de coupure

Les exigences concernant les différentes catégories d'emploi (voir 5.4) sont spécifiées au 8.2.4.2. Les pouvoirs assignés de fermeture et de coupure ne sont valables que lorsque le contacteur fonctionne selon les exigences spécifiées au 8.2.1.1 et au 8.2.1.2.

5.3.6.5 Fonctionnement conventionnel en service

Il est spécifié au 8.2.4.3 comme étant une série de manœuvres de fermeture et de coupure.

5.3.7 Courant assigné de court-circuit conditionnel

Le courant assigné de court-circuit conditionnel d'un contacteur est la valeur de courant présumé, fixée par le fabricant, que le contacteur, protégé par un dispositif de protection contre les courts-circuits spécifié par le fabricant, peut supporter de façon satisfaisante pendant la durée de fonctionnement de ce dispositif dans les conditions d'essai spécifiées au 9.3.4.

Le fabricant doit indiquer les caractéristiques du dispositif de protection contre les courts-circuits.

NOTE Le courant assigné de court-circuit conditionnel s'exprime par la valeur efficace de la composante alternative.

5.4 Catégorie d'emploi

5.4.1 Généralités

La catégorie d'emploi d'un contacteur définit l'application prévue; elle est caractérisée par une ou plusieurs des conditions de service suivantes:

- le ou les courants, exprimés en multiples du courant assigné d'emploi;
- la ou les tensions, exprimées en multiples de la tension assignée d'emploi;
- le facteur de puissance.

Les catégories d'emploi normalisées sont indiquées dans le Tableau 1.

Chaque catégorie d'emploi est caractérisée par les valeurs des courants, tensions, facteurs de puissance et autres données du Tableau 7 et du Tableau 9, ainsi que par les conditions d'essai spécifiées dans le présent document.

Il est donc inutile de spécifier séparément les pouvoirs assignés de fermeture et de coupure, car ces valeurs dépendent directement de la catégorie d'emploi indiquée dans le Tableau 7.

Sauf spécification contraire, les contacteurs de catégorie d'emploi AC-7b sont conçus en fonction des caractéristiques de démarrage des moteurs compatibles avec les pouvoirs de fermeture du Tableau 7. Lorsque le courant de démarrage d'un moteur dont le rotor est bloqué dépasse ces valeurs, il convient de diminuer en conséquence le courant d'emploi.

5.4.2 Attribution des catégories d'emploi suivant les résultats d'essai

Un contacteur qui a été soumis à l'essai pour une catégorie d'emploi ou avec n'importe quelle combinaison de paramètres (tension et courant d'emploi maximaux, etc.) peut se voir attribuer une catégorie d'emploi sans essai complémentaire sous réserve que les grandeurs d'essai, les tensions, les courants, les facteurs de puissance, le nombre de cycles de manœuvres, les durées de passage du courant et les durées de repos indiqués dans le Tableau 7 et le Tableau 9 ainsi que le circuit d'essai pour la catégorie d'emploi attribuée ne soient pas plus sévères que les caractéristiques pour lesquelles le contacteur a été soumis à l'essai, et que l'échauffement ait été vérifié à un courant au moins égal à la valeur maximale du courant assigné d'emploi en service continu.

Tableau 1 – Catégories d'emploi

Catégories d'emploi ^a	Charges types
AC-7a	Légèrement inductive
AC-7b	Moteur ^b
AC-7c	Commande de lampes à décharge électrique avec compensation ^c
AC-7d	Lampe à LED
^a Les contacteurs peuvent avoir d'autres catégories d'emploi. Dans ce cas, ils doivent satisfaire aux exigences de l'IEC 60947-4-1 pour ces catégories d'emploi. ^b La catégorie AC-7b peut être utilisée pour des marches par à-coups occasionnelles ou inversions de marche de durée limitée. Il convient que le nombre de manœuvres pendant ces périodes limitées ne dépasse pas 5/min ni 10 pour une durée de 10 min. ^c Cette catégorie est similaire à la catégorie de commande capacitive AC-6b définie dans l'IEC 60947-4-1 pour la commande de batteries de condensateurs, la caractéristique étant très dépendante de la valeur de la capacité du circuit de la lampe.	

5.5 Circuits de commande

Les caractéristiques des circuits de commande sont:

- la nature du courant;
- la fréquence assignée;
- la tension assignée des circuits de commande U_c (nature et fréquence);
- la tension assignée d'alimentation de commande U_s (nature et fréquence), le cas échéant;
- l'aptitude du circuit de commande à être relié aux circuits TBTS.

NOTE Une distinction a été établie ci-dessus entre la tension du circuit de commande, qui apparaît aux bornes des contacts à fermeture (voir 3.3.10) dans le circuit de commande, et la tension d'alimentation de commande, qui est la tension appliquée aux bornes d'entrée du circuit de commande du contacteur et qui peut être différente de la tension du circuit de commande en raison de la présence de transformateurs, redresseurs, résistances, etc. incorporés.

La tension assignée du circuit de commande et la fréquence assignée, s'il y a lieu, sont les valeurs à partir desquelles sont déterminées les caractéristiques de fonctionnement et d'échauffement du circuit de commande.

5.6 Circuits auxiliaires

Les caractéristiques des circuits auxiliaires sont le nombre et le type des contacts (contact à fermeture, contact à ouverture, etc.) de chacun de ces circuits et leurs caractéristiques assignées, conformément à l'IEC 60947-5-1.

Les caractéristiques des contacts et des interrupteurs auxiliaires doivent satisfaire aux exigences de l'IEC 60947-5-1.

5.7 Coordination avec les dispositifs de protection contre les courts-circuits

Les contacteurs sont caractérisés par le type, les valeurs assignées et les caractéristiques des dispositifs de protection contre les courts-circuits (DPCC) à utiliser pour assurer une protection adéquate du contacteur contre les courants de court-circuit. Les exigences sont spécifiées au 8.2.5.

6 Informations sur le matériel

6.1 Nature des informations

6.1.1 Généralités

Les informations indiquées du 6.1.2 au 6.1.3 doivent être fournies par le fabricant.

6.1.2 Identification

- a) nom du fabricant ou marque commerciale;
- b) désignation du type ou numéro de série;
- c) numéro du présent document.

6.1.3 Caractéristiques, valeurs assignées fondamentales et utilisation

- d) tensions assignées d'emploi (voir 5.3.2.2);
- e) catégorie d'emploi et courants assignés d'emploi (ou puissances assignées), à la tension assignée d'emploi (voir 5.3.3.4 et 5.4);
- f) valeur de la ou des fréquences assignées, par exemple: 50 Hz ou 50 Hz/60 Hz;
- g) service assigné avec l'indication de la classe de service intermittent, s'il y a lieu (voir 5.3.5).

Valeurs associées:

- h) pouvoirs assignés de fermeture et de coupure. Ces informations peuvent être remplacées, s'il y a lieu, par l'indication de la catégorie d'emploi (voir Tableau 7).

Sécurité et installation:

- i) tension assignée d'isolement (voir 5.3.2.3);
- j) tension assignée de tenue aux chocs (voir 5.3.2.4), le marquage de U_{imp} n'est pas exigé si cette tension est égale à 4 kV;
- k) code IP, dans le cas d'un contacteur sous enveloppe (voir 8.1.11);
- l) degré de pollution (voir 7.1.4.2);
- m) courant assigné de court-circuit conditionnel (voir 5.3.7) et type, courant assigné et caractéristiques du DPCC associé;
- n) pour les bornes non universelles sans vis:

- "s" ou "sol" pour les bornes déclarées pour les âmes massives;
- "r" pour les bornes déclarées pour les âmes massives et câblées;
- "f" pour les bornes déclarées pour les âmes souples.

Circuits de commande (voir 5.5):

Les informations suivantes relatives aux circuits de commande doivent figurer soit sur la bobine, soit sur le contacteur:

- o) tension assignée des circuits de commande (U_c), nature du courant et fréquence assignée;
- p) si nécessaire, nature du courant, fréquence assignée et tension assignée d'alimentation de commande (U_s).

Pour les contacteurs dont le circuit de commande est destiné à être raccordé à une alimentation TBTS:

- q) aptitude du circuit de commande à être relié à une alimentation TBTS, le circuit principal étant alimenté par une tension de valeur supérieure à celle du circuit TBTS.
- r) Si le circuit de commande est alimenté par d'autres moyens que la source d'alimentation principale (un circuit de commande raccordé à une alimentation TBTS, par exemple), il convient de fournir des caractéristiques supplémentaires ou le type de référence pour les critères de choix de l'unité d'alimentation.

