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INTERNATIONAL STANDARD

NORME INTERNATIONALE



Low-voltage switchgear and controlgear assemblies –
Part 1: General rules

Ensembles d'appareillage à basse tension –
Partie 1: Règles générales



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

Part 1: General rules

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61439-1 has been prepared by subcommittee 17D: Low-voltage switchgear and controlgear assemblies, of IEC technical committee 17: Switchgear and controlgear.

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

This second edition includes the following significant technical changes with respect to the last edition of IEC 61439-1:

- revision of service conditions in Clause 7;
- numerous changes regarding verification methods in Clause 10;
- modification of routine verification in respect of clearances and creepage distances (see 11.3);

- adaption of the tables in Annex C and Annex D to the revised requirements and verification methods;
- revision of the EMC requirements in Annex J;
- shifting of tables from Annex H to new Annex N;
- new Annex O with guidance on temperature rise verification;
- new Annex P with a verification method for short-circuit withstand strength (integration of the content of IEC/TR 61117);
- update of normative references;
- general editorial review.

NOTE It should be noted that when a dated reference to IEC 60439-1 is made in another Part of the IEC 60439 series of assembly standards not yet transferred into the new IEC 61439 series, the superseded IEC 60439-1 still applies (see also the Introduction below).

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

FDIS	Report on voting
17D/441/FDIS	17D/446/RVD

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

In this standard, terms written in small capitals are defined in Clause 3.

The "in some countries" notes regarding differing national practices are contained in the following subclauses:

- 5.4
- 8.2.2
- 8.3.2
- 8.3.3
- 8.4.2.3
- 8.5.5
- 8.6.6
- 8.8
- 9.2
- 10.11.5.4
- 10.11.5.6.1
- Annex L
- Annex M

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

A list of all parts of the IEC 61439 series, under the general title *Low-voltage switchgear and controlgear assemblies*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The purpose of this standard is to harmonize as far as practicable all rules and requirements of a general nature applicable to low-voltage switchgear and controlgear assemblies (ASSEMBLIES) in order to obtain uniformity of requirements and verification for ASSEMBLIES and to avoid the need for verification to other standards. All those requirements for the various ASSEMBLIES standards which can be considered as general have therefore been gathered in this basic standard together with specific subjects of wide interest and application, e.g. temperature rise, dielectric properties, etc.

For each type of low-voltage switchgear and controlgear assembly only two main standards are necessary to determine all requirements and the corresponding methods of verification:

- this basic standard referred to as "Part 1" in the specific standards covering the various types of low-voltage switchgear and controlgear assemblies;
- the specific ASSEMBLY standard hereinafter also referred to as the relevant ASSEMBLY standard.

For a general rule to apply to a specific ASSEMBLY standard, it should be explicitly referred to by quoting the relevant clause or sub-clause number of this standard followed by "Part 1" e.g. "9.1.3 of Part 1".

A specific ASSEMBLY standard may not require and hence need not call up a general rule where it is not applicable, or it may add requirements if the general rule is deemed inadequate in the particular case but it may not deviate from it unless there is substantial technical justification detailed in the specific ASSEMBLY standard.

Where in this standard a cross-reference is made to another clause, the reference is to be taken to apply to that clause as amended by the specific ASSEMBLY standard, where applicable.

Requirements in this standard that are subject to agreement between the ASSEMBLY manufacturer and the user are summarised in Annex C (informative). This schedule also facilitates the supply of information on basic conditions and additional user specifications to enable proper design, application and utilization of the ASSEMBLY.

For the new re-structured IEC 61439 series, the following parts are envisaged:

- a) IEC 61439-1: General rules
- b) IEC 61439-2: Power switchgear and controlgear ASSEMBLIES (PSC-ASSEMBLIES)
- c) IEC 61439-3: Distribution boards (to supersede IEC 60439-3)
- d) IEC 61439-4: ASSEMBLIES for construction sites (to supersede IEC 60439-4)
- e) IEC 61439-5: ASSEMBLIES for power distribution (to supersede IEC 60439-5)
- f) IEC 61439-6: Busbar trunking systems (to supersede IEC 60439-2)
- g) IEC/TR 61439-0: Guidance to specifying ASSEMBLIES.

This list is not exhaustive; additional Parts may be developed as the need arises.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

Part 1: General rules

1 Scope

NOTE 1 Throughout this standard, the term ASSEMBLY (see 3.1.1) is used for a low-voltage switchgear and controlgear assembly.

This part of the IEC 61439 series lays down the definitions and states the service conditions, construction requirements, technical characteristics and verification requirements for low-voltage switchgear and controlgear assemblies.

This standard cannot be used alone to specify an ASSEMBLY or used for a purpose of determining conformity. ASSEMBLIES shall comply with the relevant part of the IEC 61439 series; Parts 2 onwards.

This standard applies to low-voltage switchgear and controlgear assemblies (ASSEMBLIES) only when required by the relevant ASSEMBLY standard as follows:

- ASSEMBLIES for which the rated voltage does not exceed 1 000 V in case of a.c. or 1 500 V in case of d.c.;
- stationary or movable ASSEMBLIES with or without enclosure;
- ASSEMBLIES intended for use in connection with the generation, transmission, distribution and conversion of electric energy, and for the control of electric energy consuming equipment;
- ASSEMBLIES designed for use under special service conditions, for example in ships and in rail vehicles provided that the other relevant specific requirements are complied with;

NOTE 2 Supplementary requirements for ASSEMBLIES in ships are covered by IEC 60092-302.

- ASSEMBLIES designed for electrical equipment of machines provided that the other relevant specific requirements are complied with.

NOTE 3 Supplementary requirements for ASSEMBLIES forming part of a machine are covered by the IEC 60204 series.

This standard applies to all ASSEMBLIES whether they are designed, manufactured and verified on a one-off basis or fully standardised and manufactured in quantity.

The manufacture and/or assembly may be carried out other than by the original manufacturer (see 3.10.1).

This standard does not apply to individual devices and self-contained components, such as motor starters, fuse switches, electronic equipment, etc. which will comply with the relevant product standards.

2 Normative references

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

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-11:1981, *Basic environmental testing procedures – Part 2-11: Tests – Test Ka: Salt mist*

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

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

IEC 60227-3:1993, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 3: Non-sheathed cables for fixed wiring*

IEC 60245-3:1994, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 3: Heat resistant silicone insulated cables*

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

IEC 60364-5-54:2011, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

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IEC 60445:2010, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

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¹ There is a consolidated edition 1.1 (2001) that includes IEC 60529 (1989) and its amendment 1 (1999).

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IEC 61082-1, *Preparation of documents used in electrotechnology – Part 1: Rules*

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² There is a consolidated edition 3.2 (2010) that includes IEC 61000-4-3 (2006) and amendment 1 (2007) and amendment 2 (2010).

³ There is a consolidated edition 1.1 (2009) that includes IEC 61000-4-13 (2002) and its amendment 1 (2009).

⁴ There is a consolidated edition 2.1 (2011) that includes IEC 61000-6-4 (2006) and its amendment 1 (2010).

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IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

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CISPR 11:2009, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*⁵

CISPR 22, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*

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ISO 179 (all parts), *Plastics – Determination of Charpy impact strength*

ISO 2409:2007, *Paints and varnishes – Cross-cut test*

ISO 4628-3:2003, *Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 3: Assessment of degree of rusting*

ISO 4892-2:2006, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

3 Terms and definitions

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

3.1 General terms

3.1.1

low-voltage switchgear and controlgear assembly

ASSEMBLY

combination of one or more low-voltage switching devices together with associated control, measuring, signalling, protective, regulating equipment, with all the internal electrical and mechanical interconnections and structural parts

3.1.2

ASSEMBLY system

full range of mechanical and electrical components (enclosures, busbars, functional units, etc.), as defined by the original manufacturer, which can be assembled in accordance with the original manufacturer's instructions in order to produce various ASSEMBLIES

⁵ There is a consolidated edition 5.1 (2010) that includes CISPR 11 (2009) and its amendment 1 (2010).

3.1.3

main circuit (of an ASSEMBLY)

all the conductive parts of an ASSEMBLY included in a circuit which is intended to transmit electrical energy

[IEC 60050-441:1984, 441-13-02]

3.1.4

auxiliary circuit (of an ASSEMBLY)

all the conductive parts of an ASSEMBLY included in a circuit (other than the main circuit) intended to control, measure, signal, regulate and process data, etc.

NOTE The auxiliary circuits of an ASSEMBLY include the control and the auxiliary circuits of the switching devices.

[IEC 60050-441:1984, 441-13-03, modified]

3.1.5

busbar

low-impedance conductor to which several electric circuits can be separately connected

NOTE The term "busbar" does not presuppose the geometrical shape, size or dimensions of the conductor.

3.1.6

main busbar

busbar to which one or several distribution busbars and/or incoming and outgoing units can be connected

3.1.7

distribution busbar

busbar within one section which is connected to a main busbar and from which outgoing units are supplied

NOTE Conductors that are connected between a functional unit and a busbar are not considered as a part of the distribution busbars.

3.1.8

functional unit

part of an ASSEMBLY comprising all the electrical and mechanical elements including switching devices that contribute to the fulfilment of the same function

NOTE Conductors which are connected to a functional unit but which are external to its compartment or enclosed protected space (e.g. auxiliary cables connected to a common compartment) are not considered to form part of the functional unit.

3.1.9

incoming unit

functional unit through which electrical energy is normally fed into the ASSEMBLY

3.1.10

outgoing unit

functional unit through which electrical energy is normally supplied to one or more external circuits

3.1.11

short-circuit protective device

SCPD

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

[2.2.21 of IEC 60947-1:2007]

3.2 Constructional units of ASSEMBLIES

3.2.1

fixed part

part consisting of components assembled and wired on a common support and which is designed for fixed installation

3.2.2

removable part

part consisting of components assembled and wired on a common support which is intended to be removed entirely from the ASSEMBLY and replaced whilst the circuit to which it is connected may be live

3.2.3

connected position

position of a removable part when it is fully connected for its intended function

3.2.4

removed position

position of a removable part when it is outside the ASSEMBLY, and mechanically and electrically separated from it

3.2.5

insertion interlock

device preventing the introduction of a removable part into a location not intended for that removable part

3.2.6

fixed connection

connection which is connected or disconnected by means of a tool

3.2.7

section

constructional unit of an ASSEMBLY between two successive vertical delineations

3.2.8

sub-section

constructional unit of an ASSEMBLY between two successive horizontal or vertical delineations within a section

3.2.9

compartment

section or sub-section enclosed except for openings necessary for interconnection, control or ventilation

3.2.10

transport unit

part of an ASSEMBLY or a complete ASSEMBLY suitable for transportation without being dismantled

3.2.11

shutter

part which can be moved between:

- a position in which it permits engagement of the contacts of a removable part with fixed contacts, and
- a position in which it becomes a part of a cover or a partition shielding the fixed contacts

[IEC 60050-441:1984, 441-13-07, modified]

3.3 External design of ASSEMBLIES

3.3.1

open-type ASSEMBLY

ASSEMBLY consisting of a structure which supports the electrical equipment, the live parts of the electrical equipment being accessible

3.3.2

dead-front ASSEMBLY

open-type ASSEMBLY with a front cover; live parts may be accessible from directions other than the front

3.3.3

enclosed ASSEMBLY

ASSEMBLY which is enclosed on all sides with the possible exception of its mounting surface in such a manner as to provide a defined degree of protection

3.3.4

cubicle-type ASSEMBLY

enclosed ASSEMBLY of the floor-standing type which may comprise several sections, sub-sections or compartments

3.3.5

multi-cubicle-type ASSEMBLY

combination of a number of mechanically joined cubicle-type ASSEMBLIES

3.3.6

desk-type ASSEMBLY

enclosed ASSEMBLY with a horizontal or inclined control panel or a combination of both, which incorporates control, measuring, signalling apparatus, etc.

3.3.7

box-type ASSEMBLY

enclosed ASSEMBLY, intended to be mounted on a vertical plane

3.3.8

multi-box-type ASSEMBLY

combination of box-type ASSEMBLIES mechanically joined together, with or without a common supporting frame, the electrical connections passing between two adjacent boxes through openings in the adjoining faces

3.3.9

wall-mounted surface type ASSEMBLY

ASSEMBLY for installation on the surface of a wall

3.3.10

wall-mounted recessed type ASSEMBLY

ASSEMBLY for installation into a wall recess, where the enclosure does not support the portion of wall above

3.4 Structural parts of ASSEMBLIES

3.4.1

supporting structure

structure forming part of an ASSEMBLY designed to support various components of the ASSEMBLY and any enclosure

3.4.2**mounting structure**

structure not forming part of an ASSEMBLY designed to support an ASSEMBLY

3.4.3**mounting plate**

plate designed to support various components and suitable for installation in an ASSEMBLY

3.4.4**mounting frame**

framework designed to support various components and suitable for installation in an ASSEMBLY

3.4.5**enclosure**

housing affording the type and degree of protection suitable for the intended application

[IEC 60050-195:1998, 195-02-35]

3.4.6**cover**

external part of the enclosure of an ASSEMBLY

3.4.7**door**

hinged or sliding cover

3.4.8**removable cover**

cover which is designed for closing an opening in the external enclosure and which can be removed for carrying out certain operations and maintenance work

3.4.9**cover plate**

part of an ASSEMBLY which is used for closing an opening in the external enclosure and designed to be held in place by screws or similar means

NOTE 1 It is not normally removed after the equipment is put into service.

NOTE 2 The cover plate can be provided with cable entries.

3.4.10**partition**

part of the enclosure of a compartment separating it from other compartments

3.4.11**barrier**

part providing protection against direct contact from any usual direction of access

[IEC 60050-195:1998, 195-06-15, modified]

3.4.12**obstacle**

part preventing unintentional direct contact, but not preventing direct contact by deliberate action

[IEC 60050-195:1998, 195-06-16, modified]

NOTE Obstacles are intended to prevent unintentional contact with live parts but not intentional contact by deliberate circumvention of the obstacle. They are intended to protect skilled or instructed persons but are not intended to protect ordinary persons.

3.4.13

terminal shield

part enclosing terminals and providing a defined degree of protection against access to live parts by persons or objects

3.4.14

cable entry

part with openings which permit the passage of cables into the ASSEMBLY

3.4.15

enclosed protected space

part of an ASSEMBLY intended to enclose electrical components and which provides defined protection against external influences and contact with live parts

3.5 Conditions of installation of ASSEMBLIES

3.5.1

ASSEMBLY for indoor installation

ASSEMBLY which is designed for use in locations where the normal service conditions for indoor use as specified in 7.1 are fulfilled

3.5.2

ASSEMBLY for outdoor installation

ASSEMBLY which is designed for use in locations where the normal service conditions for outdoor use as specified in 7.1 are fulfilled

3.5.3

stationary ASSEMBLY

ASSEMBLY which is designed to be fixed at its place of installation, for instance to the floor or to a wall, and to be used at this place

3.5.4

movable ASSEMBLY

ASSEMBLY which is designed so that it can readily be moved from one place of use to another

3.6 Insulation characteristics

3.6.1

clearance

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

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

3.6.2

creepage distance

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

[IEC 60050-151:2001, 151-15-50]

NOTE A joint between two pieces of insulating material is considered part of the surface.

3.6.3**overvoltage**

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

[definition 3.7 of IEC 60664-1:2007]

3.6.4**temporary overvoltage**

overvoltage at power frequency of relatively long duration (several seconds)

[definition 3.7.1 of IEC 60664-1:2007, modified]

3.6.5**transient overvoltage**

short duration overvoltage of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped

[IEC 60050-604:1987, 604-03-13]

3.6.6**power-frequency withstand voltage**

r.m.s. value of a power-frequency sinusoidal voltage which does not cause breakdown under specified conditions of test

[definition 2.5.56 of IEC 60947-1: 2007]

NOTE The power-frequency withstand voltage is equivalent to the short-term temporary overvoltage in IEC 60664-1.

3.6.7**impulse withstand voltage**

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

[definition 3.8.1 of IEC 60664-1: 2007]

3.6.8**pollution**

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

[definition 3.11 of IEC 60664-1: 2007, modified]

3.6.9**pollution degree (of 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 The pollution degree to which the insulating materials of devices and components are exposed may be different from that of the macro-environment where the devices or components are located because of protection offered by means such as an enclosure or internal heating to prevent absorption or condensation of moisture.

NOTE 2 For the purpose of this standard, the pollution degree is of the micro-environment.

[definition 2.5.58 of IEC 60947-1: 2007]

3.6.10

micro-environment (of a clearance or creepage distance)

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

NOTE The micro-environment of the creepage distance or clearance and not the environment of the ASSEMBLY or components determines the effect on the insulation. The micro-environment may be better or worse than the environment of the ASSEMBLY or components.

[definition 3.12.2 of IEC 60664-1:2007, modified]

3.6.11

overvoltage category (of 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 upon the means employed to influence the overvoltages

NOTE In an electrical system, the transition from one overvoltage category to another of 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.

[definition 2.5.60 of IEC 60947-1: 2007]

3.6.12

surge arrester

surge protective device

SPD

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

[definition 2.2.22 of IEC 60947-1: 2007]

3.6.13

insulation co-ordination

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

[definition 2.5.61 of IEC 60947-1: 2007, modified]

3.6.14

inhomogeneous (non-uniform) field

electric field which has not an essentially constant voltage gradient between electrodes

[definition 2.5.63 of IEC 60947-1: 2007]

3.6.15

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 this surface

[definition 2.5.64 of IEC 60947-1: 2007]

3.6.16

comparative tracking index

CTI

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

NOTE The value of each test voltage and the CTI should be divisible by 25.

[definition 2.5.65 of IEC 60947-1: 2007, modified]

3.6.17

disruptive discharge

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 zero

NOTE 1 A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric, the loss may be only temporary.

NOTE 2 The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric.

NOTE 3 The term "flashover" is used when a disruptive discharge occurs over the surface of a dielectric in a gaseous or liquid medium.

NOTE 4 The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

3.7 Protection against electric shock

3.7.1

live part

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

NOTE This term does not necessarily imply a risk of electric shock.

[IEC 60050-195:1998, 195-02-19, modified]

3.7.2

hazardous live part

live part which, under certain conditions, can give a harmful electric shock

[IEC 60050-195:1998, 195-06-05]

3.7.3

exposed conductive part

conductive part of the ASSEMBLY, which can be touched and which is not normally live, but which may become a hazardous live part under fault conditions

[IEC 60050-826:2004, 826-12-10, modified]

3.7.4

protective conductor

(identification: PE)

conductor provided for purposes of safety, for example protection against electric shock

[IEC 60050-826:2004, 826-13-22]

NOTE As an example the protective conductor can electrically connect the following parts:

- exposed conductive parts;
- extraneous conductive parts;
- main earthing terminal;
- earth electrode;
- earthed point of the source or artificial neutral.

3.7.5

neutral conductor

N

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

[IEC 60050-195:1998, 195-02-06, modified]

3.7.6

PEN conductor

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

[IEC 60050-195:1998, 195-02-12]

3.7.7

fault current

current resulting from an insulation failure, the bridging of insulation or incorrect connection in an electrical circuit

3.7.8

basic protection

protection against electric shock under fault-free conditions

[IEC 60050-195:1998, 195-06-01]

NOTE Basic protection is intended to prevent contact with live parts and generally corresponds to protection against direct contact.

3.7.9

basic insulation

insulation of hazardous live parts, which provide basic protection

[IEC 60050-195:1998, 195-06-06]

NOTE This concept does not apply to insulation used exclusively for functional purposes.

3.7.10

fault protection

protection against electric shock under single-fault conditions (e.g. failure of basic insulation)

[IEC 60050-195:1998, 195-06-02, modified]

NOTE Fault protection generally corresponds to protection against indirect contact, mainly with regard to failure of basic insulation.

3.7.11

extra-low voltage

ELV

any voltage not exceeding the relevant voltage limit specified in IEC 61201

3.7.12

skilled person

person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

[IEC 60050-826:2004, 826-18-01]

3.7.13

instructed person

person adequately advised or supervised by skilled persons to enable him or her to perceive risks and to avoid hazards electricity can create

[IEC 60050-826:2004, 826-18-02]

3.7.14**ordinary person**

person who is neither a skilled person nor an instructed person

[IEC 60050-826:2004, 826-18-03]

3.7.15**authorized person**

skilled or instructed person, who is empowered to execute defined work

3.8 Characteristics**3.8.1****nominal value**

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

NOTE The nominal value is generally a rounded value.

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

3.8.2**limiting value**

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

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

3.8.3**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

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

3.8.4**rating**

set of rated values and operating conditions

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

3.8.5**nominal voltage** (of an electrical system)

approximate value of voltage used to designate or identify an electrical system

[IEC 60050-601:1985, 601-01-21 modified]

3.8.6**short-circuit current**

I_c

over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

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

3.8.7**prospective short-circuit current**

I_{cp}

r.m.s. value of the current which would flow if the supply conductors to the circuit are short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the ASSEMBLY (see 10.11.5.4)

3.8.8

cut-off current

let-through current

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

NOTE 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.

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

3.8.9

voltage ratings

3.8.9.1

rated voltage

U_n

highest nominal voltage of the electrical system, a.c. (r.m.s.) or d.c., declared by the ASSEMBLY manufacturer, to which the main circuit(s) of the ASSEMBLY is (are) designed to be connected

NOTE 1 In polyphase circuits, it is the voltage between phases.

NOTE 2 Transients are disregarded.

NOTE 3 The value of the supply voltage may exceed the rated voltage due to permissible system tolerances.

3.8.9.2

rated operational voltage (of a circuit of an ASSEMBLY)

U_e

value of voltage, declared by the ASSEMBLY manufacturer, which combined with the rated current determines its application

NOTE In polyphase circuits, it is the voltage between phases.

3.8.9.3

rated insulation voltage

U_i

r.m.s withstand voltage value, assigned by the ASSEMBLY manufacturer to the equipment or to a part of it, characterising the specified (long-term) withstand capability of the insulation

[definition 3.9.1 of IEC 60664-1: 2007, modified]

NOTE 1 In polyphase circuits, it is the voltage between phases.

NOTE 2 The rated insulation voltage is not necessarily equal to the rated operational voltage of equipment, which is primarily related to functional performance.

3.8.9.4

rated impulse withstand voltage

U_{imp}

impulse withstand voltage value, declared by the ASSEMBLY manufacturer, characterising the specified withstand capability of the insulation against transient overvoltages

[definition 3.9.2 of IEC 60664-1: 2007, modified]

3.8.10 **current ratings**

3.8.10.1 **rated current**

value of current, declared by the ASSEMBLY manufacturer which can be carried without the temperature-rise of various parts of the ASSEMBLY exceeding specified limits under specified conditions

NOTE For rated current of the ASSEMBLY (I_{nA}) see 5.3.1, and for rated current of a circuit (I_{nc}) see 5.3.2.

3.8.10.2 **rated peak withstand current**

I_{pk}
value of peak short-circuit current, declared by the ASSEMBLY manufacturer, that can be withstood under specified conditions

3.8.10.3 **rated short-time withstand current**

I_{cw}
r.m.s value of short-time current, declared by the ASSEMBLY manufacturer, that can be withstood under specified conditions, defined in terms of a current and time

3.8.10.4 **rated conditional short-circuit current**

I_{cc}
value of prospective short-circuit current, declared by the ASSEMBLY manufacturer, that can be withstood for the total operating time (clearing time) of the short-circuit protective device (SCPD) under specified conditions

NOTE The short-circuit protective device may form an integral part of the ASSEMBLY or may be a separate unit.

3.8.11 **rated diversity factor** **RDF**

per unit value of the rated current, assigned by the ASSEMBLY manufacturer, to which outgoing circuits of an ASSEMBLY can be continuously and simultaneously loaded taking into account the mutual thermal influences

3.8.12 **rated frequency**

f_n
value of frequency, declared by the ASSEMBLY manufacturer, for which a circuit is designed and to which the operating conditions refer

NOTE A circuit may be assigned a number or a range of rated frequencies or be rated for both a.c. and d.c.

3.8.13 **electromagnetic compatibility** **EMC**

NOTE For EMC related terms and definitions, see J.3.8.13.1 to J.3.8.13.5 of Annex J.

3.9 Verification

3.9.1 **design verification**

verification made on a sample of an ASSEMBLY or on parts of ASSEMBLIES to show that the design meets the requirements of the relevant ASSEMBLY standard

NOTE Design verification may comprise one or more equivalent methods see 3.9.1.1, 3.9.1.2 and 3.9.1.3.

3.9.1.1

verification test

test made on a sample of an ASSEMBLY or on parts of ASSEMBLIES to verify that the design meets the requirements of the relevant ASSEMBLY standard

NOTE Verification tests are equivalent to type tests.

3.9.1.2

verification comparison

structured comparison of a proposed design for an ASSEMBLY, or parts of an ASSEMBLY, with a reference design verified by test

3.9.1.3

verification assessment

design verification of strict design rules or calculations applied to a sample of an ASSEMBLY or to parts of ASSEMBLIES to show that the design meets the requirements of the relevant ASSEMBLY standard

3.9.2

routine verification

verification of each ASSEMBLY performed during and/or after manufacture to confirm whether it complies with the requirements of the relevant ASSEMBLY standard

3.10 Manufacturer/user

3.10.1

original manufacturer

organization that has carried out the original design and the associated verification of an ASSEMBLY in accordance with the relevant ASSEMBLY standard

3.10.2

ASSEMBLY manufacturer

organization taking the responsibility for the completed ASSEMBLY

NOTE The ASSEMBLY manufacturer may be a different organisation to the original manufacturer.

3.10.3

user

party who will specify, purchase, use and/or operate the ASSEMBLY, or someone acting on their behalf

4 Symbols and abbreviations

Alphabetical list of terms with symbols and abbreviations together with the subclause where they are first used:

Symbol/Abbreviation	Term	Subclause
CTI	comparative tracking index	3.6.17
ELV	extra-low voltage	3.7.11
EMC	electromagnetic compatibility	3.8.13
f_n	rated frequency	3.8.12
I_c	short-circuit current	3.8.6
I_{cc}	rated conditional short-circuit current	3.8.10.4
I_{cp}	prospective short-circuit current	3.8.7
I_{cw}	rated short-time withstand current	3.8.10.3
I_{nA}	rated current of the ASSEMBLY	5.3.1

Symbol/Abbreviation	Term	Subclause
I_{nc}	rated current of a circuit	5.3.2
I_{pk}	rated peak withstand current	3.8.10.2
N	neutral conductor	3.7.5
PE	protective conductor	3.7.4
PEN	PEN conductor	3.7.6
RDF	rated diversity factor	3.8.11
SCPD	short-circuit protective device	3.1.11
SPD	surge protective device	3.6.12
U_e	rated operational voltage	3.8.9.2
U_i	rated insulation voltage	3.8.9.3
U_{imp}	rated impulse withstand voltage	3.8.9.4
U_n	rated voltage	3.8.9.1

5 Interface characteristics

5.1 General

The characteristics of the ASSEMBLY shall ensure compatibility with the ratings of the circuits to which it is connected and the installation conditions and shall be declared by the ASSEMBLY manufacturer using the criteria identified in 5.2 to 5.6.

5.2 Voltage ratings

5.2.1 Rated voltage (U_n) (of the ASSEMBLY)

The rated voltage shall be at least equal to the nominal voltage of the electrical system.

5.2.2 Rated operational voltage (U_e) (of a circuit of an ASSEMBLY)

The rated operational voltage of any circuit shall not be less than the nominal voltage of the electrical system to which it is to be connected.

If different from the rated voltage of the ASSEMBLY, the appropriate rated operational voltage of the circuit shall be stated.

5.2.3 Rated insulation voltage (U_i) (of a circuit of an ASSEMBLY)

The rated insulation voltage of a circuit of an ASSEMBLY is the voltage value to which dielectric test voltages and creepage distances are referred.

The rated insulation voltage of a circuit shall be equal or higher than the values stated for U_n and for U_e for the same circuit.

NOTE For single-phase circuits derived from IT systems (see IEC 60364-5-52), the rated insulation voltage should be at least equal to the voltage between phases of the supply.

5.2.4 Rated impulse withstand voltage (U_{imp}) (of the ASSEMBLY)

The rated impulse withstand voltage shall be equal to or higher than the values stated for the transient overvoltages occurring in the electrical system(s) to which the circuit is designed to be connected.

NOTE The preferred values of rated impulse withstand voltage are those given in Table G.1 of Annex G.

5.3 Current ratings

5.3.1 Rated current of the ASSEMBLY (I_{nA})

The rated current of the ASSEMBLY is the smaller of:

- the sum of the rated currents of the incoming circuits within the ASSEMBLY operated in parallel;
- the total current which the main busbar is capable of distributing in the particular ASSEMBLY arrangement.

This current shall be carried without the temperature rise of the individual parts exceeding the limits specified in 9.2.

NOTE 1 The rated current of an incoming circuit may be lower than the rated current of the incoming device (according to the respective device standard) installed in the ASSEMBLY.

NOTE 2 The main busbar in this context is a single busbar or a combination of single busbars that are normally connected in service e.g. by means of a bus coupler.

NOTE 3 The rated current of the ASSEMBLY is the maximum permissible load current which can be distributed by the ASSEMBLY and which cannot be exceeded by adding further outgoing units.

5.3.2 Rated current of a circuit (I_{nc})

The rated current of a circuit is the value of the current that can be carried by this circuit loaded alone, under normal service conditions. This current shall be carried without the temperature rise of the various parts of the ASSEMBLY exceeding the limits specified in 9.2.

NOTE 1 The rated current of a circuit may be lower than the rated currents of the devices (according to the respective device standard) installed in this circuit.

NOTE 2 Due to the complex factors determining the rated currents, no standard values can be given.

5.3.3 Rated peak withstand current (I_{pk})

The rated peak withstand current shall be equal to or higher than the values stated for the peak value of the prospective short-circuit current of the supply system(s) to which the circuit(s) is (are) designed to be connected (see also 9.3.3).

5.3.4 Rated short-time withstand current (I_{cw}) (of a circuit of an ASSEMBLY)

The rated short-time withstand current shall be equal to or higher than the prospective r.m.s. value of the short-circuit current (I_{cp}) at each point of connection to the supply, (see also 3.8.10.3).

Different values of I_{cw} for different durations (e.g. 0,2 s; 1 s; 3 s) may be assigned to an ASSEMBLY.

For a.c., the value of the current is the r.m.s. value of the a.c. component.

5.3.5 Rated conditional short-circuit current of an ASSEMBLY (I_{cc})

The rated conditional short-circuit current shall be equal to or higher than the prospective r.m.s. value of short-circuit current (I_{cp}) for a duration limited by the operation of the short-circuit protective device that protects the ASSEMBLY.

The breaking capacity and current limitation characteristic (I^2t , I_{pk}) of the specified short-circuit protective device shall be stated by the ASSEMBLY manufacturer, taking into consideration the data given by the device manufacturer.

5.4 Rated diversity factor (RDF)

The rated diversity factor is the per unit value of the rated current, assigned by the ASSEMBLY manufacturer, to which outgoing circuits of an ASSEMBLY can be continuously and simultaneously loaded taking into account the mutual thermal influences.

Rated diversity factor can be stated:

- for groups of circuits;
- for the whole ASSEMBLY.

The rated diversity factor multiplied by the rated current of the circuits shall be equal to or higher than the assumed loading of the outgoing circuits. The assumed loading of outgoing circuits shall be addressed by the relevant ASSEMBLY standard.

NOTE 1 The assumed loading of the outgoing circuits can be a steady continuous current or the thermal equivalent of a varying current (See Annex E).

The rated diversity factor is applicable with the ASSEMBLY operating at rated current (I_{nA}).

NOTE 2 The rated diversity factor recognizes that multiple functional units are in practice not fully loaded simultaneously or are intermittently loaded.

See Annex E for further details.

NOTE 3 In Norway, the overload protection of conductors shall not solely be based on the use of diversity factors of the downstream circuits.

5.5 Rated frequency (f_n)

The rated frequency of a circuit is the value of frequency to which the operating conditions are referred. Where the circuits of an ASSEMBLY are designed for different values of frequency, the rated frequency of each circuit shall be given.

NOTE The frequency should be within the limits specified in the relevant IEC standards for the incorporated components. Unless otherwise stated by the ASSEMBLY manufacturer, the limits are assumed to be 98 % and 102 % of the rated frequency.

5.6 Other characteristics

The following characteristics shall be declared:

- a) additional requirements depending on the specific service conditions of a functional unit (e.g. type of coordination, overload characteristics);
- b) pollution degree (see 3.6.9);
- c) types of system earthing for which the ASSEMBLY is designed;
- d) indoor and/or outdoor installation (see 3.5.1 and 3.5.2);
- e) stationary or movable (see 3.5.3 and 3.5.4);
- f) degree of protection;
- g) intended for use by skilled or ordinary persons (see 3.7.12 and 3.7.14);
- h) electromagnetic compatibility (EMC) classification (see Annex J);
- i) special service conditions, if applicable (see 7.2);
- j) external design (see 3.3);
- k) mechanical impact protection, if applicable (see 8.2.1);
- l) the type of construction – fixed or removable parts (see 8.5.1 and 8.5.2.);
- m) the nature of short-circuit protective device(s) (see 9.3.2);
- n) measures for protection against electric shock;

- o) overall dimensions (including projections e.g handles, covers, doors), if required;
- p) the weight, if required.

6 Information

6.1 ASSEMBLY designation marking

The ASSEMBLY manufacturer shall provide each ASSEMBLY with one or more labels, marked in a durable manner and located in a place such that they are visible and legible when the ASSEMBLY is installed and in operation. Compliance is checked according to the test of 10.2.7 and by inspection.

The following information regarding the ASSEMBLY shall be provided on the designation label(s):

- a) ASSEMBLY manufacturer's name or trade mark (see 3.10.2);
- b) type designation or identification number or any other means of identification, making it possible to obtain relevant information from the ASSEMBLY manufacturer;
- c) means of identifying date of manufacture;
- d) IEC 61439-X (the specific part "X" shall be identified).

NOTE The relevant ASSEMBLY standard may specify where additional information is to be provided on the designation label.

6.2 Documentation

6.2.1 Information relating to the ASSEMBLY

All interface characteristics according to Clause 5, where applicable, shall be provided in the ASSEMBLY manufacturer's technical documentation supplied with the ASSEMBLY.

6.2.2 Instructions for handling, installation, operation and maintenance

The ASSEMBLY manufacturer shall provide in documents or catalogues the conditions, if any, for the handling, installation, operation and maintenance of the ASSEMBLY and the equipment contained therein.

If necessary, the instructions shall indicate the measures that are of particular importance for the proper and correct transport, handling, installation and operation of the ASSEMBLY. The provision of weight details is of particular importance in connection with the transport and handling of ASSEMBLIES.

The correct location and installation of lifting means and the thread size of lifting attachments, if applicable, shall be given in the ASSEMBLY manufacturer's documentation or the instructions on how the ASSEMBLY has to be handled.

The measures to be taken, if any, with regard to EMC associated with the installation, operation and maintenance of the ASSEMBLY shall be specified (see Annex J).

If an ASSEMBLY specifically intended for environment A is to be used in environment B the following warning shall be included in the operating instructions:

CAUTION

This product has been designed for environment A. Use of this product in environment B may cause unwanted electromagnetic disturbances in which case the user may be required to take adequate mitigation measures.

Where necessary, the above-mentioned documents shall indicate the recommended extent and frequency of maintenance.

If the circuitry is not obvious from the physical arrangement of the apparatus installed, suitable information shall be supplied, for example wiring diagrams or tables.

6.3 Device and/or component identification

Inside the ASSEMBLY, it shall be possible to identify individual circuits and their protective devices. Identification tags shall be legible, permanent and appropriate for the physical environment. Any designations used shall be in compliance with IEC 81346-1 and IEC 81346-2 and identical with those used in the wiring diagrams, which shall be in accordance with IEC 61082-1.

7 Service conditions

7.1 Normal service conditions

ASSEMBLIES conforming to this standard are intended for use under the normal service conditions detailed below.

NOTE If components, for example relays, electronic equipment, are used which are not designed for these conditions, appropriate steps should be taken to ensure proper operation.

7.1.1 Ambient air temperature

7.1.1.1 Ambient air temperature for indoor installations

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.

7.1.1.2 Ambient air temperature for outdoor installations

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 -25 °C.

7.1.2 Humidity conditions

7.1.2.1 Humidity conditions for indoor installations

The relative humidity of the air does not exceed 50 % at a maximum temperature of +40 °C. Higher relative humidity may be permitted at lower temperatures, for example 90 % at +20 °C. Moderate condensation should be borne in mind which may occasionally occur due to variations in temperature.

7.1.2.2 Humidity conditions for outdoor installations

The relative humidity may temporarily be as high as 100 % at a maximum temperature of +25 °C.

7.1.3 Pollution degree

The pollution degree (see 3.6.9) refers to the environmental conditions for which the ASSEMBLY is intended.

For switching devices and components inside an enclosure, the pollution degree of the environmental conditions in the enclosure is applicable.

For the purpose of evaluating clearances and creepage distances, the following four degrees of pollution in the micro-environment are established.

Pollution degree 1:

No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.

Pollution degree 2:

Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

Pollution degree 3:

Conductive pollution occurs or dry, non-conductive pollution occurs which is expected to become conductive due to condensation.

Pollution degree 4:

Continuous conductivity occurs due to conductive dust, rain or other wet conditions.

Pollution degree 4 is not applicable for a micro-environment inside the ASSEMBLY to this standard.

Unless otherwise stated, ASSEMBLIES for industrial applications are generally for use in a pollution degree 3 environment. However, other pollution degrees may be considered to apply, depending upon particular applications or the micro-environment.

NOTE The pollution degree of the micro-environment for the equipment may be influenced by installation in an enclosure.

7.1.4 Altitude

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

NOTE For equipment to be used at higher altitudes, it is necessary to take into account the reduction of the dielectric strength, the switching capability of the devices and of the cooling effect of the air.

7.2 Special service conditions

Where any special service conditions exist, the applicable particular requirements shall be complied with or special agreements shall be made between the ASSEMBLY manufacturer and the user. The user shall inform the ASSEMBLY manufacturer if such exceptional service conditions exist.

Special service conditions include, for example:

- a) values of temperature, relative humidity and/or altitude differing from those specified in 7.1;
- b) applications where variations in temperature and/or air pressure take place at such a speed that exceptional condensation is liable to occur inside the ASSEMBLY;
- c) heavy pollution of the air by dust, smoke, corrosive or radioactive particles, vapours or salt;
- d) exposure to strong electric or magnetic fields;

- e) exposure to extreme climatic conditions;
- f) attack by fungus or small creatures;
- g) installation in locations where fire or explosion hazards exist;
- h) exposure to heavy vibration, shocks, seismic occurrences;
- i) installation in such a manner that the current-carrying capacity or breaking capacity is affected, for example equipment built into machines or recessed into walls;
- j) exposure to conducted and radiated disturbances other than electromagnetic, and electromagnetic disturbances in environments other than those described in 9.4;
- k) exceptional overvoltage conditions or voltage fluctuations;
- l) excessive harmonics in the supply voltage or load current.