Circuits auxiliaires:

- s) caractéristiques assignées des circuits auxiliaires (voir 5.6).

6.2 Marquage

Les marquages doivent être indélébiles et facilement lisibles.

Le marquage du nom du fabricant ou de la marque commerciale et de la désignation du type ou du numéro de série est obligatoire sur le contacteur, préférentiellement sur la plaque signalétique éventuelle, de manière à regrouper les données complètes fournies par le fabricant.

NOTE 1 Aux États-Unis et au Canada, la tension assignée d'emploi U_e peut être marquée comme suit:

- a) sur le matériel destiné à être utilisé sur des systèmes triphasés à 4 conducteurs, par la valeur de la tension entre phase et terre et par celle de la tension entre phases, par exemple 277/480 V;
- b) sur le matériel destiné à être utilisé sur des systèmes triphasés à 3 conducteurs, par la valeur de la tension entre phases, par exemple 480 V.

Les informations suivantes doivent être marquées et visibles après le montage:

- sens du mouvement de l'organe de commande (voir 8.1.5.3), le cas échéant;
- indication de la position de l'organe de commande (voir aussi 8.1.6.1 et 8.1.6.2).

Les informations suivantes doivent être marquées et visibles après le câblage, avant l'installation des enveloppes et couvercles:

- symboles, code de couleur ou code littéral pour les contacteurs miniaturisés;
- identification et marquage des bornes (voir 8.1.7.4);
- code IP et classe de protection contre les chocs électriques, s'il y a lieu (marqués préférentiellement sur le contacteur, dans la mesure du possible).

Les marquages ne doivent pas être apposés sur des vis, des rondelles amovibles ou d'autres pièces amovibles.

L'indication k) doit figurer sur l'enveloppe, le cas échéant.

L'indication c) doit figurer sur le produit.

L'indication n), le cas échéant, doit figurer sur la plaque signalétique ou sur le contacteur ou, si l'espace disponible n'est pas suffisant, sur l'unité d'emballage aux dimensions les plus faibles, ou dans les informations techniques fournies avec le produit ou dans la documentation publiée par le fabricant. Dans le cas d'un groupe de bornes situées au même emplacement, il est admis d'apposer un seul marquage sur l'appareil. Le contacteur doit comporter un marquage approprié indiquant la longueur de l'isolation à retirer avant d'insérer le conducteur dans la borne.

Les indications d) à j), l), m) et o) à s) doivent figurer sur la plaque signalétique ou sur le contacteur, ou dans la documentation publiée par le fabricant.

La documentation publiée par le fabricant peut être fournie dans un format numérique, par exemple à l'aide d'un identificateur lisible par voie électronique apposé sur le matériel ou sur son emballage (voir l'IEC 63365).

Le marquage des bornes doit être conforme à l'Annexe A du présent document.

NOTE 2 Des catégories d'emploi supplémentaires conformément à l'IEC 60947-4-1 peuvent également être marquées (voir la note de bas de tableau a du Tableau 1).

6.3 Instructions d'installation, de fonctionnement et d'entretien

Le contacteur doit être installé conformément à toutes les spécifications du 6.1, compte tenu de son utilisation prévue.

Des informations doivent être fournies si le circuit de commande doit être protégé par un dispositif de protection contre les courts-circuits.

L'entretien n'est pas habituel pour les contacteurs destinés aux applications domestiques.

7 Conditions de service normal, de montage et de transport

7.1 Conditions de service normal

7.1.1 Généralités

Les contacteurs conformes au présent document doivent pouvoir fonctionner dans les conditions normalisées suivantes.

7.1.2 Température de l'air ambiant

La température de l'air ambiant ne dépasse pas +40 °C et sa moyenne, mesurée sur une période de 24 h, ne dépasse pas +35 °C.

La limite inférieure de la température de l'air ambiant est de –5 °C.

La température de l'air ambiant est celle constatée à proximité du contacteur s'il ne comporte pas d'enveloppe ou à proximité de l'enveloppe s'il en comporte une.

Les contacteurs destinés à être utilisés à des températures d'air ambiant supérieures à +40 °C (en particulier dans les pays tropicaux) ou inférieures à –5 °C doivent être conçus spécialement ou être utilisés conformément aux informations fournies dans le catalogue du fabricant.

7.1.3 Altitude

L'altitude du site d'installation ne dépasse pas 2 000 m.

Pour les installations à une altitude supérieure à 2 000 m, des instructions doivent être fournies dans la documentation du contacteur.

7.1.4 Conditions atmosphériques

7.1.4.1 Humidité

L'humidité relative de l'air ne dépasse pas 50 % à une température maximale de +40 °C. Des taux d'humidité relative plus élevés peuvent être admis à des températures plus basses, par exemple 90 % à +20 °C.

NOTE Les degrés de pollution indiqués au 7.1.4.2 définissent les conditions d'environnement de manière plus précise.

7.1.4.2 Degré de pollution

Le degré de pollution (voir 3.5.26) se rapporte aux conditions d'environnement pour lesquelles est prévu le contacteur.

NOTE L'effet sur l'isolation est déterminé par le microenvironnement des lignes de fuite ou des distances d'isolement, et non pas l'environnement du contacteur. Le microenvironnement peut être meilleur ou pire que l'environnement du contacteur. Il comprend tous les facteurs qui ont une incidence sur l'isolation, comme les conditions climatiques et électromagnétiques, la production de pollution, etc.

Pour les contacteurs destinés à être utilisés dans une enveloppe ou équipés d'une enveloppe intégrée, le degré de pollution à l'intérieur de l'enveloppe s'applique.

Pour évaluer les distances d'isolement et les lignes de fuite, les quatre degrés de pollution suivants au niveau du microenvironnement (les distances d'isolement et les lignes de fuite sont indiquées dans le Tableau 17 et le Tableau 18 en fonction des différents degrés de pollution) ont été établis:

Degré de pollution 1:

Absence de pollution ou présence d'une pollution sèche non conductrice seulement.

Degré de pollution 2:

Présence normale d'une pollution non conductrice seulement. Cependant, il peut occasionnellement se produire une conductivité temporaire sous l'effet de la condensation.

Degré de pollution 3:

Présence d'une pollution conductrice ou d'une pollution sèche non conductrice qui devient conductrice sous l'effet de la condensation.

Degré de pollution 4:

La pollution provoque une conductivité persistante, causée par de la poussière conductrice ou par la neige ou la pluie, par exemple.

Degré de pollution normalisé pour les applications domestiques et analogues:

Les contacteurs pour applications domestiques et analogues sont généralement destinés à être utilisés dans un environnement de degré de pollution 2.

7.1.5 Conditions normales d'environnement électromagnétique

Les conditions normales d'environnement électromagnétique concernent les réseaux publics de distribution électrique à basse tension comme les installations/sites résidentiels, commerciaux et pour l'industrie légère.

7.2 Conditions pendant le transport et le stockage

Les conditions pendant le transport et le stockage (température et humidité, par exemple) sont définies au 7.1. Toutefois, sauf spécification contraire, la plage de températures suivantes s'applique pendant le transport et le stockage: entre -25 °C et $+55\text{ °C}$ et, pour de courtes périodes ne dépassant pas 24 h, jusqu'à $+70\text{ °C}$.

7.3 Montage

Le contacteur doit être monté conformément aux instructions du fabricant.

8 Exigences de construction et de fonctionnement

8.1 Exigences de construction

8.1.1 Généralités

Le contacteur avec son enveloppe éventuelle, intégrée ou non, doit être conçu et construit de façon à résister aux contraintes subies pendant son installation et en service normal. Il doit en outre procurer un degré spécifié de résistance à la chaleur anormale et au feu.

NOTE Un contacteur sous enveloppe est un contacteur monté dans une enveloppe conçue et dimensionnée pour contenir un seul contacteur.

La protection contre les dangers dus aux circuits électroniques doit être maintenue en conditions normales et en conditions de premier défaut, comme cela est spécifié dans le présent document.

8.1.2 Matériaux

8.1.2.1 Généralités

L'adéquation des matériaux utilisés est vérifiée en effectuant les essais suivants sur le contacteur et/ou, si cela n'est pas faisable, sur des parties prélevées sur le contacteur.

- résistance au vieillissement (voir 8.1.2.2)
- résistance à l'humidité (voir 8.1.2.3)
- résistance à la chaleur (voir 8.1.2.4)
- résistance à la chaleur anormale et au feu (voir 8.1.2.5)
- résistance à la rouille (voir 8.1.2.6)

En ce qui concerne la résistance à la chaleur, à la chaleur anormale et aux risques du feu, les essais effectués sur le contacteur ou sur une partie appropriée prélevée sur celui-ci doivent être privilégiés.