7.3 Conditions during transport, storage and installation

A special agreement shall be made between the ASSEMBLY manufacturer and the user if the conditions during transport, storage and installation, for example temperature and humidity conditions, differ from those defined in 7.1.

8 Constructional requirements

8.1 Strength of materials and parts

8.1.1 General

ASSEMBLIES shall be constructed of materials capable of withstanding the mechanical, electrical, thermal and environmental stresses that are likely to be encountered in specified service conditions.

The external shape of the ASSEMBLY enclosure can vary to suit the application and use, some examples have been defined in 3.3. These enclosures may also be constructed from various materials e.g. insulating, metallic or a combination of these.

8.1.2 Protection against corrosion

Protection against corrosion shall be ensured by the use of suitable materials or by protective coatings to the exposed surface, taking account of the normal service conditions (see 7.1). Compliance to this requirement is checked by the test of 10.2.2.

8.1.3 Properties of insulating materials

8.1.3.1 Thermal stability

For enclosures or parts of enclosures made of insulating materials, thermal stability shall be verified according to 10.2.3.1.

8.1.3.2 Resistance of insulating materials to heat and fire

8.1.3.2.1 General

Parts of insulating materials which might be exposed to thermal stresses due to internal electrical effects, and the deterioration of which might impair the safety of the ASSEMBLY, shall not be adversely affected by normal (operational) heat, abnormal heat or fire.

8.1.3.2.2 Resistance of insulating materials to heat

The original manufacturer shall select insulating materials either by reference to the insulation temperature index (determined for example by the methods of IEC 60216) or by compliance with IEC 60085.

8.1.3.2.3 Resistance of insulating materials to abnormal heat and fire due to internal electric effects

Insulating materials used for parts necessary to retain current carrying parts in position and parts which might be exposed to thermal stresses due to internal electrical effects, and the deterioration of which might impair the safety of the ASSEMBLY, shall not be adversely affected by abnormal heat and fire and shall be verified by the glow-wire test in 10.2.3.2. For the purpose of this test, a protective conductor (PE) is not considered as a current-carrying part.

For small parts (having surface dimensions not exceeding 14 mm x 14 mm), an alternative test may be used (e.g. needle flame test, according to IEC 60695-11-5). The same procedure may be applicable for other practical reasons where the metal material of a part is large compared to the insulating material.

8.1.4 Resistance to ultra-violet radiation

For enclosures and external parts made of insulating materials which are intended to be used outdoor, resistance to ultra-violet radiation shall be verified according to 10.2.4.

8.1.5 Mechanical strength

All enclosures or partitions including locking means and hinges for doors shall be of a mechanical strength sufficient to withstand the stresses to which they may be subjected in normal service, and during short-circuit conditions (see also 10.13).

The mechanical operation of removable parts, including any insertion interlock, shall be verified by test according to 10.13.

8.1.6 Lifting provision

Where required, ASSEMBLIES shall be provided with the appropriate provision for lifting. Compliance is checked according to the test of 10.2.5.

8.2 Degree of protection provided by an ASSEMBLY enclosure

8.2.1 Protection against mechanical impact

The degree of protection provided by an ASSEMBLY enclosure against mechanical impact, if necessary, shall be defined by the relevant ASSEMBLY standards and verified in accordance with IEC 62262 (see 10.2.6).

8.2.2 Protection against contact with live parts, ingress of solid foreign bodies and water

The degree of protection provided by any ASSEMBLY against contact with live parts, ingress of solid foreign bodies and water is indicated by the IP code according to IEC 60529 and verified according to 10.3

NOTE 1 In the United States of America (USA), Canada and in Mexico enclosure "type" designations are used to specify "the degree of protection" provided to the ASSEMBLY. For applications in the USA, the appropriate enclosure type designation should be used as specified in NEMA 250. For applications in Canada, the appropriate enclosure type designation should be used as specified in CSA standard C22.2 No. 94.1 and 94.2. For applications in Mexico, the appropriate enclosure Type designation should be used as specified in NMJ-J-235/1-ANCE y NMJ-J-235/2-ANCE

The degree of protection of an enclosed ASSEMBLY shall be at least IP 2X, after installation in accordance with the ASSEMBLY manufacturer's instructions. The degree of protection provided from the front of a dead front ASSEMBLY shall be at least IP XXB.

For fixed ASSEMBLIES not subject to tilting in normal service IP X2 is not applicable.

For ASSEMBLIES for outdoor use having no supplementary protection, the second characteristic numeral shall be at least 3.

NOTE 2 For outdoor installation, supplementary protection may be protective roofing or the like.

Unless otherwise specified, the degree of protection indicated by the ASSEMBLY manufacturer applies to the complete ASSEMBLY when installed in accordance with the ASSEMBLY manufacturer's instructions, for example sealing of the open mounting surface of an ASSEMBLY, etc.

Where the ASSEMBLY does not have the same IP rating throughout, the ASSEMBLY manufacturer shall declare the IP rating for the separate parts.

Different IP ratings shall not impair the intended use of the ASSEMBLY.

NOTE 3 Examples include:

- Operating face IP 20, other parts IP 00.
- Drain holes in the base IP XXD, other parts IP 43.

No IP codes can be given unless the appropriate verifications have been made according to 10.3.

Enclosed ASSEMBLIES, for outdoor and indoor installation, intended for use in locations with high humidity and temperatures varying within wide limits, shall be provided with suitable arrangements (ventilation and/or internal heating, drain holes, etc.) to prevent harmful condensation within the ASSEMBLY. However, the specified degree of protection shall at the same time be maintained.

8.2.3 ASSEMBLY with removable parts

The degree of protection indicated for ASSEMBLIES normally applies to the connected position (see 3.2.3) of removable parts.

If, after the removal of a removable part, it is not possible to maintain the original degree of protection e.g. by closing a door, an agreement shall be reached between the ASSEMBLY manufacturer and the user as to what measures shall be taken to ensure adequate protection. Information provided by the ASSEMBLY manufacturer may take the place of such an agreement.

When shutters are used to provide adequate protection to live parts they shall be secured to prevent unintentional removal.

8.3 Clearances and creepage distances

8.3.1 General

The requirements for clearances and creepage distances are based on the principles of IEC 60664-1 and are intended to provide insulation co-ordination within the installation.

The clearances and creepage distances of equipment that form part of the ASSEMBLY shall comply with the requirements of the relevant product standard.

When incorporating equipment into the ASSEMBLY, the specified clearances and creepage distances shall be maintained during normal service conditions.

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

The clearances and creepage distances apply to phase to phase, phase to neutral, and except where a conductor is connected directly to earth, phase to earth and neutral to earth.

For bare live conductors and terminations (e.g. busbars, connections between equipment and cable lugs), the clearances and creepage distances shall at least be equivalent to those specified for the equipment with which they are directly associated.

The effect of a short-circuit up to and including the declared rating(s) of the ASSEMBLY shall not reduce permanently the clearances or creepage distances between busbars and/or connections, below the values specified for the ASSEMBLY. Deformation of parts of the enclosure or of the internal partitions, barriers and obstacles due to a short-circuit shall not reduce permanently the clearances or creepage distances below those specified in 8.3.2 and 8.3.3 (see also 10.11.5.5).

8.3.2 Clearances

The clearances shall be sufficient to enable the declared rated impulse withstand voltage (U_{imp}) of a circuit to be achieved. The clearances shall be as specified in Table 1 unless a design verification test and routine impulse withstand voltage test is carried out in accordance with 10.9.3 and 11.3, respectively.

The method of determining clearances by measurement is given in Annex F.

NOTE In the United States of America (USA) and Mexico National Electrical Codes, are used to specify minimum clearances. In the USA National Electric Code NFPA 70, Article 408.56 is applicable. In Mexico NOM-001-SEDE is applicable. For these applications, it is recommended that clearances be selected using Annex L, Table L.1 of this standard. For applications in Canada minimum electrical clearances are specified in the Canadian Electrical Code, Part 2 Product Safety Standards.

8.3.3 Creepage distances

The original manufacturer shall select a rated insulation voltage(s) (U_i) for the circuits of the ASSEMBLY from which the creepage distance(s) shall be determined. For any given circuit the rated insulation voltage shall not be less than the rated operational voltage (U_e).

The creepage distances shall not, in any case, be less than the associated minimum clearances.

Creepage distances shall correspond to a pollution degree as specified in 7.1.3 and to the corresponding material group at the rated insulation voltage given in Table 2.

The method of determining creepage distances by measurement is given in Annex F.

NOTE 1 For inorganic insulating materials, e.g. glass or ceramics, which do not track, creepage distances need not be greater than their associated clearances. However, the risk of disruptive discharge should be considered.

NOTE 2 In the United States of America (USA) and Mexico National Electrical Codes are used to specify minimum creepage distances. In the USA National Electric Code NFPA 70, Article 408.56 is applicable. In Mexico NOM-001-SEDE is applicable. For these applications, it is recommended that creepage distances be selected using Annex L, Table L.2 of this standard. For applications in Canada minimum creepage distances are specified in the Canadian Electrical Code, Part 2 Product Safety Standards.

By using ribs of a minimum height of 2 mm the creepage distance may be reduced but, irrespective of the number of ribs, shall be not less than 0,8 of the value of Table 2 and not less than the associated minimum clearance. The minimum base of the rib is determined by mechanical requirements (see Clause F.2).

8.4 Protection against electric shock

8.4.1 General

The apparatus and circuits in the ASSEMBLY shall be so arranged as to facilitate their operation and maintenance, and at the same time to ensure the necessary degree of safety.

The following requirements are intended to ensure that the required protective measures are obtained when an ASSEMBLY is installed in an electrical system conforming to the IEC 60364 series.

NOTE For generally accepted protective measures refer to IEC 61140 and IEC 60364-4-41.

Those protective measures, which are of particular importance for an ASSEMBLY, are reproduced in 8.4.2 to 8.4.6.

8.4.2 Basic protection

8.4.2.1 General

Basic protection is intended to prevent direct contact with hazardous live parts.

Basic protection can be achieved either by appropriate constructional measures on the ASSEMBLY itself or by additional measures to be taken during installation; this may require information to be given by the ASSEMBLY manufacturer.

An example of additional measures to be taken is the installation of an open-type ASSEMBLY without further provisions in a location where access is only permitted for authorized personnel.

Where basic protection is achieved by constructional measures one or more of the protective measures given in 8.4.2.2 and 8.4.2.3 may be selected. The choice of the protective measure shall be declared by the ASSEMBLY manufacturer if not specified within the relevant ASSEMBLY standard.

8.4.2.2 Basic insulation provided by insulating material

Hazardous live parts shall be completely covered with insulation that can only be removed by destruction or by the use of a tool.

The insulation shall be made of suitable materials capable of durably withstanding the mechanical, electrical and thermal stresses to which the insulation may be subjected in service.

NOTE Examples are electrical components embedded in insulation and insulated conductors.

Paints, varnishes and lacquers alone are not considered to satisfy the requirements for basic insulation.

8.4.2.3 Barriers or enclosures

Air insulated live parts shall be inside enclosures or behind barriers providing at least a degree of protection of IP XXB.

Horizontal top surfaces of accessible enclosures having a height equal to or lower than 1,6 m above the standing area, shall provide a degree of protection of at least IP XXD.

Barriers and enclosures shall be firmly secured in place and have sufficient stability and durability to maintain the required degrees of protection and appropriate separation from live

parts under normal service conditions, taking account of relevant external influences. The distance between a conductive barrier or enclosure and the live parts they protect shall not be less than the values specified for the clearances and creepage distances in 8.3.

Where it is necessary to remove barriers or open enclosures or to remove parts of enclosures, this shall be possible only if one of the conditions a) to c) is fulfilled:

- a) By the use of a key or tool, i.e. any mechanical aid, to open the door, cover or override an interlock.
- b) After isolation of the supply to live parts, against which the barriers or enclosures afford basic protection, restoration of the supply being possible only after replacement or reclosure of the barriers or enclosures. In TN-C systems, the PEN conductor shall not be isolated or switched. In TN-S systems and TN-C-S systems the neutral conductors need not be isolated or switched (see IEC 60364-5-53:2001, 536.1.2).

Example: By interlocking the door(s) with a disconnector so that they can only be opened when the disconnector is open, and closing of the disconnector without the use of a tool is impossible while the door is open.

NOTE In Norway, the neutral conductor shall be isolated or switched.

- c) Where an intermediate barrier providing a degree of protection of at least IP XXB prevents contact with live parts, such a barrier being removable only by the use of a key or tool.

8.4.3 Fault protection

8.4.3.1 Installation conditions

The ASSEMBLY shall include protective measures and be suitable for installations designed to be in accordance with IEC 60364-4-41. Protective measures suitable for particular installations (e.g. railways, ships) shall be subject to agreement between the ASSEMBLY manufacturer and the user.

When a TT earthing system is being used in the electrical network one of the following measures shall be applied in the ASSEMBLY:

- a) double or reinforced insulation of the incoming connections, or
- b) residual current device (RCD) protection on the incoming circuit

Such provisions are subject to agreement between user and manufacturer.

8.4.3.2 Requirements for the protective conductor to facilitate automatic disconnection of the supply

8.4.3.2.1 General

Each ASSEMBLY shall have a protective conductor to facilitate automatic disconnection of the supply for:

- a) protection against the consequences of faults (e.g. failure of basic insulation) within the ASSEMBLY;
- b) protection against the consequences of faults (e.g. failure of basic insulation) in external circuits supplied through the ASSEMBLY.

The requirements to be complied with are given in the following subclauses.

Requirements for identification of the protective conductor (PE, PEN) are given in 8.6.6.

8.4.3.2.2 Requirements for earth continuity providing protection against the consequences of faults within the ASSEMBLY

All exposed conductive parts of the ASSEMBLY shall be interconnected together and to the protective conductor of the supply or via an earthing conductor to the earthing arrangement.

These interconnections may be achieved either by metal screwed connections, welding or other conductive connections or by a separate protective conductor.

NOTE With metal parts of the ASSEMBLY where abrasion resistant finishes are used, e.g. gland plates with powder coatings, connection for protective earthing requires removal or penetration of the coating.

The method to verify the earth continuity between the exposed conductive parts of the ASSEMBLY and the protective circuit is given in 10.5.2.

For the continuity of these connections the following shall apply:

- a) When a part of the ASSEMBLY is removed, for example for routine maintenance, the protective circuits (earth continuity) for the remainder of the ASSEMBLY shall not be interrupted.

Means used for assembling the various metal parts of an ASSEMBLY are considered sufficient for ensuring continuity of the protective circuits if the precautions taken guarantee permanent good conductivity.

Flexible or pliable metal conduits shall not be used as protective conductors unless they are designed for that purpose.

- b) For lids, doors, cover plates and the like, the usual metal screwed connections and metal hinges are considered sufficient to ensure continuity provided that no electrical equipment exceeding the limits of extra low voltage (ELV) is attached to them.

If apparatus with a voltage exceeding the limits of extra-low voltage are attached to lids, doors, or cover plates additional measures shall be taken to ensure earth continuity. These parts shall be fitted with a protective conductor (PE) whose cross-sectional area is in accordance with Table 3 depending on the highest rated operational current I_e of the apparatus attached or, if the rated operational current of the attached apparatus is less than or equal to 16 A, an equivalent electrical connection especially designed and verified for this purpose (sliding contact, hinges protected against corrosion).

Exposed conductive parts of a device that cannot be connected to the protective circuit by the fixing means of the device shall be connected to the protective circuit of the ASSEMBLY by a conductor whose cross-sectional area is chosen according to Table 3.

Certain exposed conductive parts of an ASSEMBLY that do not constitute a danger

- either because they cannot be touched on large surfaces or grasped with the hand,
- or because they are of small size (approximately 50 mm by 50 mm) or so located as to exclude any contact with live parts,

need not be connected to a protective conductor. This applies to screws, rivets and nameplates. It also applies to electromagnets of contactors or relays, magnetic cores of transformers, certain parts of releases, or similar, irrespective of their size.

When removable parts are equipped with a metal supporting surface, these surfaces shall be considered sufficient for ensuring earth continuity of protective circuits provided that the pressure exerted on them is sufficiently high.

8.4.3.2.3 Requirements for protective conductors providing protection against the consequences of faults in external circuits supplied through the ASSEMBLY

A protective conductor within the ASSEMBLY shall be so designed that it is capable of withstanding the highest thermal and dynamic stresses arising from faults in external circuits at the place of installation that are supplied through the ASSEMBLY. Conductive structural parts may be used as a protective conductor or a part of it.

Except where verification of the short-circuit withstand strength is not required in accordance with 10.11.2, verification shall be made in accordance with 10.5.3.

In principle, with the exception of the cases mentioned below, protective conductors within an ASSEMBLY shall not include a disconnecting device (switch, disconnector, etc.).

In the run of protective conductors links shall be permitted which are removable by means of a tool and accessible only to authorized personnel (these links may be required for certain tests).

Where continuity can be interrupted by means of connectors or plug-and-socket devices, the protective circuit shall be interrupted only after the live conductors have been interrupted and continuity shall be established before the live conductors are reconnected.

In the case of an ASSEMBLY containing structural parts, frameworks, enclosures, etc., made of conducting material, a protective conductor, if provided, need not be insulated from these parts. Conductors to voltage-operated fault detection devices including the conductors connecting them to a separate earth electrode shall be insulated when specified by their manufacturer. This can also apply to the earth connection of the transformer neutral.

The cross-sectional area of protective conductors (PE, PEN) in an ASSEMBLY to which external conductors are intended to be connected shall be not less than the value calculated with the aid of the formula indicated in Annex B using the highest fault current and fault duration that may occur and taking into account the limitation of the short-circuit protective devices (SCPDs) that protect the corresponding live conductors. The short-circuit withstand strength is verified according to 10.5.3.

For PEN conductors, the following additional requirements apply:

- the minimum cross-sectional area shall be 10 mm² copper or 16 mm² aluminium;
- the PEN conductor shall have a cross-sectional area not less than that required for a neutral conductor (see 8.6.1);
- the PEN conductors need not be insulated within an ASSEMBLY;
- structural parts shall not be used as a PEN conductor. However, mounting rails made of copper or aluminium may be used as PEN conductors.

For details of requirements for terminals for external protective conductors, see 8.8.

8.4.3.3 Electrical separation

Electrical separation of individual circuits is intended to prevent electrical shock through contact with exposed-conductive-parts, which may be energized by a fault in basic insulation of the circuit.

For this type of protection, see Annex K.

8.4.4 Protection by total insulation

NOTE According to 412.2.1.1 of IEC 60364-4-41, "total insulation" is equivalent to Class II equipment.

For basic and fault protection, by total insulation, the following requirements shall be met.

- a) The apparatus shall be completely enclosed in insulating material which is equivalent of double or reinforced insulation. The enclosure shall carry the symbol \square which shall be visible from the outside.

- b) The enclosure shall at no point be pierced by conducting parts in such a manner that there is the possibility of a fault voltage being brought out of the enclosure.

This means that metal parts, such as actuator shafts which for constructional reasons have to be brought through the enclosure, shall be insulated on the inside or the outside of the enclosure from the live parts for the maximum rated insulation voltage and the maximum rated impulse withstand voltage of all circuits in the ASSEMBLY.