Toutefois, dans certains cas, des essais sur les matériaux peuvent être utilisés pour des raisons pratiques, en lieu et place des essais effectués sur le contacteur.

8.1.2.2 Résistance au vieillissement

Les contacteurs doivent résister au vieillissement.

En général, il est seulement nécessaire de soumettre aux essais les contacteurs qui comportent (ou sont fournis avec) des enveloppes ou des pièces en PVC ou matériaux thermoplastiques analogues ainsi que les pièces en caoutchouc telles que les bagues d'étanchéité et les joints.

La conformité est vérifiée par examen et, si nécessaire, par un essai conformément au 9.2.2.1.

8.1.2.3 Résistance à l'humidité

Le contacteur doit être protégé contre les effets de l'humidité qui peut se produire en service normal.

La conformité doit être vérifiée par l'essai spécifié au 9.2.2.2.

8.1.2.4 Résistance à la chaleur

Toutes les parties des contacteurs sous enveloppe, partiellement sous enveloppe ou sans enveloppe, destinées à empêcher l'accès aux parties actives ne doivent pas être endommagées de manière notable par la température la plus élevée susceptible d'être atteinte en service normal.

La conformité doit être vérifiée par les essais spécifiés au 9.2.2.3.1 et au 9.2.2.3.2.

8.1.2.5 Résistance à la chaleur anormale et au feu

Les parties en matériau isolant qui peuvent être exposées à des contraintes thermiques dues aux effets de l'électricité et dont la détérioration peut altérer la sécurité du contacteur ne doivent pas être endommagées de manière notable par une chaleur anormale ou par le feu.

La conformité doit être vérifiée par l'essai spécifié au 9.2.2.4.

Si un essai doit être effectué à plusieurs endroits sur le même échantillon, des précautions doivent être prises pour s'assurer que des détériorations causées par les essais précédents ne faussent pas les résultats de l'essai à effectuer. Les petites pièces dont les dimensions superficielles ne dépassent pas 14 mm × 14 mm ne sont pas soumises à l'essai.

8.1.2.6 Résistance à la rouille

Les parties ferreuses du contacteur, y compris les enveloppes et les couvercles, mais à l'exception des faces polaires des électroaimants, doivent être protégées contre la rouille.

La conformité doit être vérifiée par l'essai spécifié au 9.2.2.5.

8.1.3 Résistance des vis ou écrous autres que ceux des bornes qui sont destinés à être manœuvrés au cours de l'installation ou de l'entretien

Les vis ou écrous destinés à être manœuvrés pendant l'installation ou l'entretien selon les recommandations du fabricant doivent résister aux contraintes mécaniques qui se produisent en service normal.

Les vis autotaraudeuses par déformation et à découpe prévues pour l'assemblage mécanique seulement peuvent être utilisées sous réserve que les vis soient fournies assemblées avec la pièce dans laquelle elles doivent être vissées.

Un exemple de vis autotaraudeuse par déformation est représenté à la Figure 1. Un exemple de vis autotaraudeuse à découpe est représenté à la Figure 2. De plus, les vis autotaraudeuses à découpe destinées à être manœuvrées par l'installateur doivent être solidaires de la pièce correspondante de l'accessoire.

Les vis ou écrous qui transmettent une pression de contact doivent s'engager dans des filetages métalliques.

Pour les connexions électriques, aucune pression de contact ne doit être transmise au travers de matériaux isolants autres que la céramique ou un matériau avec des caractéristiques équivalentes et compensées pour toute possibilité de retrait ou de fléchissement.

La conformité doit être vérifiée par examen et par l'essai spécifié au 9.2.3.

8.1.4 Vacant

8.1.5 Organe de commande

8.1.5.1 Généralités

Les exigences du 8.1.5.2 et du 8.1.5.3 s'appliquent aux contacteurs équipés d'un organe de commande manuel.

8.1.5.2 Isolation

L'organe de commande du contacteur doit être isolé des parties actives pour la tension assignée d'isolement et, s'il y a lieu, pour la tension assignée de tenue aux chocs.

De plus:

- s'il est en métal, il doit pouvoir être raccordé de façon sûre à un conducteur de protection sauf s'il comporte une isolation supplémentaire fiable;
- s'il est en matériau isolant ou recouvert d'un tel matériau, toutes ses parties métalliques internes, qui peuvent devenir accessibles en cas de défaillance de l'isolation, doivent aussi être isolées des parties actives pour la tension assignée d'isolement.

8.1.5.3 Sens du mouvement

Le sens de manœuvre des organes de commande des appareils doit normalement être conforme à l'IEC 60447. Lorsque des appareils ne peuvent pas satisfaire à ces exigences, par exemple par suite d'applications spéciales ou d'autres positions de montage, ils doivent porter un marquage clair afin de distinguer clairement les "I" ou "O" et le sens de manœuvre.

8.1.5.4 Montage

Les organes de commande montés sur des panneaux démontables ou des portes doivent être conçus pour être dans la position appropriée par rapport au mécanisme associé lors du remplacement du panneau ou de la fermeture de la porte.

8.1.6 Indication des positions ARRÊT et MARCHE

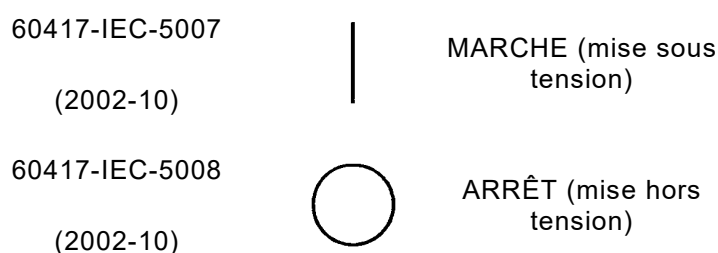
8.1.6.1 Dispositifs indicateurs

Lorsqu'un contacteur est équipé de dispositifs qui indiquent la position de fermeture et la position d'ouverture, ces positions doivent être indiquées de manière claire et distincte.

NOTE Dans le cas de contacteurs sous enveloppe, cette indication peut être visible de l'extérieur.

Cette indication est donnée par un indicateur de position (voir 3.3.15).

Si des symboles sont utilisés, ceux-ci doivent indiquer respectivement la position de fermeture et la position d'ouverture, conformément à l'IEC 60417:



Pour les contacteurs manœuvrés à l'aide de deux boutons-poussoirs, seul le bouton-poussoir destiné à la manœuvre d'ouverture doit être rouge ou marqué du symbole "O".

La couleur rouge ne doit être utilisée pour aucun autre bouton-poussoir.

Les couleurs des autres boutons-poussoirs, des boutons-poussoirs lumineux et des voyants lumineux doivent être conformes à l'IEC 60073.

8.1.6.2 Indication par l'organe de commande

Lorsque l'organe de commande est utilisé pour indiquer la position des contacts, il doit, lorsqu'il est relâché, se mettre automatiquement ou rester à la position correspondant à celle des contacts mobiles. Dans ce cas, l'organe de commande doit comporter deux positions de repos distinctes correspondant à celles des contacts mobiles, mais une troisième position distincte de l'organe de commande peut être prévue, en cas d'ouverture automatique.

8.1.7 Bornes

8.1.7.1 Exigences de construction

Toutes les pièces des bornes qui maintiennent le contact et assurent le passage du courant doivent être en métal de résistance mécanique adéquate.

Les connexions par bornes doivent être effectuées de telle sorte que la force nécessaire pour connecter les conducteurs puisse être appliquée au moyen de vis, de dispositifs sans vis ou équivalents, afin de maintenir la pression de contact nécessaire.

Les bornes doivent être réalisées de façon telle que les conducteurs puissent être fixés entre des surfaces adéquates, sans dommage appréciable, aux conducteurs ou aux bornes.

Les bornes ne doivent permettre aucun déplacement des conducteurs ni pouvoir être elles-mêmes déplacées d'une manière qui compromet la manœuvre du contacteur, et la tension d'isolement ne doit pas diminuer au-dessous des valeurs assignées.

Les bornes sans vis doivent être conçues et fabriquées de sorte que chaque conducteur soit fixé de manière individuelle.

Sauf spécification contraire du fabricant, les organes de serrage sans vis doivent accepter les âmes massives, câblées et souples.

La connexion ou la déconnexion de conducteurs sur un organe de serrage sans vis doit être effectuée comme suit:

- sur un organe de serrage universel en utilisant un outil d'usage général ou un dispositif approprié, intégré à l'organe de serrage qui permet d'ouvrir ce dernier afin d'insérer ou de retirer les conducteurs;
- sur un organe de serrage pousse-fil, par simple insertion. Pour la déconnexion des conducteurs, une manœuvre autre qu'une simple traction sur le conducteur doit être nécessaire. Il est admis d'utiliser un outil d'usage général ou un dispositif approprié, intégré à l'organe de serrage pour "ouvrir" ce dernier et faciliter l'insertion ou le retrait d'un conducteur.

La Figure 23 représente des exemples de bornes sans vis.

Les exigences du présent paragraphe doivent être vérifiées par les essais décrits au 9.2.5.3, au 9.2.5.4, au 9.2.5.5, au 9.2.5.7 et au 9.2.5.8, selon le cas.

NOTE Les pays d'Amérique du Nord ont des exigences particulières concernant les bornes adaptées à la connexion de conducteurs en aluminium et leur marquage afin d'identifier l'emploi de conducteurs en aluminium.

8.1.7.2 Capacité de connexion

Le fabricant doit préciser le type (rigide – à âme massive ou câblée – ou souple), les sections minimale et maximale des conducteurs appropriés pour la borne, et, le cas échéant, le nombre de conducteurs pouvant être connectés simultanément à la borne. Toutefois, la section maximale ne doit pas être inférieure à celle indiquée au 9.3.3.3 pour l'essai d'échauffement et la borne doit être adaptée aux conducteurs du même type (rigide – à âme massive ou câblée – ou souple) inférieurs d'au moins deux tailles, comme cela est indiqué dans la colonne correspondante du Tableau 2.

Les valeurs normalisées des sections des conducteurs ronds en cuivre (exprimées à la fois en unités du système métrique et en tailles AWG/MCM) sont indiquées dans le Tableau 2, qui fournit également la correspondance approximative entre les dimensions des conducteurs exprimées selon le système métrique de l'ISO et selon le système AWG/MCM.

Tableau 2 – Sections normalisées des conducteurs ronds en cuivre

Sections ISO mm ²	AWG/MCM	
	Tailles	Sections équivalentes mm ²
0,2	24	0,205
–	22	0,324
0,5	20	0,519
0,75	18	0,82
1	–	–
1,5	16	1,3
2,5	14	2,1
4	12	3,3
6	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6

NOTE Le tiret, lorsqu'il existe, est compté comme une section par référence à la capacité de connexion.

8.1.7.3 Connexion

Les bornes pour la connexion des conducteurs externes doivent être facilement accessibles au cours de l'installation.

Les vis et écrous de serrage ne doivent pas être utilisés pour fixer tout autre composant, même s'ils peuvent maintenir les bornes en place ou les empêcher de tourner.

8.1.7.4 Identification et marquage des bornes

Les bornes doivent être identifiées de façon claire et permanente, conformément à l'IEC 60445.

Les bornes destinées exclusivement à la connexion du conducteur neutre doivent être identifiées par la lettre "N", conformément à l'IEC 60445.

La borne de terre de protection doit être identifiée conformément au 8.1.9.3.

Des exigences supplémentaires pour le marquage et l'identification des bornes sont spécifiées à l'Annexe A.

8.1.8 Exigences supplémentaires pour les contacteurs équipés d'un pôle neutre

Lorsqu'un contacteur comporte un pôle destiné exclusivement à la connexion du neutre, ce pôle doit être clairement identifié par la lettre "N" (voir 8.1.7.4).

Un pôle neutre de sectionnement ne doit pas couper le courant avant les autres pôles et ne doit pas établir le courant après les autres pôles.

La valeur du courant thermique conventionnel doit être la même pour tous les pôles.

8.1.9 Dispositions en vue de la mise à la terre

8.1.9.1 Exigences de construction

Les masses (châssis, bâti et parties fixes des enveloppes métalliques, par exemple) autres que celles qui ne peuvent pas constituer un danger doivent être interconnectées électriquement et reliées à une borne de terre de protection pour la connexion à une prise de terre ou à un conducteur de protection extérieur.

Cette exigence peut être remplie par les parties normales de construction qui assurent une continuité électrique adéquate et s'applique au contacteur utilisé seul ou incorporé dans un ensemble.

Il est considéré que les masses ne représentent aucun danger si elles ne peuvent être ni touchées sur de grandes surfaces ni saisies à la main, si elles sont de petite taille (environ 50 mm × 50 mm) ou si elles sont disposées de telle sorte qu'elles excluent tout contact avec des parties actives.

Des exemples de telles masses sont les vis, rivets, plaques signalétiques, noyaux de transformateurs, électroaimants et certaines pièces de déclencheurs, de toutes dimensions.

8.1.9.2 Borne de terre de protection

La borne de terre de protection doit être facilement accessible et placée de telle sorte que la liaison du contacteur à la prise de terre ou au conducteur de protection soit maintenue lorsque le couvercle ou toute autre partie amovible est enlevé.

La borne de terre de protection doit être protégée de manière appropriée contre la corrosion.

Dans le cas des contacteurs qui comportent une structure/enveloppe/etc. conductrice, des dispositions doivent être prises, si nécessaire, afin d'assurer la continuité électrique entre les masses des contacteurs et la gaine métallique des conducteurs de connexion.

La borne de terre de protection ne doit pas avoir d'autre fonction, sauf lorsqu'elle est destinée à être raccordée à un conducteur PEN. Dans ce cas, elle doit avoir également la fonction d'une borne de neutre en plus de satisfaire aux exigences applicables à la borne de terre de protection.

8.1.9.3 Marquage et identification de la borne de terre de protection

La borne de terre de protection doit être identifiée de façon claire et permanente par son marquage.

L'identification doit être réalisée par une couleur (vert-jaune) ou par la notation PE ou PEN, selon le cas, conformément à l'IEC 60445:2021, Article 7, ou, dans le cas des conducteurs PEN, par un symbole graphique sur le contacteur.

Le symbole graphique à utiliser est le symbole:

60417-IEC-5019 (2006-08)  Terre de protection (masse) de l'IEC 60417.

NOTE Le symbole  (60417-IEC-5017 (2006-08)) recommandé précédemment est progressivement remplacé par le symbole privilégié 60417-IEC-5019 indiqué ci-dessus.

8.1.10 Enveloppes

8.1.10.1 Généralités

Les exigences du 8.1.10.2 et du 8.1.10.3 ne s'appliquent qu'aux enveloppes fournies avec le contacteur ou destinées à être utilisées avec celui-ci.

8.1.10.2 Conception

L'enveloppe doit être conçue de telle sorte que, lorsqu'elle est ouverte et que les autres dispositifs de protection éventuels sont retirés, toutes les parties qui doivent demeurer accessibles pour l'installation et l'entretien, comme cela est prescrit par fabricant, soient facilement accessibles.

Un espace suffisant doit être ménagé à l'intérieur de l'enveloppe pour le passage des conducteurs externes, depuis leur entrée dans l'enveloppe jusqu'aux bornes, pour assurer une connexion adéquate.

Les parties fixes d'une enveloppe métallique doivent être connectées électriquement aux autres masses du contacteur et être connectées à une borne permettant leur mise à la terre ou à un conducteur de protection.

En aucun cas, une partie métallique amovible de l'enveloppe ne doit, lorsqu'elle est en place, se trouver isolée de la partie où est fixée la borne de terre.

Les parties amovibles de l'enveloppe doivent être solidement assemblées aux parties fixes par un dispositif de telle sorte qu'elles ne puissent pas se desserrer ni se détacher de manière accidentelle par suite de la manœuvre du contacteur ou sous l'effet des vibrations induites par cette manœuvre.

Pour les enveloppes qui procurent un degré de protection compris entre IP1X et IP4X inclus, un espace suffisant doit être prévu pour installer un orifice de vidange. Le 11.3 de l'IEC 60529:1989 s'applique, avec l'ajout suivant:

Les orifices de vidange et de ventilation sont considérés comme des ouvertures normales.

Les enveloppes doivent avoir une résistance mécanique adéquate (voir 8.1.12).

En outre, il ne doit pas être possible de retirer un couvercle de l'enveloppe sans l'aide d'un outil.

Une enveloppe intégrée est considérée comme une partie non amovible.

Si l'enveloppe est utilisée pour le montage de boutons-poussoirs, ceux-ci ne doivent pas pouvoir être retirés de l'extérieur de l'enveloppe.

8.1.10.3 Isolation

Si, afin d'empêcher tout contact accidentel entre une enveloppe métallique et les parties actives, l'enveloppe est complètement ou partiellement revêtue d'un matériau isolant, ce revêtement doit être solidement fixé à l'enveloppe.