If an actuator is made of metal (whether covered by insulating material or not), it shall be provided with insulation rated for the maximum rated insulation voltage and the maximum impulse withstand voltage of all circuits in the ASSEMBLY.

If an actuator is principally made of insulating material, any of its metal parts which may become accessible in the event of insulation failure shall also be insulated from live parts for the maximum rated insulation voltage and the maximum rated impulse withstand voltage of all circuits in the ASSEMBLY.

- c) The enclosure, when the ASSEMBLY is ready for operation and connected to the supply, shall enclose all live parts, exposed conductive parts and parts belonging to a protective circuit in such a manner that they cannot be touched. The enclosure shall give at least the degree of protection IP 2XC (see IEC 60529).

If a protective conductor, which is extended to electrical equipment connected to the load side of the ASSEMBLY, is to be passed through an ASSEMBLY whose exposed conductive parts are insulated, the necessary terminals for connecting the external protective conductors shall be provided and identified by suitable marking.

Inside the enclosure, the protective conductor and its terminal shall be insulated from the live parts and the exposed conductive parts in the same way as the live parts are insulated.

- d) Exposed conductive parts within the ASSEMBLY shall not be connected to the protective circuit, i.e. they shall not be included in a protective measure involving the use of a protective circuit. This applies also to built-in apparatus, even if they have a connecting terminal for a protective conductor.
- e) If doors or covers of the enclosure can be opened without the use of a key or tool, a barrier of insulating material shall be provided that will afford protection against unintentional contact not only with the accessible live parts, but also with the exposed conductive parts that are only accessible after the cover has been opened; this barrier, however, shall not be removable except with the use of a tool.

8.4.5 Limitation of steady-state touch current and charge

If the ASSEMBLY contains items of equipment that may have steady-state touch current and charges after they have been switched off (capacitors, etc.) a warning plate is required.

Small capacitors such as those used for arc extinction, for delaying the response of relays, etc., shall not be considered dangerous.

NOTE Unintentional contact is not considered dangerous if the voltages resulting from static charges fall below a d.c. voltage of 60 V in less than 5 s after disconnection from the power supply.

8.4.6 Operating and servicing conditions

8.4.6.1 Devices to be operated or components to be replaced by ordinary persons

Protection against any contact with live parts shall be maintained when operating devices or when replacing components.

The minimum level of protection shall be IP XXC. During the replacement of certain lamps or fuselinks openings larger than those defined by degree of protection IP XXC are allowed.

8.4.6.2 Requirements related to accessibility in service by authorized persons

8.4.6.2.1 General

For accessibility in service by authorized persons, one or more of the following requirements in 8.4.6.2.2 to 8.4.6.2.4 shall be fulfilled subject to agreement between the ASSEMBLY manufacturer and the user. These requirements shall be complementary to the basic protection specified in 8.4.2.

If doors or covers of the ASSEMBLY can be opened by authorized persons by overriding an interlock to obtain access to live parts, then the interlock shall automatically be restored on reclosing the door(s) or replacing the cover(s).

8.4.6.2.2 Requirements related to accessibility for inspection and similar operations

The ASSEMBLY shall be constructed in such a way that certain operations, according to agreement between the ASSEMBLY manufacturer and the user, can be performed when the ASSEMBLY is in service and under voltage.

Such operations may consist of:

- visual inspection of
 - switching devices and other apparatus,
 - settings and indicators of relays and releases,
 - conductor connections and marking;
- adjusting and resetting of relays, releases and electronic devices;
- replacement of fuse-links;
- replacement of indicating lamps;
- certain fault location operations, for example voltage and current measuring with suitably designed and insulated devices.

8.4.6.2.3 Requirements related to accessibility for maintenance

To enable maintenance as agreed upon between the ASSEMBLY manufacturer and the user on an isolated functional unit or isolated group of functional units in the ASSEMBLY, with adjacent functional units or groups still under voltage, necessary measures shall be taken. The choice depends on such factors as service conditions, frequency of maintenance, competence of the authorized person, as well as local installation rules. Such measures may include:

- sufficient space between the actual functional unit or group and adjacent functional units or groups. It is recommended that parts likely to be removed for maintenance have, as far as possible, retainable fastening means;
- use of barriers or obstacles designed and arranged to protect against direct contact with equipment in adjacent functional units or groups;
- use of terminal shields;
- use of compartments for each functional unit or group;
- insertion of additional protective means provided or specified by the ASSEMBLY manufacturer.

8.4.6.2.4 Requirements related to accessibility for extension under voltage

When it is required to enable future extension of an ASSEMBLY with additional functional units or groups, with the rest of the ASSEMBLY still under voltage, the requirements specified in 8.4.6.2.3 shall apply, subject to agreement between the ASSEMBLY manufacturer and the user. These requirements also apply for the insertion and connection of additional outgoing cables when the existing cables are under voltage.

The extension of busbars and connection of additional units to their incoming supply shall not be made under voltage, unless the ASSEMBLY is designed for this purpose.

8.4.6.2.5 Obstacles

Obstacles shall prevent either:

- unintentional bodily approach to live parts, or
- unintentional contact with live parts during the operation of live equipment in normal service.

Obstacles may be removed without using a key or tool but shall be so secured as to prevent unintentional removal. The distance between a conductive obstacle and the live parts they protect shall not be less than the values specified for the clearances and creepage distances in 8.3.

Where a conductive obstacle is separated from hazardous live parts by basic protection only, it is an exposed conductive part, and measures for fault protection shall also be applied.

8.5 Incorporation of switching devices and components

8.5.1 Fixed parts

For fixed parts (see 3.2.1), the connections of the main circuits (see 3.1.3) shall only be connected or disconnected when the ASSEMBLY is not under voltage. In general, removal and installation of fixed parts requires the use of a tool.

The disconnection of a fixed part shall require the isolation of the complete ASSEMBLY or part of it.

In order to prevent unauthorized operation, the switching device may be provided with means to secure it in one or more of its positions.

NOTE Where working on live circuits is permitted, relevant safety precautions may be necessary.

8.5.2 Removable parts

The removable parts shall be so constructed that their electrical equipment can be safely removed from or connected to the main circuit whilst this circuit is live. The removable parts may be provided with an insertion interlock (see 3.2.5).

Clearances and creepage distances (see 8.3) shall be complied with during transfer from one position to another.

A removable part shall be fitted with a device, which ensures that it can only be removed and inserted after its main circuit has been switched off from the load.

In order to prevent unauthorized operation, the removable parts or their associated ASSEMBLY location may be provided with a lockable means to secure them in one or more of their positions.

8.5.3 Selection of switching devices and components

Switching devices and components incorporated in ASSEMBLIES shall comply with the relevant IEC standards.

The switching devices and components shall be suitable for the particular application with respect to the external design of the ASSEMBLY (e.g. open type or enclosed), their rated voltages, rated currents, rated frequency, service life, making and breaking capacities, short-circuit withstand strength, etc.

The rated insulation voltage, and rated impulse withstand voltage of the devices installed in the circuit shall be equal or higher than the corresponding value assigned to that circuit. In some cases overvoltage protection may be necessary e.g. for equipment fulfilling overvoltage category II (see 3.6.11). The switching devices and components having a short-circuit withstand strength and/or a breaking capacity which is insufficient to withstand the stresses likely to occur at the place of installation, shall be protected by means of current-limiting protective devices, for example fuses or circuit-breakers. When selecting current-limiting protective devices for built-in switching devices, account shall be taken of the maximum permissible values specified by the device manufacturer, having due regard to co-ordination (see 9.3.4).

Co-ordination of switching devices and components, for example co-ordination of motor starters with short-circuit protective devices, shall comply with the relevant IEC standards.

NOTE Guidance is given in IEC/TR 61912-1 and IEC/TR 61912-2.

8.5.4 Installation of switching devices and components

Switching devices and components shall be installed and wired in the ASSEMBLY in accordance with instructions provided by their manufacturer and in such a manner that their proper functioning is not impaired by interaction, such as heat, switching emissions, vibrations, electromagnetic fields, which are present in normal operation. In the case of electronic assemblies, this may necessitate the separation or screening of all electronic signal processing circuits.

When fuses are installed the original manufacturer shall state the type and rating of the fuse-links to be used.

8.5.5 Accessibility

Adjusting and resetting devices, which have to be operated inside the ASSEMBLY shall be easily accessible.

Functional units mounted on the same support (mounting plate, mounting frame) and their terminals for external conductors shall be so arranged as to be accessible for mounting, wiring, maintenance and replacement.

Unless otherwise agreed between the ASSEMBLY manufacturer and the user, the following accessibility requirements associated with floor-mounted ASSEMBLIES shall apply:

- The terminals, excluding terminals for protective conductors, shall be situated at least 0,2 m above the base of the ASSEMBLIES and, moreover, be so placed that the cables can be easily connected to them.
- Indicating instruments that need to be read by the operator shall be located within a zone between 0,2 m and 2,2 m above the base of the ASSEMBLY.
- Operating devices such as handles, push buttons, or similar shall be located at such a height that they can easily be operated; this means that their centreline shall be located within a zone between 0,2 m and 2 m above the base of the ASSEMBLY. Devices which are

infrequently operated, e.g. less than once per month, may be installed at a height up to 2,2 m.

- Actuators for emergency switching devices (see 536.4.2 of IEC 60364-5-53:2001) shall be accessible within a zone between 0,8 m and 1,6 m above the base of the ASSEMBLY.

NOTE In some countries, national codes or regulations may further limit the minimum and maximum height.

8.5.6 Barriers

Barriers for manual switching devices shall be so designed that the switching emissions do not present a danger to the operator.

To minimize danger when replacing fuse-links, interphase barriers shall be applied, unless the design and location of the fuses makes this unnecessary.

8.5.7 Direction of operation and indication of switching positions

The operational positions of components and devices shall be clearly identified. If the direction of operation is not in accordance with IEC 60447, then the direction of operation shall be clearly identified.

8.5.8 Indicator lights and push-buttons

Unless otherwise specified in the relevant product standard the colours of indicator lights and push-buttons shall be in accordance with IEC 60073.

8.6 Internal electrical circuits and connections

8.6.1 Main circuits

The busbars (bare or insulated) shall be arranged in such a manner that an internal short-circuit is not to be expected. They shall be rated at least in accordance with the information concerning the short-circuit withstand strength (see 9.3) and designed to withstand at least the short-circuit stresses limited by the protective device(s) on the supply side of the busbars.

Within one section, the conductors (including distribution busbars) between the main busbars and the supply side of functional units as well as the components included in these units may be rated on the basis of the reduced short-circuit stresses occurring on the load side of the respective short-circuit protective device within each unit, provided that these conductors are arranged so that under normal operation an internal short-circuit between phases and/or between phases and earth is not to be expected (see 8.6.4).

Unless otherwise agreed between the ASSEMBLY manufacturer and the user, the minimum cross-sectional area of the neutral within a three phase and neutral circuit shall be:

- For circuits with a phase conductor cross-sectional area up to and including 16 mm², 100 % of that of the corresponding phases.
- For circuits with a phase conductor cross-sectional area above 16 mm², 50 % of that of the corresponding phases with a minimum of 16 mm².

It is assumed that the neutral currents do not exceed 50 % of the phase currents.

NOTE For certain applications which lead to high values of zero sequence harmonics (e.g. 3rd order harmonics) higher cross-sections of the N conductor might be required as these harmonics of the phases are added in the N conductor and lead to high current load at higher frequencies. This is subject to special agreement between the ASSEMBLY manufacturer and the user.

The PEN shall be dimensioned as specified in 8.4.3.2.3.

8.6.2 Auxiliary circuits

The design of the auxiliary circuits shall take into account the supply earthing system and ensure that an earth-fault or a fault between a live part and an exposed conductive part shall not cause unintentional dangerous operation.

In general, auxiliary circuits shall be protected against the effects of short circuits. However, a short-circuit protective device shall not be provided if its operation is liable to cause a danger. In such a case, the conductors of auxiliary circuits shall be arranged in such a manner that a short-circuit is not to be expected (see 8.6.4).

8.6.3 Bare and insulated conductors

The connections of current-carrying parts shall not suffer undue alteration as a result of normal temperature rise, ageing of the insulating materials and vibrations occurring in normal operation. In particular, the effects of thermal expansion and of the electrolytic action in the case of dissimilar metals, and the effects of the endurance of the materials to the temperatures attained, shall be taken into consideration.

Connections between current-carrying parts shall be established by means that ensure a sufficient and durable contact pressure.

If verification of temperature rise is carried out on the basis of tests (see 10.10.2) the selection of conductors and their cross-sections used inside the ASSEMBLY shall be the responsibility of the original manufacturer. If verification of temperature rise is made following the rules of 10.10.3, the conductors shall have a minimum cross-section according to IEC 60364-5-52. Examples on how to adapt this standard for conditions inside an ASSEMBLY are given in the tables included in Annex H. In addition to the current-carrying capacity of the conductors, the selection is governed by:

- the mechanical stresses to which the ASSEMBLY may be subjected;
- the method used to lay and secure the conductors;
- the type of insulation;
- the type of components being connected (e.g. switchgear and controlgear in accordance with IEC 60947 series; electronic devices or equipment).

In the case of insulated solid or flexible conductors:

- They shall be rated for at least the rated insulation voltage (see 5.2.3) of the circuit concerned.
- Conductors connecting two termination points shall have no intermediate joint, e.g. spliced or soldered.
- Conductors with only basic insulation shall be prevented from coming into contact with bare live parts at different potentials.
- Contact of conductors with sharp edges shall be prevented.
- Supply conductors to apparatus and measuring instruments in covers or doors shall be so installed that no mechanical damage can occur to the conductors as a result of movement of these covers or doors.
- Soldered connections to apparatus shall be permitted in ASSEMBLIES only in cases where provision is made for this type of connection on the apparatus and the specified type of conductor is used.
- For apparatus other than those mentioned above, soldering cable lugs or soldered ends of stranded conductors are not acceptable under conditions of heavy vibration. In locations where heavy vibrations exist during normal operation, for example in the case of dredger and crane operation, operation on board ships, lifting equipment and locomotives, attention should be given to the support of conductors.

- Generally only one conductor should be connected to a terminal; the connection of two or more conductors to one terminal is permissible only in those cases where the terminals are designed for this purpose.

The dimensioning of solid insulation between separate circuits shall be based on the circuit of highest rated insulation voltage.

8.6.4 Selection and installation of non-protected live conductors to reduce the possibility of short-circuits

Live conductors in an ASSEMBLY that are not protected by short-circuit protective devices (see 8.6.1 and 8.6.2) shall be selected and installed throughout the entire ASSEMBLY in such a manner that an internal short-circuit between phases or between phase and earth is a remote possibility. Examples of conductor types and installation requirements are given in Table 4. Non-protected live conductors selected and installed as in Table 4 shall have a total length not exceeding 3 m between the main busbar and each respective SCPD.

8.6.5 Identification of the conductors of main and auxiliary circuits

With the exception of the cases mentioned in 8.6.6, the method and the extent of identification of conductors, for example by arrangement, colours or symbols, on the terminals to which they are connected or on the end(s) of the conductors themselves, is the responsibility of the ASSEMBLY manufacturer and shall be in agreement with the indications on the wiring diagrams and drawings. Where appropriate, identification according to IEC 60445 shall be applied.

8.6.6 Identification of the protective conductor (PE, PEN) and of the neutral conductor (N) of the main circuits

The protective conductor shall be readily distinguishable by location and/or marking or colour. If identification by colour is used, it shall only be green and yellow (twin-coloured), which is strictly reserved for the protective conductor. When the protective conductor is an insulated single-core cable, this colour identification shall be used, preferably throughout the whole length.

Any neutral conductor of the main circuit shall be readily distinguishable by location and/or marking or colour (see IEC 60445 where blue is required).

NOTE In some countries (e.g. USA, Australia, South Africa) other colours for the neutral conductor are required.

8.7 Cooling

ASSEMBLIES can be provided with natural cooling and/or active cooling (e.g. forced cooling, internal air conditioning, heat exchanger etc.). If special precautions are required at the place of installation to ensure proper cooling, the ASSEMBLY manufacturer shall furnish the necessary information (for instance indication of the need for spacing with respect to parts that are liable to impede the dissipation of heat or produce heat themselves).

8.8 Terminals for external conductors

The ASSEMBLY manufacturer shall indicate whether the terminals are suitable for connection of copper or aluminium conductors, or both. The terminals shall be such that the external conductors may be connected by a means (screws, connectors, etc.) which ensures that the necessary contact pressure corresponding to the current rating and the short-circuit strength of the apparatus and the circuit is maintained.

In the absence of a special agreement between the ASSEMBLY manufacturer and the user, terminals shall be capable of accommodating copper conductors from the smallest to the largest cross-sectional areas corresponding to the appropriate rated current (see Annex A).

Where aluminium conductors are to be terminated, the type, size and termination method of the conductors shall be as agreed between the ASSEMBLY manufacturer and the user.

In the case where external conductors for electronic circuits with low level currents and voltages (less than 1 A and less than 50 V a.c. or 120 V d.c.) have to be connected to an ASSEMBLY, Table A.1 does not apply.

The available wiring space shall permit proper connection of the external conductors of the indicated material and, in the case of multicore cables, spreading of the cores.

NOTE 1 In the United States of America (USA) and Mexico National Electrical Codes should be used for determining the minimum wire bending space requirements. In the USA NFPA 70, Article 312 is applicable. In Mexico NOM-001-SEDE is applicable. In Canada, wire space and wire bending space is prescribed in the Canadian Electrical Code, Part 2 Standard, C22.2 No. 0.12, Wire Space and Wire Bending Space in Enclosures for Equipment Rated 750 V or Less.

The conductors shall not be subjected to stresses, which are likely to reduce their normal life expectancy.

Unless otherwise agreed between the ASSEMBLY manufacturer and the user, on three-phase and neutral circuits, terminals for the neutral conductor shall allow the connection of copper conductors having a minimum cross-sectional area:

- equal to half the cross-sectional area of the phase conductor, with a minimum of 16 mm², if the size of the phase conductor exceeds 16 mm²;
- equal to the full cross-sectional area of the phase conductor, if the size of the latter is less than or equal to 16 mm².


NOTE 2 For conductors other than copper conductors, the above cross-sections should be replaced by cross-sections of equivalent conductivity, which may require larger terminals.

NOTE 3 For certain applications which lead to high values of zero sequence harmonics (e.g. 3rd order harmonics) higher cross-sections of the N conductor might be required as these harmonics of the phases are added in the N conductor and lead to high current load at higher frequencies. This is subject to special agreement between the ASSEMBLY manufacturer and the user.

If connecting facilities for incoming and outgoing neutral, protective and PEN conductors are provided; they shall be arranged in the vicinity of the associated phase conductor terminals.

NOTE 4 IEC 60204-1 requires a minimum cross-section of the conductor and does not allow the connection of PEN into the electrical equipment of the machinery.

Openings in cable entries, cover plates, etc., shall be so designed that, when the cables are properly installed, the stated protective measures against contact and degree of protection shall be obtained. This implies the selection of means of entry suitable for the application as stated by the ASSEMBLY manufacturer.

The terminals for external protective conductors shall be marked according to IEC 60445. As an example see graphical symbol  No. 5019 of IEC 60417. This symbol is not required where the external protective conductor is intended to be connected to an internal protective conductor, which is clearly identified with the colours green and yellow.