La conformité doit être vérifiée par examen.

8.1.11 Degrés de protection des contacteurs sous enveloppe

L'IEC 60529 définit les degrés de protection des matériels sous enveloppe et fournit des recommandations pour l'application de cette norme aux contacteurs considérés.

8.1.12 Résistance aux impacts

Les parties externes des contacteurs sous enveloppe, partiellement sous enveloppe et les parties des contacteurs sans enveloppe doivent résister aux impacts qui peuvent se produire en service normal.

La conformité doit être vérifiée par l'essai spécifié au 9.2.6.

8.1.13 Durabilité des marquages

Le contacteur doit comporter une plaque signalétique marquée d'une façon durable.

La conformité doit être vérifiée par l'essai spécifié au 9.2.7.

8.1.14 Conditions anormales et de défaut

Le présent paragraphe s'applique exclusivement aux contacteurs qui contiennent des circuits électroniques. Dans le présent document, le terme "circuit électronique" exclut les circuits dans lesquels tous les composants sont passifs (y compris les diodes, résistances, varistances, condensateurs, parasurtenseurs et inductances).

Le produit doit être conçu de manière à éviter les modes de fonctionnement ou les séquences de manœuvres qui peuvent provoquer une condition de défaut ou la défaillance d'un composant à l'origine d'un danger, sauf si des mesures supplémentaires pour empêcher tout danger sont prévues par l'installation et décrites dans les informations sur l'installation fournies avec le produit. Les exigences spécifiées dans le présent paragraphe s'appliquent également aux conditions anormales de fonctionnement, le cas échéant.

Une analyse des circuits ou des essais doivent être réalisés pour déterminer si la défaillance d'un composant particulier (y compris les systèmes d'isolement) est susceptible d'entraîner ou non un danger.

Cette analyse doit inclure les situations dans lesquelles une défaillance du composant ou de l'isolation (principale et supplémentaire) est susceptible d'entraîner:

- des effets sur le risque de choc électrique;
- un risque de détérioration qui débouche sur la projection de flammes, de particules en combustion ou de métal en fusion.

L'analyse ou les essais doivent inclure l'effet des conditions de court-circuit ou de circuit ouvert du composant. Des essais sont nécessaires, sauf si l'analyse peut démontrer de façon concluante que la défaillance d'un composant n'entraîne aucun risque de feu ou danger de choc électrique en conditions de court-circuit ou de circuit ouvert.

La conformité doit être vérifiée par l'essai du 9.2.8.

Il est considéré que les contacteurs déjà soumis à l'essai conformément aux Articles 101 et 102 de l'IEC 60669-2-1:2021 satisfont aux exigences du 8.1.14 et que l'essai du 9.2.8 est donc déjà couvert.

Il est considéré que les composants dont la fiabilité a été évaluée conformément aux normes de produits applicables satisfont à ces exigences et ne nécessitent aucune étude supplémentaire, sous réserve qu'ils aient été soumis à l'essai dans des conditions correspondant à celles pour lesquelles le produit est conçu.

8.2 Exigences de fonctionnement

8.2.1 Conditions de fonctionnement

8.2.1.1 Généralités

Le contacteur doit être manœuvré conformément aux instructions du fabricant.

Les contacts mobiles des contacteurs multipolaires destinés à assurer simultanément l'établissement et la coupure doivent être accouplés mécaniquement de manière telle que tous les pôles soient fermés ou coupés pratiquement en même temps, que la manœuvre soit manuelle ou automatique (cependant, pour un pôle neutre de sectionnement, voir 8.1.8).

8.2.1.2 Limites de fonctionnement

Les contacteurs doivent se fermer de manière satisfaisante pour toute valeur comprise entre 85 % et 110 % de leur tension assignée d'alimentation de commande U_s . Lorsqu'une plage de tensions est déclarée, la valeur de 85 % doit s'appliquer à la valeur inférieure et la valeur de 110 % doit s'appliquer à la valeur supérieure.

Les limites entre lesquelles les contacteurs doivent relâcher leurs contacts et s'ouvrir complètement sont comprises entre 75 % et 20 % de leur tension assignée d'alimentation de commande U_s . Lorsqu'une plage est spécifiée, la valeur de 20 % doit s'appliquer à la valeur supérieure et la valeur de 75 % doit s'appliquer à la valeur inférieure.

Les limites entre lesquelles un contacteur qui comporte un électroaimant commandé électroniquement doit relâcher ses contacts et s'ouvrir complètement sont comprises entre 75 % et 20 % ou entre 75 % et 10 % de leur tension assignée d'alimentation de commande U_s , lorsqu'elles sont spécifiées par le fabricant. Dans ce cas, le contacteur doit en outre être soumis à l'essai de relâchement des contacts comme suit:

Un condensateur C doit être inséré en série dans le circuit d'alimentation U_s , la longueur totale des conducteurs de connexion étant ≤ 3 m.

Le condensateur est court-circuité par un interrupteur d'impédance négligeable. La tension d'alimentation doit alors être réglée sur 110 % de U_s .

Il doit être vérifié que le matériel relâche ses contacts lorsque l'interrupteur est réglé sur la position d'ouverture.

La valeur du condensateur doit être

$$C = 30 + 200\,000 / (f \times U)$$

où C est exprimé en nF, f est la fréquence assignée minimale exprimée en Hz et U est la valeur maximale de U_s exprimée en V.

Par exemple, pour une bobine dont les caractéristiques assignées sont de 12 V à 24 V – 50 Hz, la valeur du condensateur est de 196 nF (calcul réalisé avec la valeur maximale de U_s). La tension d'essai est la valeur la plus élevée de la plage de tensions assignées d'alimentation U_s déclarée.

NOTE La valeur du condensateur simule un câblage de commande type constitué d'un câble de 100 m de longueur et de 1,5 mm² de section (0,3 nF/m, c'est-à-dire 30 nF pour 100 m) raccordé à une sortie statique dont le courant de fuite est de 1,3 mA (200 000 dans la formule $\approx \frac{10^9 \times 1,3 \times 10^{-3}}{2 \times \pi}$).

Les valeurs limites pour la fermeture s'appliquent lorsque les bobines ont atteint une température stable correspondant à l'application indéfinie de 100 % de U_s à une température ambiante de +40 °C.

Les valeurs limites pour le relâchement des contacts s'appliquent lorsque la résistance du circuit de la bobine est égale à celle obtenue à –5 °C. Cela peut être vérifié par calcul en utilisant les valeurs obtenues à la température ambiante normale.

Ces limites sont valables pour la fréquence déclarée, le cas échéant.

8.2.2 Échauffement

8.2.2.1 Généralités

Les échauffements des différents organes du contacteur, mesurés au cours d'un essai effectué dans les conditions spécifiées au 9.3.3.3, ne doivent pas dépasser les valeurs limites précisées dans le Tableau 3 ainsi qu'au 8.2.2.2 et au 8.2.2.3.

Dans le cas d'un électroaimant commandé électroniquement, le mesurage de la température des bobines par variation de résistance peut être irréalisable, auquel cas d'autres méthodes sont admises (couples thermoélectriques, calcul ou autres méthodes appropriées, par exemple).

NOTE 1 Les échauffements en service normal peuvent être différents des valeurs d'essai, selon les conditions d'installation et la taille des conducteurs raccordés.

Tableau 3 – Limites d'échauffement pour les bobines isolées dans l'air

Classes des matériaux isolants	Limites d'échauffement (mesurées par variation de la résistance)
	K
Bobines isolées dans l'air	
A	85
E	100
B	110
F	135
H	160
NOTE La classification des isolations est spécifiée dans l'IEC 60085.	

NOTE 2 Les limites d'échauffement indiquées dans le Tableau 3 et dans le Tableau 5 ne s'appliquent que si la température de l'air ambiant reste comprise entre –5 °C et +40 °C.

8.2.2.2 Bornes

L'échauffement des bornes ne doit pas dépasser les valeurs indiquées dans le Tableau 4.

Tableau 4 – Limites d'échauffement des bornes

Matériaux de la borne	Limites d'échauffement
	K ^a
Cuivre nu	60
Laiton nu	65
Cuivre laiton ou étamé	65
Cuivre ou laiton argenté ou nickelé	70 ^a
Autres métaux	^b
^a La limite d'échauffement de 70 K pour les bornes est fondée sur la connexion de câbles isolés au PVC. L'emploi en service de conducteurs connectés de dimensions significativement inférieures à celles indiquées dans le Tableau 15 est susceptible d'engendrer une augmentation de la température des bornes et des parties internes. Il convient de ne pas utiliser de tels conducteurs sans l'accord du fabricant, car des températures supérieures peuvent entraîner une défaillance du contacteur. ^b Les limites d'échauffement doivent être fixées en fonction de l'expérience acquise en service ou des essais de durée, mais ne doivent pas dépasser 65 K.	

8.2.2.3 Parties accessibles

L'échauffement des parties accessibles ne doit pas dépasser les valeurs indiquées dans le Tableau 5.

Tableau 5 – Limites d'échauffement des parties accessibles

Parties accessibles	Limites d'échauffement ^a
	K
Organes de commande manuelle:	
Métalliques	15
Non métalliques	25
Parties destinées à être touchées, mais pas à être tenues à la main:	
Métalliques	30
Non métalliques	40
Parties qu'il n'est pas nécessaire de toucher en service normal:	
Métalliques	40
Non métalliques	50
Parties non destinées à être touchées en service normal	
Parties extérieures d'enveloppes adjacentes à des entrées de câbles:	
Métalliques	40
Non métalliques	50
^a Des valeurs différentes peuvent être prescrites pour des conditions d'essai différentes et pour des appareils de petites dimensions, mais ne dépassant pas de plus de 10 K les valeurs de ce tableau.	

8.2.2.4 Température de l'air ambiant

Les limites d'échauffement indiquées dans le Tableau 4 et le Tableau 5 ne s'appliquent que si la température de l'air ambiant reste comprise dans les limites indiquées au 7.1.2.

8.2.2.5 Circuit principal

Le circuit principal d'un contacteur doit pouvoir supporter, sans dépasser les limites d'échauffement spécifiées au 8.2.2.2 lorsqu'il est soumis à l'essai conformément au 9.3.3.3.4:

- pour un contacteur prévu pour un service continu: son courant thermique conventionnel (voir 5.3.3.2 et/ou 5.3.3.3);
- pour un contacteur prévu pour un service intermittent ou un service périodique: son courant assigné d'emploi (voir 5.3.3.4).

8.2.2.6 Circuits de commande

Les circuits de commande d'un contacteur doivent permettre d'assurer le service assigné conformément au 5.3.5 et d'effectuer les essais d'échauffement spécifiés au 9.3.3.3.5 sans que les échauffements dépassent les limites spécifiées dans le Tableau 3, le Tableau 4 et le Tableau 5.

8.2.2.7 Enroulements des bobines et des électroaimants

8.2.2.7.1 Enroulements pour service de 8 heures (service continu)

Le circuit principal étant parcouru par un courant égal à la valeur maximale du courant conformément au 8.2.2.5, les enroulements des bobines doivent supporter en régime continu et à la fréquence assignée leur tension assignée d'alimentation de commande, sans que les échauffements dépassent les limites spécifiées dans le Tableau 3 et au 8.2.2.3.

NOTE Selon la technologie (pour certaines bobines d'électroaimants commandées électroniquement, par exemple), la tension d'alimentation de commande ne peut pas être appliquée directement sur les enroulements de la bobine raccordée comme en service normal.

8.2.2.7.2 Enroulements pour service intermittent

Le circuit principal n'étant parcouru par aucun courant, les enroulements des bobines doivent supporter à la fréquence assignée leur tension assignée d'alimentation de commande comme cela est indiqué dans le Tableau 6, suivant leur classe de service intermittent, sans que les échauffements dépassent les limites spécifiées dans le Tableau 3 et au 8.2.2.3.

NOTE Selon la technologie (pour certaines bobines d'électroaimants commandées électroniquement, par exemple), la tension d'alimentation de commande ne peut pas être appliquée directement sur les enroulements de la bobine raccordée comme en service normal.

Tableau 6 – Données pour les cycles d'essai de service intermittent

Classes de service intermittent	Un cycle de manœuvres de fermeture-ouverture toutes les	Durée de maintien de l'alimentation de la bobine de commande
1	3 600 s	Le temps de passage du courant doit normalement correspondre au facteur de marche spécifié par le fabricant
3	1 200 s	
12	300 s	
30	120 s	
300	12 s	
1 200	3 s	

8.2.2.7.3 Enroulements spéciaux (pour services temporaire et périodique)

Les enroulements spéciaux doivent être soumis à l'essai dans les conditions de fonctionnement correspondant au service le plus sévère auquel ils sont destinés et leurs caractéristiques assignées doivent être indiquées par le fabricant.

8.2.2.8 Circuits auxiliaires

Les circuits auxiliaires d'un contacteur, y compris les interrupteurs auxiliaires, doivent pouvoir supporter leur courant thermique conventionnel sans que les échauffements dépassent les limites spécifiées dans le Tableau 4 et le Tableau 5 lorsqu'ils sont soumis à l'essai conformément au 9.3.3.3.7.

NOTE Si un circuit auxiliaire fait partie intégrante d'un contacteur, il suffit de le soumettre à l'essai en même temps que le circuit principal, mais à son courant d'emploi réel.

8.2.2.9 Autres parties

Les échauffements qui ont lieu au cours de l'essai ne doivent occasionner aucun dommage aux parties transportant le courant des parties adjacentes du contacteur. En ce qui concerne les matériaux isolants, en particulier, le fabricant doit démontrer la conformité par référence à l'indice de température du matériau isolant (déterminé selon les méthodes de l'IEC 60216 (toutes les parties), par exemple) ou par conformité à l'IEC 60085.

8.2.3 Propriétés diélectriques

8.2.3.1 Généralités

Les propriétés diélectriques sont fondées sur les publications fondamentales de sécurité IEC 60664-1 et IEC 61140.

- a) Les exigences suivantes permettent d'assurer la coordination de l'isolement d'un contacteur en fonction des conditions présentes dans l'installation.
- b) Le contacteur doit pouvoir supporter:
 - la tension assignée de tenue aux chocs (voir 5.3.2.4) qui correspond à la catégorie de surtension indiquée à l'Annexe F;
 - la tension de tenue à fréquence industrielle.

NOTE L'Annexe F met en correspondance la tension nominale du système d'alimentation et la tension assignée de tenue aux chocs du contacteur.

La tension assignée de tenue aux chocs pour une valeur donnée de la tension assignée d'emploi ne doit pas être inférieure à la tension nominale correspondante du système d'alimentation du circuit indiquée à l'Annexe F à l'endroit où doit être utilisé le contacteur, ni à la catégorie de surtension appropriée.

- c) Les exigences du présent paragraphe doivent être vérifiées par les essais décrits au 9.3.3.4.

8.2.3.2 Tension de tenue aux chocs

a) Circuit principal

- 1) Les distances d'isolement entre les parties actives et les parties destinées à être reliées à la terre, ainsi que les distances entre les pôles doivent supporter la tension d'essai indiquée dans le Tableau 16 en fonction de la tension assignée de tenue aux chocs.
- 2) L'isolation solide d'un contacteur associée aux distances d'isolement au point a) 1) ci-dessus doit être soumise à la tension de choc spécifiée au point a) 1).

b) Circuits auxiliaires et circuits de commande

- 1) Pour les circuits auxiliaires et les circuits de commande qui sont directement alimentés par le circuit principal à la tension assignée d'emploi, les distances d'isolement entre les parties actives et les parties destinées à être reliées à la terre, ainsi que les distances entre les pôles doivent supporter la tension d'essai indiquée dans le Tableau 16 en fonction de la tension de tenue aux chocs du circuit principal. Voir aussi le point a) 2) du 8.2.3.2.

- 2) Les circuits auxiliaires et les circuits de commande qui ne sont pas alimentés directement par le circuit principal peuvent avoir une tenue aux surtensions différente de celle du circuit principal. Les distances d'isolement et l'isolation solide associée de ces circuits, en courant alternatif ou continu, doivent supporter la tension appropriée, conformément à l'Annexe F.

8.2.3.3 Tension de tenue à fréquence industrielle des circuits principaux, auxiliaires et de commande

- a) Les essais diélectriques à fréquence industrielle sont utilisés dans les cas suivants:
 - essais diélectriques considérés comme essais de type pour la vérification de l'isolation solide;
 - vérification de la tenue diélectrique comme critère de défaut après les essais de type de manœuvre ou de court-circuit;
 - essais individuels de série.
- b) Essais de type des propriétés diélectriques
Les essais des propriétés diélectriques sont des essais de type et doivent être effectués conformément au 9.3.3.4.
- c) Vérification de la tenue diélectrique après essais de manœuvre ou de court-circuit
La vérification de la tenue diélectrique après des essais de manœuvre et de court-circuit, comme critère de défaillance, est toujours effectuée à la tension à fréquence industrielle conformément au point d) du 9.3.3.4.1.
- d) Vérification de la tenue diélectrique au cours des essais individuels de série
Les essais destinés à déceler les défauts de construction et de fabrication sont effectués à la tension à fréquence industrielle conformément au point b) du 9.3.3.4.2.