The terminals for external protective conductors (PE, PEN) and metal sheathing of connecting cables (steel conduit, lead sheath, etc.) shall, where required, be bare and, unless otherwise specified, suitable for the connection of copper conductors. A separate terminal of adequate size shall be provided for the outgoing protective conductor(s) of each circuit.

Unless otherwise agreed between the ASSEMBLY manufacturer and the user, terminals for protective conductors shall allow the connection of copper conductors having a cross-section depending on the cross-section of the corresponding phase conductors according to Table 5.

In the case of enclosures and conductors of aluminium or aluminium alloys, particular consideration shall be given to the danger of electrolytic corrosion. The connecting means to ensure the continuity of the conductive parts with external protective conductors shall have no other function.

NOTE 5 Special precautions may be necessary with metal parts of the ASSEMBLY, particularly gland plates, where abrasion resistant finishes, for example powder coatings, are used.

Identification of terminals shall comply with IEC 60445 unless otherwise stated.

9 Performance requirements

9.1 Dielectric properties

9.1.1 General

Each circuit of the ASSEMBLY shall be capable of withstanding:

- temporary overvoltages;
- transient overvoltages.

The ability to withstand temporary overvoltages, and the integrity of solid insulation, is verified by the power-frequency withstand voltage and the ability to withstand transient overvoltages is verified by the impulse withstand voltage.

9.1.2 Power-frequency withstand voltage

The circuits of the ASSEMBLY shall be capable of withstanding the appropriate power-frequency withstand voltages given in Tables 8 and 9 (see 10.9.2.1). The rated insulation voltage of any circuit of the ASSEMBLY shall be equal to or higher than its maximum operational voltage.

9.1.3 Impulse withstand voltage

9.1.3.1 Impulse withstand voltages of main circuits

Clearances from live parts to exposed conductive parts and between live parts of different potential shall be capable of withstanding the test voltage given in Table 10 appropriate to the rated impulse withstand voltage.

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

9.1.3.2 Impulse withstand voltages of auxiliary circuits

- a) Auxiliary circuits that are connected to the main circuit and operate at the rated operational voltage without any means for reduction of overvoltage shall comply with the requirements of 9.1.3.1.
- b) Auxiliary circuits that are not connected to the main circuit may have an overvoltage withstand capacity different from that of the main circuit. The clearances of such circuits – a.c. or d.c. – shall be capable of withstanding the appropriate impulse withstand voltage in accordance with Annex G.

9.1.4 Protection of surge protective devices

When overvoltage conditions require surge protective devices (SPD's) to be connected to the main circuit, such SPD's shall be protected to prevent uncontrolled short-circuit conditions as specified by the SPD manufacturer.

9.2 Temperature rise limits

The ASSEMBLY and its circuits shall be able to carry their rated currents under specified conditions (see 5.3.1, 5.3.2 and 5.3.3), taking into consideration the ratings of the components, their disposition and application, without exceeding the limits given in Table 6 when verified in accordance with 10.10. The temperature rise limits given in Table 6 apply for a mean ambient air temperature up to 35 °C.

The temperature rise of an element or part is the difference between the temperature of this element or part measured in accordance with 10.10.2.3.3 and the ambient air temperature outside the ASSEMBLY. If the mean ambient air temperature is higher than 35 °C, then the temperature rise limits have to be adapted for this special service condition, so that the sum of the ambient temperature and the individual temperature rise limit remains the same. If the mean ambient air temperature is lower than 35 °C the same adaptation of the temperature rise limits is allowed subject to agreement between the user and ASSEMBLY manufacturer.

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

NOTE 1 If the temperature rise limits have been changed to cover a different ambient temperature, then the rated current of all busbars, functional units etc. may need to be changed accordingly. The original manufacturer should state the measures to be taken, if any, to ensure compliance with the temperature limits. For ambient temperatures up to 50 °C this can be done by calculation, assuming that the over temperature of each component or device is proportional to the power loss generated in this component. There are devices where the power loss is substantially proportional to I^2 and others that have substantially fixed losses.

NOTE 2 In the United States of America (USA) and Mexico National Electrical Codes, are used to specify maximum temperature rises. In the USA, NFPA 70, Article 110.14C is applicable. In Mexico NOM-001-SEDE is applicable. For these applications, temperature rises should be selected using Annex M, Table M.1 of this standard. In Canada, maximum temperature rise is prescribed in the Canadian Electrical Code, Part 2, Product Safety Standards.

9.3 Short-circuit protection and short-circuit withstand strength

9.3.1 General

ASSEMBLIES shall be capable of withstanding the thermal and dynamic stresses resulting from short-circuit currents not exceeding the rated values.

NOTE 1 The short-circuit stresses may be reduced by the use of current-limiting devices e.g. inductance, current-limiting fuses or other current-limiting switching devices.

ASSEMBLIES shall be protected against short-circuit currents by means of, for example, circuit-breakers, fuses or combinations of both, which may either be incorporated in the ASSEMBLY or arranged outside it.

NOTE 2 For ASSEMBLIES intended for use in IT systems (see IEC 60364-5-52), the short-circuit protective device should have a sufficient breaking capacity on each single pole at line-to-line voltage to clear a double earth fault.

NOTE 3 Unless otherwise specified in the ASSEMBLY manufacturer's operating and maintenance instructions ASSEMBLIES that have been subjected to a short circuit may not be suitable for future service without inspection and/or maintenance by skilled personnel.

9.3.2 Information concerning short-circuit withstand strength

For ASSEMBLIES with a short-circuit protective device (SCPD) incorporated in the incoming unit, the ASSEMBLY manufacturer shall indicate the maximum allowable value of prospective short-circuit current at the input terminals of the ASSEMBLY. This value shall not exceed the appropriate rating(s) (see 5.3.3, 5.3.4 and 5.3.5). The corresponding power factor and peak values shall be those shown in 9.3.3.

If a circuit breaker with time-delay release is used as the short-circuit protective device, the ASSEMBLY manufacturer shall state the maximum time-delay and the current setting corresponding to the indicated prospective short-circuit current.

For ASSEMBLIES where the short-circuit protective device is not incorporated in the incoming unit, the ASSEMBLY manufacturer shall indicate the short-circuit withstand strength in one or more of the following ways:

- a) rated short-time withstand current (I_{cw}) together with the associated duration (see 5.3.4) and rated peak withstand current (I_{pk}) (see 5.3.3);
- b) rated conditional short-circuit current (I_{cc}) (see 5.3.5).

For times up to a maximum of 3 s, the relationship between the rated short-time current and the associated duration is given by the formula $I^2t = \text{constant}$, provided that the peak value does not exceed the rated peak withstand current.

The ASSEMBLY manufacturer shall indicate the characteristics of the short-circuit protective devices necessary for the protection of the ASSEMBLY.

For an ASSEMBLY having several incoming units which are unlikely to be in operation simultaneously, the short-circuit withstand strength can be indicated for each of the incoming units in accordance with the above.

For an ASSEMBLY having several incoming units which are likely to be in operation simultaneously, and for an ASSEMBLY having one incoming unit and one or more outgoing high-power units likely to contribute to the short-circuit current, it is necessary to determine the values of the prospective short-circuit current in each incoming unit, in each outgoing unit and in the busbars based on data provided by the user.

9.3.3 Relationship between peak current and short-time current

For determining the electrodynamic stresses, the value of peak current shall be obtained by multiplying the r.m.s. value of the short-circuit current by the factor n . The values for the factor n and the corresponding power factor are given in Table 7.

9.3.4 Co-ordination of protective devices

The co-ordination of protective devices within the ASSEMBLY with those to be used external to the ASSEMBLY shall be the subject of an agreement between the ASSEMBLY manufacturer and the user. Information given in the ASSEMBLY manufacturer's catalogue may take the place of such an agreement.

If the operating conditions require maximum continuity of supply, the settings or selection of the short-circuit protective devices within the ASSEMBLY should, where possible, be so co-ordinated that a short circuit occurring in any outgoing circuit is cleared by the switching device installed in the circuit without affecting the other outgoing circuits, thus ensuring selectivity of the protective system.

Where short-circuit protective devices are connected in series and are intended to operate simultaneously to reach the required short-circuit switching capability (i.e. back-up protection), the ASSEMBLY manufacturer shall inform the user (e.g. by a warning label in the ASSEMBLY or in the operating instructions, see 6.2) that none of the protective devices are allowed to be replaced by another device which is not of identical type and rating, unless the device is tested and approved in combination with the back-up device since the switching capability of the whole combination may otherwise be compromised.

9.4 Electromagnetic compatibility (EMC)

For EMC related performance requirements, see J.9.4 of Annex J.

10 Design verification

10.1 General

Design verification is intended to verify compliance of the design of an ASSEMBLY or ASSEMBLY system with the requirements of this series of standards.

Where tests on the ASSEMBLY have been conducted in accordance with the IEC 60439 series, and the test results fulfill the requirements of the relevant part of IEC 61439, the verification of these requirements need not be repeated.

Repetition of verifications in the product standards of switching devices or components incorporated in the ASSEMBLY, which have been selected in accordance with 8.5.3 and installed in accordance with the instructions of their manufacturer is not required. Tests on individual devices to their respective product standards are not an alternative to the design verifications in this standard for the ASSEMBLY.

If modifications are made to a verified ASSEMBLY, Clause 10 shall be used to check if these modifications affect the performance of the ASSEMBLY. New verifications shall be carried out if an adverse effect is likely.

The various methods include:

- verification testing;
- verification comparison with a tested reference design;
- verification assessment, i.e. confirmation of the correct application of calculations and design rules, including use of appropriate safety margins.

See Annex D.

When there is more than one method for the same verification, they are considered equivalent and the selection of the appropriate method is the responsibility of the original manufacturer.

The tests shall be performed on a representative sample of an ASSEMBLY in a clean and new condition.

The performance of the ASSEMBLY may be affected by the verification tests (e.g. short-circuit test). These tests should not be performed on an ASSEMBLY that is intended to be placed in service.

An ASSEMBLY which is verified in accordance with this standard by an original manufacturer (see 3.10.1) and manufactured or assembled by another does not require the original design verifications to be repeated if all the requirements and instructions specified and provided by the original manufacturer are met in full. Where the ASSEMBLY manufacturer incorporates their own arrangements not included in the original manufacturer's verification, the ASSEMBLY manufacturer is deemed to be the original manufacturer in respect of these arrangements.

Design verification shall comprise the following:

a) Construction:

- 10.2 Strength of materials and parts;
- 10.3 Degree of protection of enclosures;
- 10.4 Clearances and creepage distances;
- 10.5 Protection against electric shock and integrity of protective circuits;
- 10.6 Incorporation of switching devices and components;
- 10.7 Internal electrical circuits and connections;

- 10.8 Terminals for external conductors.
- b) Performance:
- 10.9 Dielectric properties;
- 10.10 Verification of temperature rise;
- 10.11 Short-circuit withstand strength;
- 10.12 Electromagnetic compatibility;
- 10.13 Mechanical operation.

The reference designs, the number of ASSEMBLIES or parts thereof used for verification, the selection of the verification method when applicable, and the order in which the verification is carried out shall be at the discretion of the original manufacturer.

The data used, calculations made and comparison undertaken for the verification of ASSEMBLIES shall be recorded in verification reports.

10.2 Strength of materials and parts

10.2.1 General

The mechanical, electrical and thermal capability of constructional materials and parts of the ASSEMBLY shall be deemed to be proven by verification of construction and performance characteristics.

Where an empty enclosure in accordance with IEC 62208 is used, and it has not been modified so as to degrade the performance of the enclosure, no repetition of the enclosure testing to 10.2 is required.

10.2.2 Resistance to corrosion

10.2.2.1 Test procedure

The resistance to corrosion of representative samples of ferrous metallic enclosures including internal and external ferrous metallic constructional parts of the ASSEMBLY shall be verified.

The test shall be carried out on:

- an enclosure or representative sample enclosure with representative internal parts in place and door(s) closed as in normal use, or
- representative enclosure parts and internal parts separately.

In all cases hinges, locks and fastenings shall also be tested unless they have previously been subjected to an equivalent test and their resistance to corrosion has not been compromised by their application.

Where the enclosure is subjected to the test it shall be mounted as for normal use according to the original manufacturer's instructions.

The test specimens shall be new and in a clean condition and shall be subjected to severity test A or B, as detailed in 10.2.2.2 and 10.2.2.3.

NOTE The salt mist test provides an atmosphere that accelerates corrosion and does not imply that the ASSEMBLY is suitable for salt laden atmosphere.

10.2.2.2 Severity test A

This test is applicable to:

- metallic indoor enclosures;

- external metallic parts of indoor ASSEMBLIES;
- internal metallic parts of indoor and outdoor ASSEMBLIES upon which intended mechanical operation may depend.

The test consists of:

6 cycles of 24 h each to damp heat cycling test according to IEC 60068-2-30 (Test Db) at $(40 \pm 3) ^\circ\text{C}$ and relative humidity of 95 %

and

2 cycles of 24 h each to salt mist test according to IEC 60068-2-11; (Test Ka: Salt mist), at a temperature of $(35 \pm 2) ^\circ\text{C}$.

10.2.2.3 Severity test B

This test is applicable to:

- metallic outdoor enclosures;
- external metallic parts of outdoor ASSEMBLIES.

The test comprises two identical 12 day periods.

Each 12 day period comprises:

5 cycles of 24 h each to damp heat cycling test according to IEC 60068-2-30 (Test Db) at $(40 \pm 3) ^\circ\text{C}$ and relative humidity of 95 %

and

7 cycles of 24 h each to salt mist test according to IEC 60068-2-11; (Test Ka: Salt mist), at a temperature of $(35 \pm 2) ^\circ\text{C}$.

10.2.2.4 Results to be obtained

After the test, the enclosure or samples shall be washed in running tap water for 5 min, rinsed in distilled or demineralized water then shaken or subjected to air blast to remove water droplets. The specimen under test shall then be stored under normal service conditions for 2 h.

Compliance is checked by visual inspection to determine that:

- there is no evidence of iron oxide, cracking or other deterioration more than that allowed by ISO 4628-3 for a degree of rusting Ri1. However surface deterioration of the protective coating is allowed. In case of doubt associated with paints and varnishes, reference shall be made to ISO 4628-3 to verify that the samples conform to the specimen Ri1;
- the mechanical integrity is not impaired;
- seals are not damaged,
- doors, hinges, locks, and fastenings work without abnormal effort.

10.2.3 Properties of insulating materials

10.2.3.1 Verification of thermal stability of enclosures

The thermal stability of enclosures manufactured from insulating material shall be verified by the dry heat test. The test shall be carried out according to IEC 60068-2-2 Test Bb, at a

temperature of 70 °C, with natural air circulation, for a duration of 168 h and with a recovery of 96 h.

Parts, intended for decorative purposes that have no technical significance shall not be considered for the purpose of this test.

The enclosure, mounted as for normal use, is 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. If the dimensions of the enclosure are too large for the available heating cabinet, the test may be carried out on a representative sample of the enclosure.

The use of an electrically heated cabinet is recommended.

Natural circulation may be provided by holes in the walls of the cabinet.

The enclosure or sample shall show no crack visible to normal or corrected vision without additional magnification 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 is pressed with a force of 5 N.

NOTE The force of 5 N can be obtained in the following way: the enclosure or 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 traces of the cloth shall remain on the sample and the material of the enclosure or sample shall not stick to the cloth.

10.2.3.2 Verification of resistance of insulating materials to abnormal heat and fire due to internal electric effects

The glow-wire test principles of IEC 60695-2-10 and the details given in IEC 60695-2-11 shall be used to verify the suitability of materials used:

- a) on parts of ASSEMBLIES, or
- b) on parts taken from these parts.

The test shall be carried out on material with the minimum thickness used for the parts in a) or b).

If an identical material having representative cross-sections as the parts has already satisfied the requirements of 8.1.3.2.3 then the test need not be repeated. It is the same for all parts which have been previously tested according to their own specifications.

For a description of the test, see Clause 4 of IEC 60695-2-11:2000. The apparatus to be used shall be as described in Clause 5 of IEC 60695-2-11:2000.

The temperature of the tip of the glow-wire shall be as follows:

- 960 °C for parts necessary to retain current-carrying parts in position;
- 850 °C for enclosures intended for mounting in hollow walls;
- 650 °C for all other parts, including parts necessary to retain the protective conductor.

As an alternative the original manufacturer shall provide data on the suitability of materials from the insulating material supplier to demonstrate compliance with the requirements of 8.1.3.2.3.

10.2.4 Resistance to ultra-violet (UV) radiation

This test applies only to enclosures and external parts of ASSEMBLIES intended to be installed outdoors and which are constructed of insulating materials or metals that are entirely coated by synthetic material. Representative samples of such parts shall be subjected to the following test:

UV test according to ISO 4892-2 Method A, Cycle 1 providing a total test period of 500 h. For enclosures constructed of insulating materials compliance is checked by verification that the flexural strength (according to ISO 178) and Charpy impact (according to ISO 179) of insulating materials have 70 % minimum retention.

The test shall be made on six test specimens of standard size according to ISO 178 and on six test specimens of standard size according to ISO 179. The test specimens shall be made under the same conditions as those used for the manufacture of the enclosure concerned.

For the test carried out in accordance with ISO 178, the surface of the sample exposed to UV shall be turned face down and the pressure applied to the non exposed surface.

For the test carried out in accordance with ISO 179 for materials whose impact bending strength cannot be determined prior to exposure because no rupture has occurred, not more than three of the exposed test specimens shall be allowed to break.

For compliance, enclosures constructed of metals entirely coated by synthetic material, the adherence of the synthetic material shall have a minimum retention of category 3 according to ISO 2409.

Samples shall not show cracks or deterioration visible to normal or corrected vision without additional magnification.

This test need not be carried out if the original manufacturer can provide data from the material supplier to demonstrate that material of the same type and thickness or thinner complies with this requirement.

10.2.5 Lifting

For ASSEMBLIES with provision for lifting means compliance is verified by the following tests.

The maximum number of sections allowed by the original manufacturer to be lifted together shall be equipped with components and/or weights to achieve a weight of 1,25 times its maximum shipping weight. With doors closed it shall be lifted with the specified lifting means and in the manner defined by the original manufacturer.

From a standstill position, the ASSEMBLY shall be raised smoothly without jerking in a vertical plane to a height of ≥ 1 m and lowered in the same manner to a standstill position. This test is repeated a further two times after which the ASSEMBLY is raised up and suspended clear of the floor for 30 min without any movement.

Following this test the ASSEMBLY shall be raised smoothly without jerking from a standstill position to a height of ≥ 1 m and moved $(10 \pm 0,5)$ m horizontally, then lowered to a standstill position. This sequence, shall be carried out three times at uniform speed, each sequence being carried out within 1 min.

After the test, with the test weights in place, the ASSEMBLY shall show no cracks or permanent distortions visible to normal or corrected vision without additional magnification, which could impair any of its characteristics.

10.2.6 Mechanical impact

Mechanical impact tests where required by the specific ASSEMBLY standard are to be carried out in accordance with IEC 62262.

10.2.7 Marking

Marking made by moulding, pressing, engraving or similar, including labels with a laminated plastic covering, shall not be submitted to the following test.

The test is made by rubbing the marking by hand for 15 s with a piece of cloth soaked in water and then for 15 s with a piece of cloth soaked with petroleum spirit.

NOTE The petroleum spirit is defined as a solvent hexane with a content of aromatics of maximum 0,1 % in volume, a kauributanol value of 29, an initial boiling point of 65 °C, a final boiling point of 69 °C and a density of approximately 0,68 g/cm³.

After the test the marking shall be legible to normal or corrected vision without additional magnification.