8.2.3.4 Distances d'isolement

Les distances d'isolement doivent avoir une valeur suffisante pour permettre au matériel de supporter la tension assignée de tenue aux chocs, conformément au 8.2.3.2.

Les distances d'isolement doivent avoir une valeur supérieure à celles du Tableau 17 pour le cas B (champ homogène) (voir 3.5.30) et être vérifiées par un essai sur prélèvement conformément au 9.3.3.4.3. Cet essai n'est pas exigé si les distances d'isolement qui correspondent à la tension assignée de tenue aux chocs et au degré de pollution sont supérieures aux valeurs indiquées dans le Tableau 17 pour le cas A (champ hétérogène).

La méthode de mesure des distances d'isolement est donnée à l'Annexe E.

8.2.3.5 Lignes de fuite

- a) Dimensions

Pour les degrés de pollution 1 et 2, les lignes de fuite ne doivent pas être inférieures aux distances d'isolement associées déterminées conformément au 8.2.3.4. Pour le degré de pollution 3, les lignes de fuite ne doivent pas être inférieures aux distances d'isolement du cas A (voir Tableau 17) pour réduire le risque de décharge disruptive dû aux surtensions, même si ces distances d'isolement sont inférieures aux valeurs du cas A, comme cela est admis au 8.2.3.4.

La méthode de mesure des lignes de fuite est donnée à l'Annexe E.

Les lignes de fuite doivent correspondre au degré de pollution spécifié au 7.1.4.2 et au groupe de matériau correspondant à la tension assignée d'isolement ou à la tension locale indiquée dans le Tableau 18.

Les groupes de matériaux sont classés comme suit, selon la plage de valeurs de l'indice de résistance au cheminement (IRC) (voir 3.5.33):

- Groupe de matériau I $600 \leq \text{IRC}$
- Groupe de matériau II $400 \leq \text{IRC} < 600$
- Groupe de matériau IIIa $175 \leq \text{IRC} < 400$
- Groupe de matériau IIIb $100 \leq \text{IRC} < 175$

NOTE Les valeurs de l'IRC se réfèrent aux valeurs obtenues selon la méthode avec la Solution A de l'IEC 60112, pour le matériau isolant utilisé.

b) Emploi de nervures

Une ligne de fuite peut être réduite à 0,8 fois la valeur appropriée du Tableau 18 en utilisant des nervures de 2 mm de hauteur minimale, quel que soit le nombre de nervures. La base minimale de la nervure est déterminée par des exigences mécaniques (voir l'Article E.2).

8.2.3.6 Isolation solide

L'isolation solide doit être vérifiée soit par des essais à fréquence industrielle, conformément au point c) du 9.3.3.4.1, soit par des essais en courant continu si les essais en courant alternatif ne peuvent pas être effectués.

Les règles de dimensionnement pour l'isolation solide et les tensions d'essai en courant continu sont à l'étude.

8.2.3.7 Espacements entre des circuits séparés

Pour dimensionner les distances d'isolement, les lignes de fuite et l'isolation solide entre des circuits séparés, les tensions assignées les plus élevées (tension assignée de tenue aux chocs pour les distances d'isolement et l'isolation solide associée et tension assignée d'isolement ou tension locale pour les lignes de fuite) doivent être utilisées.

8.2.3.8 Exigences pour les contacteurs avec séparation de protection

Les exigences pour les contacteurs avec séparation de protection sont spécifiées à l'Annexe I.

8.2.4 Exigences de fonctionnement en conditions normales de charge et de surcharge

8.2.4.1 Généralités

Les exigences relatives aux caractéristiques normales de charge et de surcharge conformément au 5.3.6 sont fournies au 8.2.4.2, au 8.2.4.3 et au 8.2.4.4 ci-après.

8.2.4.2 Pouvoirs de fermeture et de coupure

Les contacteurs doivent pouvoir établir et couper les courants sans défaillance dans les conditions précisées dans le Tableau 7 pour les catégories d'emploi exigées et le nombre de manœuvres indiquées au 9.3.3.5.

Les valeurs des durées de passage du courant et des durées de repos indiquées dans le Tableau 7 et le Tableau 8 ne doivent pas être dépassées.

Tableau 7 – Pouvoirs de fermeture et de coupure. Conditions de fermeture et de coupure correspondant aux catégories d'emploi

Catégories	Conditions de fermeture et de coupure						
	I_c/I_e	P_t/P	U_r/U_e	$\cos \varphi$	Durée de passage du courant ^a s	Durée de repos s	Nombre de cycles de manœuvres
AC-7a	1,5		1,05	0,80	0,05	b	50
AC-7b	8,0		1,05	0,45	0,05	b	50
AC-7c ^c	1,5		1,05	c	0,05	b	50
AC-7d ^d		1,5 ^e	1,05	d	0,05	10 s	50
I_c est le courant établi et coupé, exprimé comme la valeur efficace des composantes symétriques, étant entendu que la valeur de crête réelle au cours de la manœuvre de fermeture peut avoir une valeur supérieure à la valeur de crête symétrique; I_e est le courant assigné d'emploi; P_t est la puissance qui correspond aux valeurs d'essai I_{peak} et I^2t (voir Tableau 20); P est la puissance assignée; U_r est la tension de rétablissement à fréquence industrielle; U_e est la tension assignée d'emploi; $\cos \varphi$ est le facteur de puissance du circuit d'essai.							
^a La durée peut être inférieure à 0,05 s, sous réserve que les contacts puissent être positionnés de manière appropriée avant leur réouverture. ^b Voir Tableau 8 ^c L'essai doit être effectué sur un circuit d'essai spécifique (voir 9.3.3.5.2, point d) 2)). ^d L'essai doit être effectué sur un circuit d'essai spécifique (voir 9.3.3.5.2, point d) 3)). ^e P_t doit être calculée avec un rapport de 1,5 (tolérance de $\pm 0,2$) de manière à obtenir une valeur du Tableau 20.							

Tableau 8 – Relation entre le courant coupé I_c et la durée de repos pour la vérification des pouvoirs assignés de fermeture et de coupure

Courant coupé I_c A	Durée de repos s
$I_c \leq 100$	10
$100 < I_c \leq 200$	20
$200 < I_c \leq 300$	30

La valeur de la durée de repos peut être réduite avec l'accord du fabricant.

8.2.4.3 Fonctionnement conventionnel en service

Les essais relatifs au fonctionnement en service d'un contacteur sont destinés à vérifier que le contacteur est capable d'établir, de transporter et de couper sans défaillance les courants qui parcourent son circuit principal dans les conditions correspondant à la catégorie d'emploi spécifiée, s'il y a lieu.

Les contacteurs doivent pouvoir établir et couper, sans défaillance, les courants dans les conditions conventionnelles indiquées dans le Tableau 9 pour les catégories d'emploi exigées et le nombre de cycles de manœuvres spécifiés au 9.3.3.6.

Tableau 9 – Fonctionnement conventionnel en service. Conditions de fermeture et de coupure correspondant aux catégories d'emploi

Catégories	Conditions de fermeture et de coupure						
	I_c/I_e	P_t/P	U_r/U_e	$\cos \varphi$	Durée de passage du courant ^a s	Durée de repos s	Nombre de cycles de manœuvres
AC-7 ^a	1,0		1,05	0,80	0,05	b	30 000
AC-7 ^b	d		c	0,45	0,05	b	30 000
AC-7c ^e	1,0		1,05	e	0,05	b	30 000
AC-7d ^f		1	1,05	f	0,05	10 s	30 000
I_c est le courant établi et coupé, exprimé comme la valeur efficace des composantes symétriques, étant entendu que la valeur de crête réelle au cours de la manœuvre de fermeture peut avoir une valeur supérieure à la valeur de crête symétrique; I_e est le courant assigné d'emploi; P_t est la puissance qui correspond aux valeurs d'essai I_{peak} et I^2t (voir Tableau 20); P est la puissance assignée; U_r est la tension de rétablissement à fréquence industrielle; U_e est la tension assignée d'emploi; $\cos \varphi$ est le facteur de puissance du circuit d'essai.							
^a La durée peut être inférieure à 0,05 s, sous réserve que les contacts puissent être positionnés de manière appropriée avant leur réouverture. ^b Ces durées de repos ne doivent pas être supérieures aux valeurs du Tableau 8. ^c $U_r/U_e = 1,0$ pour l'établissement et $U_r/U_e = 0,17$ pour la coupure. ^d $I_c/I_e = 6,0$ pour l'établissement et $I_c/I_e = 1,0$ pour la coupure. ^e L'essai doit être effectué sur un circuit d'essai spécifique (voir 9.3.3.5.2, point d) 2)). ^f L'essai doit être effectué sur un circuit d'essai spécifique (voir 9.3.3.5.2, point d) 3)).							