10.3 Degree of protection of ASSEMBLIES

The degree of protection provided in accordance with 8.2.2, 8.2.3 and 8.4.2.3 shall be verified in accordance with IEC 60529; the test may be carried out on one representative equipped ASSEMBLY in a condition stated by the original manufacturer. Where an empty enclosure in accordance with IEC 62208 is used, a verification assessment shall be performed to ensure that any external modification that has been carried out does not result in a deterioration of the degree of protection. In this case no further testing is required.

IP tests shall be carried out:

- with all covers and doors in place and closed as in normal service;
- in a de-energised state unless stated otherwise by the original manufacturer.

ASSEMBLIES having a degree of protection of IP 5X shall be tested according to category 2 in 13.4 of IEC 60529:1989.

ASSEMBLIES having a degree of protection of IP 6X shall be tested according to category 1 in 13.4 of IEC 60529:1989.

The test device for IP X3 and IP X4 as well as the type of support for the enclosure during the IP X4 test shall be stated in the test report.

The IP X1 test may be carried out by moving the drip box instead of rotating the ASSEMBLY.

Ingress of water in the IP X1 to IP X6 tests on an ASSEMBLY is permissible only if its route of entry is obvious and the water is only in contact with the enclosure at a location where it will not impair safety.

The IP 5X test is deemed to be a failure if harmful amount of dust is visible on electrical equipment housed within the enclosure.

10.4 Clearances and creepage distances

It shall be verified that the clearances and creepage distances comply with the requirements of 8.3.

The clearances and creepage distances shall be measured in accordance with Annex F.

10.5 Protection against electric shock and integrity of protective circuits

10.5.1 Effectiveness of the protective circuit

The effectiveness of protective circuit is verified for the following functions:

- a) protection against the consequences of a fault within the ASSEMBLY (internal faults) as outlined in 10.5.2, and
- b) protection against the consequences of faults in external circuits supplied through the ASSEMBLY (external faults) as outlined in 10.5.3.

10.5.2 Effective earth continuity between the exposed conductive parts of the ASSEMBLY and the protective circuit

It shall be verified that the different exposed conductive parts of the ASSEMBLY are effectively connected to the terminal for the incoming external protective conductor and that the resistance of the circuit does not exceed 0,1 Ω .

Verification shall be made using a resistance measuring instrument which is capable of driving a current of at least 10 A (a.c. or d.c.). The current is passed between each exposed conductive part and the terminal for the external protective conductor. The resistance shall not exceed 0,1 Ω .

NOTE It is recommended to limit the duration of the test where low-current equipment otherwise may be adversely affected by the test.

10.5.3 Short-circuit withstand strength of the protective circuit

10.5.3.1 General

The rated short-circuit withstand strength shall be verified. Verification may be by comparison with a reference design or by test as detailed in 10.5.3.3 to 10.5.3.5.

The original manufacturer shall determine the reference design(s) that will be used in 10.5.3.3 and 10.5.3.4.

10.5.3.2 Protective circuits that are exempted from short-circuit withstand verification

Where a separate protective conductor is provided in accordance with 8.4.3.2.3, short-circuit testing is not required if one of the conditions of 10.11.2. is fulfilled.

10.5.3.3 Verification by comparison with a reference design – Utilising a check list

Verification is achieved when comparison of the ASSEMBLY to be verified with an already tested design utilising items 1 to 6 and 8 to 10 of the check list in Table 13 shows no deviations.

To ensure the same current carrying capacity for that portion of the fault current that flows through the exposed conductive parts, the design, number and arrangement of the parts that provide contact between the protective conductor and the exposed conductive parts, shall be the same as in the tested reference design.

10.5.3.4 Verification by comparison with a reference design – Utilising calculation

Verification by comparison with a reference design based on calculation is to be in accordance with 10.11.4

To ensure the same current carrying capacity for that portion of the fault current that flows through the exposed conductive parts, the design, number and arrangement of the parts that

provide contact between the protective conductor and the exposed conductive parts, shall be the same as in the tested reference design.

10.5.3.5 Verification by test

Subclause 10.11.5.6 applies.

10.6 Incorporation of switching devices and components

10.6.1 General

Compliance with the design requirements of 8.5 for the incorporation of switching devices and components shall be confirmed by the original manufacturer's inspection.

10.6.2 Electromagnetic compatibility

The performance requirements of J.9.4 for electromagnetic compatibility shall be confirmed by inspection or where necessary by test (see J.10.12).

10.7 Internal electrical circuits and connections

Compliance with the design requirements of 8.6 for internal electrical circuits and connections shall be confirmed by the original manufacturer's inspection.

10.8 Terminals for external conductors

Compliance with the design requirements of 8.8 for terminals for external conductors shall be confirmed by the original manufacturer's inspection.

10.9 Dielectric properties

10.9.1 General

For this test, all the electrical equipment of the ASSEMBLY shall be connected, except those items of apparatus which, according to the relevant specifications, are designed for a lower test voltage; current-consuming apparatus (e.g. windings, measuring instruments, voltage surge suppression devices) in which the application of the test voltage would cause the flow of a current, shall be disconnected. Such apparatus shall be disconnected at one of their terminals unless they are not designed to withstand the full test voltage, in which case all terminals may be disconnected.

For test voltage tolerances and the selection of test equipment, see IEC 61180.

10.9.2 Power-frequency withstand voltage

10.9.2.1 Main, auxiliary and control circuits

Main circuits as well as auxiliary and control circuits that are connected to the main circuit shall be subjected to the test voltage according to Table 8.

Auxiliary and control circuits, whether a.c. or d.c., that are not connected to the main circuit shall be subjected to the test voltage according to Table 9.

10.9.2.2 Test voltage

The test voltage shall have a substantially 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 that specified in Table 8 or 9 as appropriate with a permitted tolerance of $\pm 3\%$.

10.9.2.3 Application of the test voltage

The power frequency voltage at the moment of application shall not exceed 50 % of the full test value. It shall then be increased progressively to this full value and maintained for $5 \left(\begin{smallmatrix} +2 \\ 0 \end{smallmatrix} \right)$ s as follows:

- a) between all live parts of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and exposed conductive parts, with the main contacts of all switching devices in the closed position or bridged by a suitable low resistance link;
- b) between each live part of different potential of the main circuit and, the other live parts of different potential and exposed conductive parts connected together, with the main contacts of all switching devices in the closed position or bridged by a suitable low resistance link;
- c) between each control and auxiliary circuit not normally connected to the main circuit and the
 - main circuit;
 - other circuits;
 - exposed conductive parts.

10.9.2.4 Acceptance criteria

The overcurrent relay shall not operate and there shall be no disruptive discharge (see 3.6.17) during the tests.

10.9.3 Impulse withstand voltage

10.9.3.1 General

Verification shall be made by test or by assessment.

In place of the impulse withstand voltage test the original manufacturer may perform, at his discretion, an equivalent a.c. or d.c. voltage test, in accordance with 10.9.3.3 or 10.9.3.4.

10.9.3.2 Impulse withstand voltage test

The impulse voltage generator shall be adjusted to the required impulse voltage with the ASSEMBLY connected. The value of the test voltage shall be that specified in 9.1.3. The accuracy of the applied peak voltage shall be $\pm 3\%$.

Auxiliary circuits not connected to main circuits shall be connected to earth. The 1,2/50 μ s impulse voltage shall be applied to the ASSEMBLY five times for each polarity at intervals of 1 s minimum as follows:

- a) between all the live parts of different potential of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and exposed conductive parts, with the main contacts of all switching devices in the closed position or bridged by a suitable low resistance link;

- b) between each live part of different potential of the main circuit and, the other live parts of different potential and exposed conductive parts connected together, with the main contacts of all switching devices in the closed position or bridged by a suitable low resistance link.
- c) between each control and auxiliary circuit not normally connected to the main circuit and the
 - main circuit;
 - other circuits;
 - exposed conductive parts.

For an acceptable result there shall be no disruptive discharge during the tests.

10.9.3.3 Alternative power-frequency voltage test

The test voltage shall have a substantially 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 that specified in 9.1.3 and Table 10 as appropriate with a permitted tolerance of $\pm 3\%$.

The power-frequency voltage shall be applied once, at full value, for a duration sufficient for the magnitude to be ascertained, but it shall not be less than 15 ms.

It shall be applied to the ASSEMBLY in the manner described in 10.9.3.2. a) b) and c) above.

For an acceptable result the overcurrent relay shall not operate and there shall be no disruptive discharge during the tests.

10.9.3.4 Alternative d.c. voltage test

The test voltage shall have negligible ripple.

The high-voltage source 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 that specified in 9.1.3 and Table 10 as appropriate with a permitted tolerance of $\pm 3\%$.

The d.c. voltage shall be applied once for each polarity for a duration sufficient for the magnitude to be ascertained, but it shall not be less than 15 ms or greater than 100 ms.

It shall be applied to the ASSEMBLY in the manner of 10.9.3.2. a) and b) above.

For an acceptable result the overcurrent relay shall not operate and there shall be no disruptive discharge during the tests.

10.9.3.5 Verification assessment

Clearances shall be verified by measurement, or verification of measurements on design drawings, employing the measurement methods stated in Annex F. The clearances shall be at least 1,5 times the values specified in Table 1.

NOTE The 1,5 factor to values in Table 1 is applied to avoid impulse withstand voltage tests for design verification. It is a safety factor that takes into consideration manufacturing tolerances.

It shall be verified by assessment of the device manufacturer's data that all incorporated devices are suitable for the specified rated impulse withstand voltage (U_{imp}).

10.9.4 Testing of enclosures made of insulating material

For ASSEMBLIES with enclosures made of insulating material, an additional dielectric test shall be carried out by applying an a.c. test voltage between a metal foil laid on the outside of the enclosure over openings and joints, and the interconnected live and exposed conductive parts within the ASSEMBLY located next to the openings and joints. For this additional test, the test voltage shall be equal to 1,5 times the values indicated in Table 8.

10.9.5 External operating handles of insulating material

In the case of handles made of or covered by insulating material, a dielectric test shall be carried out by applying a test voltage equal to 1,5 times the test voltage indicated in Table 8 between the live parts and a metal foil wrapped round the whole surface of the handle. During this test, the exposed conductive parts shall not be earthed or connected to any other circuit.

10.10 Verification of temperature rise

10.10.1 General

It shall be verified that the temperature-rise limits specified in 9.2 for the different parts of the ASSEMBLY or ASSEMBLY system will not be exceeded.

Verification shall be made by one or more of the following methods (see Annex O for guidance):

- testing (10.10.2);
- derivation (from a tested design) of ratings for similar variants (10.10.3);
- calculation for a single compartment ASSEMBLY not exceeding 630 A according to 10.10.4.2 or for ASSEMBLIES not exceeding 1600 A according to 10.10.4.3.

In ASSEMBLIES rated for frequencies above 60 Hz verification of temperature rise by test (10.10.2) or by derivation from a similar design tested at the same intended frequency (10.10.3) is always required.

The current carrying capability of the circuits to be verified is determined by the rated current (see 5.3.2) and the RDF (see 5.4).

10.10.2 Verification by testing

10.10.2.1 General

Verification by test comprises the following:

- If the ASSEMBLY system to be verified comprises a number of variants, the most onerous arrangement(s) of the ASSEMBLY system shall be selected according to 10.10.2.2.
- The ASSEMBLY variant(s) selected shall be verified by one of the following methods (see Annex O):

- 1) considering individual functional units, the main and distribution busbars and the ASSEMBLY collectively according to 10.10.2.3.5;
 - 2) considering individual functional units separately and the complete ASSEMBLY including the main and distribution busbars according to 10.10.2.3.6;
 - 3) considering individual functional units and the main and distribution busbars separately as well as the complete ASSEMBLY according to 10.10.2.3.7.
- c) When the ASSEMBLY variant(s) tested are the most onerous variants out of an ASSEMBLY system then the test results can be used to establish the ratings of similar variants without further testing. Rules for such derivations are given in 10.10.3.

10.10.2.2 Selection of the representative arrangement

10.10.2.2.1 General

The test shall be made on one or more representative arrangements loaded with one or more representative load combinations chosen to obtain with reasonable accuracy the highest possible temperature rise.

The selection of the representative arrangements to be tested is given in 10.10.2.2.2 and 10.10.2.2.3 and is the responsibility of the original manufacturer. The original manufacturer shall take into consideration in his selection for test, the configurations to be derived from the tested arrangements according to 10.10.3.

10.10.2.2.2 Busbars

For busbar systems consisting of single or multiple rectangular sections of conductor, where the variants differ only in the reduction of one or more of

- height,
- thickness,
- quantity of bars per conductor,

and have the same

- arrangement of bars,
- center line spacing of conductors,
- enclosure and
- busbar compartment (if any),

the busbars with the greatest cross-sectional area shall be selected as the representative arrangement as a minimum for the test. For ratings of smaller busbar size variants or other materials see 10.10.3.3.

10.10.2.2.3 Functional units

a) Selection of comparable functional unit groups

Functional units intended to be used at different rated currents can be considered to have a similar thermal behaviour and form a comparable range of units, if they fulfil the following conditions:

- 1) the function and basic wiring diagram of the main circuit is the same (e.g. incoming unit, reversing starter, cable feeder);
- 2) the devices are of the same frame size and belong to the same series;
- 3) the mounting structure is of the same type;
- 4) the mutual arrangement of the devices is the same;
- 5) the type and arrangement of conductors is the same;

- 6) the cross-section of the main circuit conductors within a functional unit shall have a rating at least equal to that of the lowest rated device in the circuit. Selection of cables shall be as tested or in accordance with IEC 60364-5-52. Examples on how to adapt this standard for conditions inside an ASSEMBLY are given in the tables included in Annex H. The cross-section of bars shall be as tested or as given in Annex N.

b) Selection of a critical variant out of each comparable group as a specimen for test

For the critical variant the most onerous compartment (where applicable) and enclosure conditions (with respect to shape, size, design of partitions and enclosure ventilation) shall be tested.

The maximum possible current rating for each variant of functional unit is established. For functional units containing only one device this is the rated current of the device. For functional units with several devices, it is that of the device with the lowest rated current. If a combination of devices connected in series is intended to be used at a lower current (e.g. motor starter combination), this lower current shall be used.

For each functional unit the power loss is calculated at the maximum possible current using the data given by the device manufacturer for each device together with the power losses of the associated conductors.

For functional units with currents up to and including 630 A, the critical unit in each range is the functional unit with the highest total power loss.

For functional units with currents above 630 A the critical unit in each range is that which has the highest rated current. This ensures that additional thermal effects relating to eddy currents and current displacement are taken into consideration.

The critical functional unit shall at least be tested:

- inside the smallest compartment (if any) which is intended for this functional unit; and
- with the worst variant of internal separation (if any) with respect to size of ventilation openings; and
- with the enclosure with the highest installed power loss per volume; and
- with the worst variant of ventilation of the enclosure with respect to the kind of ventilation (natural or forced convection) and size of ventilation openings.

If the functional unit can be arranged in different orientations (horizontal, vertical), then the most onerous arrangement shall be tested.

NOTE Additional test may be made on the discretion of the original manufacturer for less critical arrangements and variants of functional units.

10.10.2.3 Methods of test

10.10.2.3.1 General

In 10.10.2.3.5 to 10.10.2.3.7 three methods for test are given, which differ in the number of tests needed and in the range of applicability of the test results, an explanation is provided in Annex O.

The temperature-rise test on the individual circuits shall be made with the type of current for which they are intended, and at the design frequency. Any convenient value of the test voltage may be used to produce the desired current. Coils of relays, contactors, releases, etc., shall be supplied with rated operational voltage.

The ASSEMBLY shall be mounted as in normal use, with all covers including bottom cover plates, etc., in place.

If the ASSEMBLY includes fuses, these shall be fitted for the test with fuse-links as specified by the manufacturer. The power losses of the fuse-links used for the test shall be stated in the test report. Fuse-link power loss may be determined by measurement or alternatively as declared by the fuse-link manufacturer.

The size and the disposition of external conductors used for the test shall be stated in the test report.

The test shall be made for a time sufficient for the temperature rise to reach a constant value. In practice, this condition is reached when the variation at all measured points (including the ambient air temperature) does not exceed 1 K/h.

To shorten the test, if the devices allow it, the current may be increased during the first part of the test, it being reduced to the specified test current afterwards.

When a control electro-magnet is energized during the test, the temperature is measured when thermal equilibrium is reached in both the main circuit and the control electro-magnet.

The average value of the actual incoming test currents shall be between -0 % and +3 % of the intended value. Each phase shall be within ± 5 % of the intended value.

Tests on an individual section of the ASSEMBLY are acceptable. To make the test representative the external surfaces at which additional sections may be connected shall be thermally insulated with a covering to prevent any undue cooling.

When testing individual functional units within a section or a complete ASSEMBLY, the adjacent functional units can be replaced by heating resistors if the rating of each does not exceed 630 A and their rating is not to be verified with this test.

In ASSEMBLIES where there is a possibility that additional control circuits or devices may be incorporated, heating resistors shall simulate the power dissipation of these additional items.

10.10.2.3.2 Test conductors

In the absence of detailed information concerning the external conductors and the service conditions, the cross-section of the external test conductors shall be chosen considering the rated current of each circuit as follows:

a) For values of rated current up to and including 400 A:

- 1) the conductors shall be single-core, copper cables or insulated wires with cross-sectional areas as given in Table 11;
- 2) as far as practicable, the conductors shall be in free air;
- 3) the minimum length of each temporary connection from terminal to terminal shall be:
 - 1 m for cross-sections up to and including 35 mm²;
 - 2 m for cross-sections larger than 35 mm².

b) For values of rated current higher than 400 A but not exceeding 800 A:

- 1) The conductors shall be single-core copper cables with cross-sectional areas as given in Table 12, or the equivalent copper bars given in Table 12 as specified by the original manufacturer.
- 2) Cables or copper bars shall be spaced at approximately the distance between terminals. Multiple parallel cables per terminal shall be bunched together and arranged with approximately 10 mm air space between each other. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals or are not available, it is allowed to use other bars having the same cross-sectional dimensions ± 10 % and the same or smaller cooling surfaces. Cables or copper bars shall not be interleaved.

- 3) For single-phase or multi-phase tests, the minimum length of any temporary connection to the test supply shall be 2 m. The minimum length to a star point may be reduced to 1,2 m where agreed by the original manufacturer.
- c) **For values of rated current higher than 800 A but not exceeding 4 000 A:**
- 1) The conductors shall be copper bars of the sizes stated in Table 12 unless the ASSEMBLY is designed only for cable connection. In this case, the size and arrangement of the cables shall be as specified by the original manufacturer.
 - 2) Copper bars shall be spaced at approximately the distance between terminals. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals or are not available, it is allowed to use other bars having the same cross-sectional dimensions $\pm 10\%$ and the same or smaller cooling surfaces. Copper bars shall not be interleaved.
 - 3) For single-phase or multi-phase tests, the minimum length of any temporary connection to the test supply shall be 3 m, but this can be reduced to 2 m provided that the temperature rise at the supply end of the connection is not more than 5 K below the temperature rise in the middle of the connection length. The minimum length to a star point shall be 2 m.
- d) **For values of rated current higher than 4 000 A:**
- The original manufacturer shall determine all relevant items of the test, such as type of supply, number of phases and frequency (where applicable), cross-sections of test conductors, etc. This information shall form part of the test report.

10.10.2.3.3 Measurement of temperatures

Thermocouples or thermometers shall be used for temperature measurements. For windings, the method of measuring the temperature by resistance variation shall generally be used.