8.2.4.4 Aptitude à supporter les courants de surcharge

Les contacteurs de catégorie d'emploi AC-7b doivent supporter les courants de surcharge indiqués dans le Tableau 10, comme cela est spécifié au 9.3.5.

Tableau 10 – Exigences de tenue aux courants de surcharge

Courant d'essai	Durée de l'essai
$8 \times I_e \text{ max/AC-7b}$	10 s

8.2.5 Coordination avec les dispositifs de protection contre les courts-circuits

Le courant assigné de court-circuit conditionnel des contacteurs protégés par un ou plusieurs dispositifs de protection contre les courts-circuits (DPCC) doit être vérifié par des essais de court-circuit, comme cela est spécifié au 9.3.4. Ces essais doivent être effectués:

- à la valeur appropriée du courant présumé indiquée dans le Tableau 24 (courant d'essai I_r);
et
- au courant assigné de court-circuit conditionnel I_q , s'il est supérieur au courant d'essai I_r .

Les caractéristiques assignées du DPCC doivent convenir à toutes les valeurs données du courant assigné d'emploi, de la tension assignée d'emploi et à la catégorie d'emploi correspondante.

Les conditions d'essai sont indiquées au 9.3.4.3.

La coordination implique l'exigence suivante: en conditions de court-circuit, le contacteur ne doit pas exposer les personnes ou installations à un danger. Il est admis qu'il ne soit plus en mesure de fonctionner.

NOTE L'emploi d'un DPCC non conforme aux recommandations du fabricant peut annuler la coordination.

8.3 Compatibilité électromagnétique (CEM)

8.3.1 Généralités

Les contacteurs qui ne contiennent pas de circuits électroniques sont insensibles aux perturbations électromagnétiques et ne génèrent aucune perturbation significative en conditions de service normal. Aucun essai CEM n'est alors exigé.

Dans le présent document, le terme "circuit électronique" exclut les circuits dans lesquels tous les composants sont passifs (y compris les diodes, résistances, varistances, condensateurs, parasurtenseurs et inductances).

8.3.2 Immunité

Le comportement des contacteurs électromécaniques pour usages domestiques et analogues en présence de variations d'amplitude de la tension est spécifié au 8.2.1.2.

Les contacteurs qui contiennent des circuits électroniques doivent avoir une immunité satisfaisante aux perturbations électromagnétiques.

Afin de vérifier la conformité à ces exigences pour les essais appropriés, voir 9.4.2.

8.3.3 Émissions

Les contacteurs pour usages domestiques et analogues qui ne contiennent pas de circuits électroniques ne peuvent générer de perturbations électromagnétiques qu'au cours des manœuvres électriques. La durée des perturbations est de l'ordre des millisecondes.

Provisoirement, en attendant que des études ultérieures soient effectuées, la fréquence et le niveau de ces émissions sont considérés comme faisant partie de l'environnement électromagnétique normal des contacteurs électromécaniques pour usages domestiques et analogues, et aucun essai relatif aux émissions électromagnétiques n'est nécessaire.

Les essais d'harmoniques ne sont pas exigés pour les contacteurs qui contiennent un électroaimant commandé électroniquement, car aucune électronique n'est utilisée dans le circuit principal.

Les émissions continues à hautes fréquences (supérieures à 9 kHz) des matériels qui contiennent des circuits de commutation électroniques ne doivent pas dépasser les limites spécifiées au 9.4.3.

8.4 Logiciels intégrés

Des recommandations pour le développement des logiciels intégrés destinés à l'appareillage, notamment en matière de codage sécurisé, sont fournies dans l'IEC TR 63201 en vue d'établir plus spécifiquement:

- un plan de gestion des logiciels conformément à l'Article 5 de l'IEC TR 63201:2019;
- une gestion du cycle de conception conformément à l'Article 7 de l'IEC TR 63201:2019.

9 Essais

9.1 Types d'essais

9.1.1 Généralités

Les essais doivent être effectués pour vérifier la conformité aux exigences du présent document. Le cas échéant, les essais peuvent être effectués en séquences (voir les séquences d'essais à l'Annexe B).

9.1.2 Essais de type

Les essais de type sont destinés à vérifier la conformité de la conception des contacteurs au présent document. Ils comprennent les vérifications suivantes:

- limites d'échauffement (voir 9.3.3.3);
- propriétés diélectriques (voir 9.3.3.4);
- pouvoirs assignés de fermeture et de coupure (voir 9.3.3.5);
- fonctionnement conventionnel en service (voir 9.3.3.6);
- manœuvre et limites de fonctionnement (voir 9.3.3.1 et 9.3.3.2);
- aptitude à supporter les courants de surcharge (voir 9.3.5);
- fonctionnement en condition de court-circuit (voir 9.3.4);
- propriétés mécaniques des bornes (voir 9.2.5);
- degrés de protection des contacteurs sous enveloppe (voir 9.2.4);
- résistance au vieillissement (voir 9.2.2.1)
- résistance à l'humidité (voir 9.2.2.2)
- résistance à la chaleur (voir 9.2.2.3)
- résistance à la chaleur anormale et au feu (voir 9.2.2.4)
- résistance à la rouille (voir 9.2.2.5)
- résistance au cheminement (voir 9.2.2.6);
- vis ou écrous autres que ceux des bornes qui sont destinés à être manœuvrés au cours de l'installation ou de l'entretien (voir 9.2.3);
- résistance aux impacts (voir 9.2.6);
- durabilité des marquages (voir 9.2.7);
- claquage des composants (voir 9.2.8);
- essais CEM (voir 9.4).

Le cas échéant, les essais de type sont regroupés dans des séquences d'essais.

Les séquences d'essais, le nombre d'échantillons et les résultats à obtenir sont indiqués à l'Annexe B.

Sauf spécification contraire, chaque essai (ou séquence d'essais) est effectué sur un échantillon neuf et propre.

Sauf spécification contraire, les contacteurs sont soumis à l'essai à une température de l'air ambiant de $25\text{ °C} \pm 10\text{ °C}$.

9.1.3 Essais individuels de série

Les essais individuels sont destinés à détecter les défauts de construction et de fabrication, ainsi qu'à vérifier le fonctionnement correct du contacteur. Ils doivent être effectués sur chaque contacteur dans des conditions identiques ou équivalentes à celles spécifiées pour des essais de type (voir 9.3.6.1).

Les essais individuels de série des contacteurs comprennent les vérifications suivantes:

- le fonctionnement et les limites de fonctionnement (voir 9.3.6.2);
- les essais diélectriques (voir 9.3.6.3).

9.1.4 Essais sur prélèvement pour la vérification des distances d'isolement

Les essais sur prélèvement pour la vérification des distances d'isolement sont effectués conformément au 9.3.3.4.3. Les plans d'échantillonnage et les procédures d'essai sont à l'étude.

9.2 Conformité aux exigences de construction

9.2.1 Généralités

La vérification de la conformité aux exigences de construction définies au 8.1 concerne par exemple:

- les matériaux;
- le contacteur;
- le degré de protection des contacteurs sous enveloppe;
- les propriétés mécaniques des bornes;
- l'organe de commande;
- l'indicateur de position (voir 3.3.15).

9.2.2 Matériaux

9.2.2.1 Essai de résistance au vieillissement

Les contacteurs ayant des joints séparés, des presse-étoupes à vis, des membranes et pièces constituées en caoutchouc, PVC ou matériaux thermoplastiques analogues sont soumis à un essai dans une étuve dont l'atmosphère a la composition et la pression de l'air ambiant et est ventilée par circulation naturelle, les joints, presse-étoupes et membranes étant en suspension libre.

La température à l'intérieur de l'enceinte est de $70\text{ °C} \pm 2\text{ °C}$.

Les échantillons doivent être conservés dans l'étuve pendant sept jours (168 h). Il est recommandé d'utiliser une étuve chauffée électriquement. La circulation naturelle de l'air peut être assurée par des trous dans les parois de l'étuve.

Après le traitement, les échantillons doivent être retirés de l'étuve et conservés à température ambiante et à une humidité relative comprise entre 45 % et 55 % pendant au moins quatre jours (96 h).