The thermometers or thermocouples shall be protected against air currents and heat radiation.

The temperature shall be measured at all points where a temperature-rise limit (see 9.2) must be observed. Particular attention shall be given to joints in conductors and terminals within the main circuits. For measurement of the temperature of air inside an ASSEMBLY, several measuring devices shall be arranged in convenient places.

10.10.2.3.4 Ambient air temperature

The ambient air temperature shall be measured by means of at least two thermometers or thermocouples equally distributed around the ASSEMBLY at approximately half its height and at a distance of approximately 1 m from the ASSEMBLY. The thermometers or thermocouples shall be protected against air currents and heat radiation.

The ambient temperature during the test shall be between $+10\text{ }^{\circ}\text{C}$ and $+40\text{ }^{\circ}\text{C}$.

10.10.2.3.5 Verification of the complete ASSEMBLY

Incoming and outgoing circuits of the ASSEMBLY shall be loaded with their rated currents (see 5.3.2) being equivalent to a rated diversity factor of 1 (see 5.4 and Annex O).

If the rated current of the incoming circuit or distribution busbar system is less than the sum of the rated currents of all outgoing circuits, then the outgoing circuits shall be split into groups corresponding to the rated current of the incoming circuit or distribution busbar system. The groups shall be formed in a manner so that the highest possible temperature rise is obtained. Sufficient groups shall be formed and tests undertaken so as to include all different variants of functional units in at least one group.

Where the fully loaded circuits do not distribute exactly the total incoming current, the remaining current shall be distributed via any other appropriate circuit. This test shall be repeated until all types of outgoing circuit have been verified at their rated current.

Change in the arrangement of functional units within a verified ASSEMBLY, or section of an ASSEMBLY may necessitate additional tests as the thermal influence of the adjacent units may differ significantly.

NOTE 10.10.2.3.6 provides a means of testing an ASSEMBLY with diversity factor less than one and fewer tests than specified in 10.10.2.3.7.

10.10.2.3.6 Verification considering individual functional units separately and the complete ASSEMBLY

The rated currents of the circuits according to 5.3.2 and the rated diversity factor according to 5.4 shall be verified in two stages.

The rated current of each critical variant functional unit (10.10.2.2.3.b)) shall be verified separately in accordance with 10.10.2.3.7 c).

The ASSEMBLY is verified by loading the incoming circuit to its rated current and all outgoing functional units collectively to their rated current multiplied by the diversity factor.

If the rated current of the incoming circuit or distribution busbar system is less than the sum of the test currents of all outgoing circuits (i.e. the rated currents multiplied by the diversity factor), then the outgoing circuits shall be split into groups corresponding to the rated current of the incoming circuit or distribution busbar system. The groups shall be formed in a manner so that the highest possible temperature rise is obtained. Sufficient groups shall be formed and tests undertaken so as to include all different variants of functional units in at least one group.

Where the fully loaded circuits do not distribute exactly the total incoming current, the remaining current shall be distributed via any other appropriate circuit. This test shall be repeated until all types of outgoing circuit have been verified at their test current.

Change in the arrangement of functional units within a verified ASSEMBLY, or section of an ASSEMBLY may necessitate additional tests as the thermal influence of the adjacent units may differ significantly.

10.10.2.3.7 Verification considering individual functional units and the main and distribution busbars separately as well as the complete ASSEMBLY

ASSEMBLIES shall be verified by separate verification of standard elements a) to c) as selected in accordance with 10.10.2.2 and 10.10.2.2.3, and verification of a complete ASSEMBLY d) under worst case conditions as detailed below:

- a) Main busbars shall be tested separately. They shall be mounted in the ASSEMBLY enclosure as in normal use with all covers and all partitions that separate the main busbars from other compartments, in place. If the main busbar has joints, then they shall be included in the test. The test shall be carried out at rated current. The test current shall pass through the full length of the busbars. Where the design of the ASSEMBLY permits, and, to minimise the influence of the external test conductors on the temperature rise, the length of the main busbar within the enclosure for the test shall be a minimum of 2 m and include a minimum of one joint when the busbars are extendable.
- b) Distribution busbars shall be tested separately from the outgoing units. They shall be mounted in the enclosure as in normal use with all covers and all partitions that separate the busbar from other compartments, in place. Distribution busbars shall be connected to the main busbar. No other conductors, e.g. connections to functional units, shall be connected to the distribution busbar. In order to consider the most onerous condition, the test shall be carried out at rated current and the test current shall pass through the full

length of the distribution busbar. If the main busbar is rated for a higher current, it shall be fed with additional current so that it carries its rated current to its junction with the distribution busbar.

- c) Functional units shall be tested individually. The functional unit shall be mounted in the enclosure as in normal use with all covers and all internal partitions in place. If it can be mounted at different places the most unfavourable place shall be used. It shall be connected to the main or the distribution busbar as in normal use. If the main busbar and/or the distribution busbar (if any) are rated for a higher current, they shall be fed with additional currents so that they carry their individual rated currents to the respective junction points. The test shall be carried out at rated current for the functional unit.
- d) The complete ASSEMBLY shall be verified by temperature rise testing of the most onerous arrangement(s) possible in service and as defined by the original manufacturer. For this test the incoming circuit is loaded to its rated current and each outgoing functional unit to its rated current multiplied by the rated diversity factor. If the rated current of the incoming circuit or distribution busbar system is less than the sum of the test currents of all outgoing circuits (i.e. the rated currents multiplied by the diversity factor), then the outgoing circuits shall be split into groups corresponding to the rated current of the incoming circuit or distribution busbar system. The groups shall be formed in a manner so that the highest possible temperature rise is obtained. Sufficient groups shall be formed and tests undertaken so as to include all different variants of functional units in at least one group.

10.10.2.3.8 Results to be obtained

At the end of the test, the temperature rise shall not exceed the values specified in Table 6. The apparatus shall operate satisfactorily within the voltage limits specified for them at the temperature inside the ASSEMBLY.

10.10.3 Derivation of ratings for similar variants

10.10.3.1 General

The following sub-clauses define how the rated currents of variants can be verified by derivation from similar arrangements verified by test.

Temperature-rise tests on the circuit(s) carried out at 50 Hz are applicable to 60 Hz for rated currents up to and including 800 A. In the absence of tests at 60 Hz for currents above 800 A, the rated current at 60 Hz shall be reduced to 95 % of that at 50 Hz. Alternatively, where the maximum temperature rise at 50 Hz does not exceed 90 % of the permissible value, then derating for 60 Hz is not required. Tests carried out at a particular frequency are applicable at the same current rating to lower frequencies including d.c.

10.10.3.2 ASSEMBLIES

ASSEMBLIES verified by derivation from a similar tested arrangement shall comply with the following:

- a) the functional units shall belong to the same group as the functional unit selected for test (see 10.10.2.2.3);
- b) the same type of construction as used for the test;
- c) the same or increased overall dimensions as used for the test;
- d) the same or increased cooling conditions as used for the test (forced or natural convection, same or larger ventilation openings);
- e) the same or reduced internal separation as used for the test (if any);
- f) the same or reduced power losses in the same section as used for the test.

The ASSEMBLY being verified may comprise all or only part of the electrical circuits of the ASSEMBLY previously verified. Alternative arrangement(s) of functional units within the

ASSEMBLY or section compared to the tested variant is allowed as long as the thermal influences of the adjacent units are not more severe.

Thermal tests performed on 3-phase, 3-wire ASSEMBLIES are considered as representing 3-phase, 4-wire and single-phase, 2-wire or 3-wire ASSEMBLIES, provided that the neutral conductor is sized equal to or greater than the phase conductors arranged in the same manner.

10.10.3.3 Busbars

Ratings established for aluminium busbars are valid for copper busbars with the same cross sectional dimensions and configuration. However, ratings established for copper busbars shall not be used to establish ratings of aluminium busbars.

The ratings of variants not selected for test according to 10.10.2.2.2 shall be determined by multiplying their cross-section with the current density of a larger cross-section busbar of the same design that has been verified by test.

If additionally a smaller cross-section than the one to be derived has been tested, which also fulfils the conditions of 10.10.2.2.2, then the rating of the intermediate variants may be established by interpolation.

10.10.3.4 Functional units

After the critical variant of each group of comparable functional units (see 10.10.2.2.3 a)) has been subjected to a test for verification of temperature rise, the actual rated currents of all other functional units in the group shall be calculated using the results of these tests.

For each functional unit tested a de-rating factor (rated current, resulting from the test divided by the maximum possible current of this functional unit, see 10.10.2.2.3 b)) shall be calculated.

The rated current of each non-tested functional unit in the range shall be the maximum possible current of the functional unit multiplied by the de-rating factor established for the variant tested in the range.

10.10.3.5 Functional units – Device substitution

A device may be substituted with a similar device from another series to that used in the original verification, provided that the power loss and terminal temperature rise of the device, when tested in accordance with its product standard, is the same or lower. In addition, the physical arrangement within the functional unit and the rating of the functional unit shall be maintained.

NOTE In addition to temperature rise other requirements are considered including the short-circuit requirements, see Table 13.

10.10.4 Verification assessment

10.10.4.1 General

Two calculation methods are provided. Both determine the approximate air temperature rise inside the enclosure, which is caused by the power losses of all circuits, and compare this temperature with the limits for the installed equipment. The methods differ only in the way the relationship between the delivered power loss and the air temperature rise inside the enclosure is ascertained.

Because the actual local temperatures of the current-carrying parts cannot be calculated by these methods, some limits and safety margins are necessary and are included.

10.10.4.2 Single compartment assembly with rated current not exceeding 630 A

10.10.4.2.1 Verification method

Verification of the temperature rise of a single compartment ASSEMBLY with the total supply current not exceeding 630 A and for rated frequencies up to and including 60 Hz may be made by calculation if all the following conditions are fulfilled:

- a) the power loss data for all built-in components is available from the component manufacturer;
- b) there is an approximately even distribution of power losses inside the enclosure;
- c) the rated current of the circuits of the ASSEMBLY to be verified (see 10.10.1) shall not exceed 80 % of the rated conventional free air thermal current (I_{th}) if any, or the rated current (I_n) of the switching devices and electrical components included in the circuit. Circuit protection devices shall be selected to ensure adequate protection to outgoing circuits, e.g. thermal motor protection devices at the calculated temperature in the ASSEMBLY;

NOTE 1 There is no common characteristic for switching devices and electrical components that describes the value of current to be used here. For the purpose of verifying the temperature rise limits the value of current is used, which describes the maximum continuous operational current that can be carried without overheating. This is e.g. for contactors the rated operational current I_e AC1 and for circuit breakers the rated current I_n .

- d) the mechanical parts and the installed equipment are so arranged that air circulation is not significantly impeded;
- e) conductors carrying currents in excess of 200 A, and the adjacent structural parts are so arranged that eddy-current and hysteresis losses are minimised;
- f) all conductors shall have a minimum cross-sectional area based on 125 % of the permitted current rating of the associated circuit. Selection of cables shall be in accordance with IEC 60364-5-52. Examples on how to adapt this standard for conditions inside an ASSEMBLY are given in Annex H. The cross-section of bars shall be as tested or as given in Annex N. Where the device manufacturer specifies a conductor with a larger cross-sectional area this shall be used;
- g) the temperature rise depending on the power loss installed in the enclosure for the different installation methods (e.g. flush mounting, surface mounting), is:
 - available from the enclosure manufacturer;
 - determined in accordance with 10.10.4.2.2; or
 - in accordance with performance and installation criteria from the cooling equipment manufacturer when active cooling (e.g. forced cooling, internal air conditioning, heat exchanger etc.) is incorporated.

The effective power losses of all circuits including interconnecting conductors shall be calculated based on rated current of the circuits. The total power loss of the ASSEMBLY is calculated by adding the power losses of the circuits taking additionally into account that the total load current is limited to the rated current of the ASSEMBLY. The power losses of the conductors are determined by calculation (see Annex H).

NOTE 2 There are devices where the power loss is substantially proportional to I^2 and others that have substantially fixed losses.

NOTE 3 Example: A single compartment ASSEMBLY with a rated current of 100 A (limited by the distribution bars) is equipped with 20 outgoing circuits. The assumed rated current for each circuit is 8 A. The total effective power loss should be calculated for 12 outgoing circuits loaded with 8 A each.

The temperature rise within the ASSEMBLY is then determined from the total power loss using the data mentioned in g).

10.10.4.2.2 Determination of the power loss capability of an enclosure by test

The power loss shall be simulated by means of heating resistors that produce heat equivalent to the intended power loss capability of the enclosure. The heating resistors shall be

distributed evenly over the height of the enclosure and installed in suitable places inside the enclosure.

The cross-section of the leads to these resistors shall be such that no appreciable amount of heat is conducted away from the enclosure.

The test shall be carried out in accordance with 10.10.2.3.1 to 10.10.2.3.4 and the air temperature rise shall be measured in the top of the enclosure. Enclosure temperatures shall not exceed the values given in Table 6.

10.10.4.2.3 Results to be obtained

The ASSEMBLY is verified if the air temperature determined from the calculated power loss does not exceed the permissible operating air temperature as declared by the device manufacturer. This means for switching devices or electrical components in the main circuits that the continuous load does not exceed its permissible load at the calculated air temperature and not more than 80 % of its rated current (see 10.10.4.2.1 c).

10.10.4.3 ASSEMBLY with rated current not exceeding 1 600 A

10.10.4.3.1 Verification method

Verification of the temperature-rise of a single or multiple compartment ASSEMBLY with the total supply current not exceeding 1 600 A and for rated frequencies up to and including 60 Hz, may be made by calculation in accordance with the method of IEC 60890 if all the following conditions are fulfilled:

- a) the power loss data for all built-in components is available from the component manufacturer;
- b) there is an approximately even distribution of power losses inside the enclosure;
- c) the rated current of the circuits of the ASSEMBLY to be verified (see 10.10.1) shall not exceed 80 % of the rated conventional free air thermal current (I_{th}) if any, or the rated current (I_n) of the switching devices and electrical components included in the circuit. Circuit protection devices shall be selected to ensure adequate protection to outgoing circuits, e.g. thermal motor protection devices at the calculated temperature in the ASSEMBLY;

NOTE 1 There is no common characteristic for switching devices and electrical components that describes the value of current to be used here. For the purpose of verifying the temperature rise limits the value of current is used, which describes the maximum continuous operational current that can be carried without overheating. This is e.g. for contactors the rated operational current I_e AC1 and for circuit breakers the rated current I_n .

- d) the mechanical parts and the installed equipment are so arranged that air circulation is not significantly impeded;
- e) conductors carrying currents in excess of 200 A, and the adjacent structural parts are so arranged that eddy-current and hysteresis losses are minimised;
- f) all conductors shall have a minimum cross-sectional area based on 125 % of the permitted current rating of the associated circuit. Selection of cables shall be in accordance with IEC 60364-5-52. Examples on how to adapt this standard for conditions inside an ASSEMBLY are given in Annex H. The cross-section of bars shall be as tested or as given in Annex N. Where the device manufacturer specifies a conductor with a larger cross-sectional area this shall be used;
- g) for enclosures with natural ventilation, the cross-section of the air outlet openings is at least 1,1 times the cross section of the air inlet openings;
- h) there are no more than three horizontal partitions in the ASSEMBLY or a section of an ASSEMBLY;
- i) for enclosures with compartments and natural ventilation the cross section of the ventilating openings in each horizontal partition is at least 50 % of the horizontal cross section of the compartment.

The effective power losses of all circuits including interconnecting conductors shall be calculated based on rated current of the circuits. The total power loss of the ASSEMBLY is calculated by adding the power losses of the circuits taking additionally into account that the total load current is limited to the rated current of the ASSEMBLY. The power losses of the conductors are determined by calculation (see Annex H).

NOTE 2 There are devices where the power loss is substantially proportional to I^2 and others that have substantially fixed losses.

NOTE 3 Example: A single compartment ASSEMBLY with a rated current of 100 A (limited by the distribution bars) is equipped with 20 outgoing circuits. The assumed rated current for each circuit is 8 A. The total effective power loss should be calculated for 12 outgoing circuits loaded with 8 A each.

The temperature rise within the ASSEMBLY is then determined from the total power loss using the method of IEC 60890.

10.10.4.3.2 Results to be obtained

The ASSEMBLY is verified if the calculated air temperature at the mounting height of any device does not exceed the permissible ambient air temperature as declared by the device manufacturer.

This means for switching devices or electrical components in the main circuits that the continuous load does not exceed its permissible load at the calculated local air temperature and not more than 80 % of its rated current (see 10.10.4.3.1 c).

10.11 Short-circuit withstand strength

10.11.1 General

The short-circuit current ratings declared shall be verified except where exempt, see 10.11.2. Verification may be, by comparison with a reference design (10.11.3 and 10.11.4.) or by test (10.11.5). For verification the following applies:

- If the ASSEMBLY system to be verified comprises a number of variants, the most onerous arrangement(s) of the ASSEMBLY shall be selected, taking into account the rules in 10.11.3.
- The ASSEMBLY variants selected for test shall be verified according to 10.11.5.
- When the ASSEMBLIES tested are the most onerous variants of the larger product range of an ASSEMBLY system then the test results can be used to establish the ratings of similar variants without further testing. Rules for such derivations are given in 10.11.3 and 10.11.4.

10.11.2 Circuits of ASSEMBLIES which are exempted from the verification of the short-circuit withstand strength

A verification of the short-circuit withstand strength is not required for the following:

- ASSEMBLIES having a rated short-time withstand current (see 5.3.4) or rated conditional short-circuit current (see 5.3.5) not exceeding 10 kA r.m.s;
- ASSEMBLIES, or circuits of ASSEMBLIES, protected by current-limiting devices having a cut-off current not exceeding 17 kA with the maximum allowable prospective short-circuit current at the terminals of the incoming circuit of the ASSEMBLY;
- Auxiliary circuits of ASSEMBLIES intended to be connected to transformers whose rated power does not exceed 10 kVA for a rated secondary voltage of not less than 110 V, or 1,6 kVA for a rated secondary voltage less than 110 V, and whose short-circuit impedance is not less than 4 %.

All other circuits shall be verified.

10.11.3 Verification by comparison with a reference design – Utilising a check list

Verification is undertaken by comparison of the ASSEMBLY to be verified with an already tested design using the check list provided in Table 13.

Should any elements identified in the check list not comply with the requirements of the check list and be marked 'NO', one of the following means of verification shall be used (see 10.11.4 and 10.11.5).

10.11.4 Verification by comparison with a reference design – Utilising calculation

Assessment of the rated short-time withstand current of an ASSEMBLY and its circuits, by calculation, shall be undertaken by a comparison of the ASSEMBLY to be assessed with an ASSEMBLY, already verified by test. The assessment to verify the main circuits of an ASSEMBLY shall be in accordance with Annex P. In addition each of the circuits of the ASSEMBLY to be assessed shall meet the requirements of items 6, 8, 9 and 10 in Table 13.

The data used, calculations made and comparison undertaken shall be recorded.

If the assessment in accordance with Annex P is not passed or any of the items listed above are not fulfilled then the ASSEMBLY and its circuits shall be verified by test in accordance with 10.11.5.

10.11.5 Verification by test

10.11.5.1 Test arrangements

The ASSEMBLY or its parts as necessary to complete the test shall be mounted as in normal use. It is sufficient to test a single functional unit if the remaining functional units are of the same construction. Similarly it is sufficient to test a single busbar configuration if the remaining busbar configurations are of the same construction. Table 13 provides clarification on items not requiring additional tests.

10.11.5.2 Performance of the test – General

If the test circuit incorporates fuses, fuse-links with the maximum let-through current and, if required, of the type indicated by the original manufacturer as being acceptable, shall be used.

The supply conductors and the short-circuit connections required for testing the ASSEMBLY shall have sufficient strength to withstand short-circuits and be so arranged that they do not introduce any additional stresses on the ASSEMBLY.

Unless otherwise agreed, the test circuit shall be connected to the input terminals of the ASSEMBLY. Three-phase ASSEMBLIES shall be connected on a three-phase basis.

All parts of the equipment intended to be connected to the protective conductor in service, including the enclosure, shall be connected as follows:

- a) for ASSEMBLIES suitable for use on three-phase four-wire systems (see also IEC 60038) with an earthed star point and marked accordingly, to the neutral point of supply or to a substantially inductive artificial neutral permitting a prospective fault current of at least 1 500 A;
- b) for ASSEMBLIES also suitable for use in three-phase three-wire as well as on three-phase four-wire systems and marked accordingly, to the phase conductor least likely to arc to earth.

Except for ASSEMBLIES according to 8.4.4, the connection mentioned in a) and b) shall include a fusible element consisting of a copper wire of 0,8 mm diameter and at least 50 mm long, or

of an equivalent fusible element for the detection of a fault current. The prospective fault current in the fusible element circuit shall be $1\,500\text{ A} \pm 10\%$, except as stated in Notes 2 and 3. If necessary, a resistor limiting the current to that value shall be used.

NOTE 1 A copper wire of 0,8 mm diameter will melt at 1 500 A, in approximately half a cycle, at a frequency between 45 Hz and 67 Hz (or 0,01 s for d.c.).

NOTE 2 The prospective fault current may be less than 1 500 A in the case of small equipment, according to the requirements of the relevant product standard, 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 be accepted, subject to the agreement of the ASSEMBLY 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 given in Table 14.

10.11.5.3 Testing of main circuits

10.11.5.3.1 General

Circuits shall be tested with the highest thermal and dynamic stresses that may result from short circuit currents up to the rated values for one or more of the following conditions as declared by the original manufacturer.

- a) Not dependent upon a SCPD. The ASSEMBLY shall be tested with the rated peak withstand current and the rated short-time withstand current for the specified duration (see 5.3 and 9.3.2 a)).
- b) Dependent upon an incoming SCPD included within the ASSEMBLY. The ASSEMBLY shall be tested with an incoming prospective short-circuit current for a period of time that is limited by the incoming SCPD.
- c) Dependent upon an upstream SCPD. The ASSEMBLY shall be tested to the let through values permitted by the upstream SCPD as defined by the original manufacturer.

Where an incoming or outgoing circuit includes a SCPD that reduces the peak and/or duration of the fault current, then the circuit shall be tested allowing the SCPD to operate and interrupt the fault current (see 5.3.5 rated conditional short-circuit current I_{cc}). If the SCPD contains an adjustable short-circuit release, then this shall be set to the maximum allowed value (see 9.3.2, second paragraph).

One of each type of circuit shall be subject to a short-circuit test as described in 10.11.5.3.2 to 10.11.5.3.5.

10.11.5.3.2 Outgoing circuits

The outgoing terminals of outgoing circuits shall be provided with a bolted short-circuit connection. When the protective device in the outgoing circuit is a circuit-breaker, the test circuit may include a shunting resistor in accordance with 8.3.4.1.2 b) of IEC 60947-1:2007 in parallel with the reactor used to adjust the short-circuit current.

For circuit-breakers having a rated current up to and including 630 A, a conductor 0,75 m in length having a cross-sectional area corresponding to the rated current (see Tables 11 and 12) shall be included in the test circuit. At the original manufacturer's discretion a shorter connection than 0,75 m may be used.

The switching device shall be closed and held closed in the manner normally used in service. The test voltage shall then be applied once and,

- a) for a time sufficiently long to enable the short-circuit protective device in the outgoing unit to operate to clear the fault and, in any case, for not less than 10 cycles (test voltage duration), or

- b) in cases where the outgoing circuit does not include a SCPD, for a magnitude and duration as specified for the busbars by the original manufacturer. Testing of outgoing circuits may also result in the operation of the incoming circuit SCPD.

10.11.5.3.3 Incoming circuit and main busbars

ASSEMBLIES containing main busbars shall be tested to prove the short-circuit withstand strength of the main busbars and the incoming circuit including at least one joint where the busbars are intended to be extendable. The short-circuit shall be placed such that the length of main busbar included in the test is $(2 \pm 0,4)$ m. For the verification of rated short-time withstand current (see 5.3.4) and rated peak withstand current (see 5.3.3), this distance may be increased and the test conducted at any convenient voltage providing the test current is the rated value (see 10.11.5.4 b)). Where the design of the ASSEMBLY is such that the length of the busbars to be tested is less than 1,6 m and the ASSEMBLY is not intended to be extended, then the complete length of busbar shall be tested, the short-circuit being established at the end of these busbars. If a set of busbars consists of different sections (as regards cross-sections, center line spacing of the conductors, type and number of supports per metre), each section shall be tested separately or concurrently, provided that the above conditions are met.

10.11.5.3.4 Connections to the supply side of outgoing units

Where an ASSEMBLY contains conductors, including distribution busbars, if any, between a main busbar and the supply side of outgoing functional units that do not fulfil the requirements of 8.6.4 one circuit of each type shall be subject to an additional test.

A short-circuit is obtained by bolted connections on the conductors connecting the busbars to a single outgoing unit, as near as practicable to the terminals on the busbar side of the outgoing unit. The value and duration of the short-circuit current shall be the same as that for the main busbars.

10.11.5.3.5 Neutral conductor

If a neutral conductor exists within a circuit it shall be subjected to one test to prove its short-circuit withstand strength in relation to the nearest phase conductor of the circuit under test including any joints. Phase to neutral short-circuit connections shall be applied as specified in 10.11.5.3.3.

Unless otherwise agreed between the original manufacturer and the user, the value of the test current in the neutral shall be at least 60 % of the phase current during the three-phase test.

The test need not be executed if the test is intended to be made with a current of 60 % of the phase current and if the neutral conductor is:

- the same shape and cross-section as the phase conductors;
- supported in an identical manner as the phase conductors and with support centres along the length of the conductor not greater than that of the phases;
- spaced at a distance from the nearest phase(s) not less than that between phases;
- spaced at a distance from earthed metalwork not less than the phase conductors.

10.11.5.4 Value and duration of the short-circuit current

For all short-circuit withstand ratings, the dynamic and thermal stresses shall be verified with a prospective current, at the supply side of the specified protective device, if any, equal to the value of the rated short-time withstand current, rated peak withstand current or rated conditional short-circuit current assigned.

For the verification of all the short-circuit withstand ratings (see 5.3.3 to 5.3.5 inclusive), the value of the prospective short-circuit current at a test voltage equal to 1,05 times the rated

operational voltage shall be determined from a calibration oscillogram which is taken with the supply conductors to the ASSEMBLY short-circuited by a connection of negligible impedance placed as near as possible to the input supply of the ASSEMBLY. The oscillogram shall show that there is a constant flow of current such that it is measurable at a time equivalent to the operation of the protective device incorporated in the ASSEMBLY or for the specified duration (see 9.3.2. a)).

The value of current during the calibration is the average of the r.m.s. values of the a.c. component in all phases. When making the tests at maximum operational voltage, the calibration current in each phase shall be equal to the rated short-circuit current within a $\begin{smallmatrix} +5 \\ 0 \end{smallmatrix}$ % tolerance and the power factor shall be within a $\begin{smallmatrix} 0,00 \\ -0,05 \end{smallmatrix}$ tolerance.

All tests shall be made at the rated frequency of the ASSEMBLY with a tolerance of ± 25 %, and at the power factor appropriate to the short-circuit current in accordance with Table 7.

- a) For a test at rated conditional short circuit current I_{CC} , whether the protective devices are in the incoming circuit of the ASSEMBLY or elsewhere, the test voltage shall be applied for a time sufficiently long to enable the short-circuit protective devices to operate to clear the fault and, in any case, for not less than 10 cycles. The test shall be conducted at 1,05 times the rated operational voltage with prospective short circuit currents, at the supply side of the specified protective device, equal to the value of the rated conditional short-circuit current. Tests at lower voltages are not permitted.

NOTE In South Africa (ZA) National Electrical Code SANS 10142-1, Subclause 6.8, requires that the supply voltage be equal to 1,1 times the nominal voltage where the rated operational voltage is up to and including 500 V.

- b) For a test at rated short-time withstand current and rated peak withstand current, the dynamic and thermal stresses shall be verified with a prospective current equal to the value of rated short-time withstand current and rated peak withstand current declared. The current shall be applied for the specified time during which the r.m.s. value of its a.c. component shall remain constant.

In the case of test station difficulty of making the short-time or peak withstand tests at the maximum operational voltage, the tests according to 10.11.5.3.3, 10.11.5.3.4 and 10.11.5.3.5 may be made at any convenient voltage, with the original manufacturer's agreement, the actual test current being, in this case, equal to the rated short-time current or peak withstand current. This shall be stated in the test report. If, however, momentary contact separation occurs in the protective device, if any, during the test, the test shall be repeated at the maximum operational voltage.

If necessary, due to test limitations, a different test period is permissible; in such a case, the test current should be modified in accordance with the formula $I^2t = \text{constant}$, provided that the peak value does not exceed the rated peak withstand current without the original manufacturer's consent and that the r.m.s. value of the short-time current is not less than the rated value in at least one phase for at least 0,1 s after current initiation.

The peak current withstand test and the short-time current test may be separated. In this case, the time during which the short-circuit is applied for the peak current withstand test shall be such that the value I^2t is not larger than the equivalent value for the short-time current test, but it shall be not less than three cycles.

Where the required test current in each phase cannot be achieved the positive tolerance may be exceeded with the agreement of the original manufacturer.

10.11.5.5 Results to be obtained

After the test deformation of busbars and conductors is acceptable provided that the clearances and creepage distances specified in 8.3 are still complied with. In case of any doubt clearances and creepage distances shall be measured (see 10.4).

The characteristics of the insulation shall remain such that the mechanical and dielectric properties of the equipment satisfy the requirements of the relevant ASSEMBLY standard. A busbar insulator or support or cable restraint has not separated into two or more pieces. Also there shall be no cracks appearing on opposite sides of a support and no cracks, including surface cracks, running the full length or width of the support. In case of any doubt that the insulation properties of the ASSEMBLY are not maintained an additional power frequency test at two times U_e with a minimum of 1 000 V shall be performed in accordance with 10.9.2.

There shall be no loosening of parts used for the connection of conductors and the conductors shall not separate from the outgoing terminals.

Distortion of the busbars or structure of the ASSEMBLY that impairs its normal use shall be deemed a failure.

Any distortion of the busbars or structure of the ASSEMBLY that impairs normal insertion or removal of the removable parts shall be deemed a failure.

Deformation of the enclosure or of the internal partitions, barriers and obstacles due to short-circuit is permissible to the extent that the degree of protection is not apparently impaired and the clearances or creepage distances are not reduced to values, which are less than those specified in 8.3. Additionally after the tests of 10.11.5.3 incorporating short-circuit protective devices, the tested equipment shall be capable of withstanding the dielectric test of 10.9.2, at a value of voltage for the "after test" condition prescribed in the relevant short-circuit protective device standard for the appropriate short-circuit test, as follows:

- a) between all live parts and the exposed conductive parts of the ASSEMBLY, and
- b) between each pole and all other poles connected to the exposed conductive parts of the ASSEMBLY.

If tests a) and b) above are conducted, they shall be carried out with any fuses replaced and with any switching device closed.

The fusible element (see 10.11.5.2.), if any, shall not indicate a fault current.

In case of any doubt, it shall be checked that the apparatus incorporated in the ASSEMBLY are in a condition as prescribed in the relevant specifications.

10.11.5.6 Testing of the protective circuit

10.11.5.6.1 General

This test does not apply for circuits according to 10.11.2.

A single-phase test supply shall be connected to the incoming terminal of one phase and to the terminal for the incoming protective conductor. When the ASSEMBLY is provided with a separate protective conductor, the nearest phase conductor shall be used. For each representative outgoing unit, a separate test shall be made with a bolted short-circuit connection between the corresponding outgoing phase terminal of the unit and the terminal for the relevant outgoing protective conductor.

Each outgoing unit on test shall be fitted with its intended protective device. Where alternative protective devices can be incorporated in the outgoing unit, the protective device which lets through the maximum values of peak current and I^2t shall be used.

For this test, the frame of the ASSEMBLY shall be insulated from earth. The test voltage shall be equal to 1,05 times the single-phase value of the rated operational voltage. Unless otherwise agreed between the original manufacturer and the user, the value of the test current in the protective conductor shall be at least 60 % of the phase current during the three-phase test of the ASSEMBLY.

NOTE In South Africa (ZA) National Electrical Code SANS 10142-1, Subclause 6.8, requires that the supply voltage be equal to 1,1 times the nominal voltage where the rated operational voltage is up to and including 500 V.

All other conditions of this test shall be analogous to 10.11.5.2 to 10.11.5.4 inclusive.

10.11.5.6.2 Results to be obtained

The continuity and the short-circuit withstand strength of the protective circuit, whether it consists of a separate conductor or the frame, shall not be significantly impaired. Besides visual inspection, this may be verified by measurements with a current in the order of the rated current of the relevant outgoing unit. Deformation of the enclosure or of the internal partitions, barriers and obstacles due to short-circuit is permissible to the extent that the degree of protection is not apparently impaired and the clearances or creepage distances are not reduced to values, which are less than those specified in 8.3.

NOTE 1 Where the frame is used as a protective conductor, sparks and localized heating at joints are permitted, provided they do not impair the electrical continuity and provided that adjacent flammable parts are not ignited.

NOTE 2 A comparison of the resistances measured before and after the test, between the terminal for the incoming protective conductor and the terminal for the relevant outgoing protective conductor, gives an indication of conformity with this condition.

10.12 Electromagnetic compatibility (EMC)

For EMC tests, see J.10.12.

10.13 Mechanical operation

This verification test shall not be made on such devices (e.g. withdrawable circuit breaker) of the ASSEMBLY which have already been type tested according to their relevant product standard unless their mechanical operation has been modified by their mounting.

For parts, which need verification by test (see 8.1.5), satisfactory mechanical operation shall be verified after installation in the ASSEMBLY. The number of operating cycles shall be 200.

At the same time, the operation of the mechanical interlocks associated with these movements shall be checked. The test is passed if the operating conditions of the apparatus, interlocks, specified degree of protection etc., have not been impaired and if the effort required for operation is practically the same as before the test.

11 Routine verification

11.1 General

Routine verification is intended to detect faults in materials and workmanship and to ascertain proper functioning of the manufactured ASSEMBLY. It is made on every ASSEMBLY. The ASSEMBLY manufacturer shall determine if routine verification is carried out during and/or after manufacture. Where appropriate, routine verification shall confirm that design verification is available.

Routine verification is not required to be carried out on devices and self-contained components incorporated in the ASSEMBLY when they have been selected in accordance with 8.5.3 and installed in accordance with the instructions of the device manufacturer.

Verification shall comprise the following categories:

- a) Construction (see 11.2 to 11.8):
 - 1) degree of protection of enclosures;
 - 2) clearances and creepage distances;

- 3) protection against electric shock and integrity of protective circuits;
 - 4) incorporation of built-in components;
 - 5) internal electrical circuits and connections;
 - 6) terminals for external conductors;
 - 7) mechanical operation.
- b) Performance (see 11.9 to 11.10):
- 1) dielectric properties;
 - 2) wiring, operational performance and function.

11.2 Degree of protection of enclosures

A visual inspection is necessary to confirm that the prescribed measures to achieve the designated degree of protection are maintained.

11.3 Clearances and creepage distances

Where the clearances are:

- less than the values given in Table 1, an impulse voltage withstand test in accordance with 10.9.3 shall be carried out;
- not evident by visual inspection to be larger than the values given in Table 1 (see 10.9.3.5) verification shall be by physical measurement or by an impulse voltage withstand test in accordance with 10.9.3.

The prescribed measures with regard to creepage distances (see 8.3.3) shall be subject to a visual inspection. Where it is not evident by visual inspection verification shall be by physical measurement.

11.4 Protection against electric shock and integrity of protective circuits

The prescribed protective measures with regard to basic protection and fault protection (see 8.4.2 and 8.4.3) shall be subject to a visual inspection.

The protective circuits shall be checked by visual inspection to ascertain that the measures prescribed in 8.4.3 are verified.

Screwed and bolted connections shall be checked for the correct tightness on a random basis.

11.5 Incorporation of built-in components

The installation and identification of built-in components shall be in accordance with the ASSEMBLY manufacturing instructions.

11.6 Internal electrical circuits and connections

The connections, especially screwed and bolted connections, shall be checked for the correct tightness on a random basis.

Conductors shall be checked in accordance with the ASSEMBLY manufacturing instructions.

11.7 Terminals for external conductors

The number, type and identification of terminals shall be checked in accordance with the ASSEMBLY manufacturing instructions.

11.8 Mechanical operation

The effectiveness of mechanical actuating elements, interlocks and locks including those associated with removable parts shall be checked.

11.9 Dielectric properties

A power-frequency withstand test shall be performed on all circuits in accordance with 10.9.1 and 10.9.2 but for a duration of 1 s.

This test need not be made on auxiliary circuits:

- which are protected by a short-circuit protective device with a rating not exceeding 16 A;
- if an electrical function test has been made previously at the rated operational voltage for which the auxiliary circuits are designed.

As an alternative for ASSEMBLIES with incoming protection rated up to 250 A the verification of insulation resistance may be by measurement using an insulation measuring device at a voltage of at least 500 V d.c.

In this case, the test is satisfactory if the insulation resistance between circuits and exposed conductive parts is at least 1 000 Ω/V per circuit referred to the supply voltage to earth of these circuits.

11.10 Wiring, operational performance and function

It shall be verified that the information and markings specified in Clause 6 are complete.

Depending on the complexity of the ASSEMBLY, it may be necessary to inspect the wiring and to carry out an electrical function test. The test procedure and the number of tests depend on whether or not the ASSEMBLY includes complicated interlocks, sequence control facilities, etc.

NOTE In some cases, it may be necessary to make or repeat this test on site before putting the installation into operation.

Table 1 – Minimum clearances in air ^a (8.3.2)

Rated impulse withstand voltage U_{imp} kV	Minimum clearance mm
$\leq 2,5$	1,5
4,0	3,0
6,0	5,5
8,0	8,0
12,0	14,0
^a Based on inhomogeneous field conditions and pollution degree 3.	

Table 2 – Minimum creepage distances (8.3.3)

Rated insulation voltage U_i	Minimum creepage distance mm							
	Pollution degree							
	1	2			3			
	Material group ^c	Material group ^c			Material group ^c			
	All material groups	I	II	IIIa and IIIb	I	II	IIIa	IIIb
32	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
40	1,5	1,5	1,5	1,5	1,5	1,6	1,8	1,8
50	1,5	1,5	1,5	1,5	1,5	1,7	1,9	1,9
63	1,5	1,5	1,5	1,5	1,6	1,8	2	2
80	1,5	1,5	1,5	1,5	1,7	1,9	2,1	2,1
100	1,5	1,5	1,5	1,5	1,8	2	2,2	2,2
125	1,5	1,5	1,5	1,5	1,9	2,1	2,4	2,4
160	1,5	1,5	1,5	1,6	2	2,2	2,5	2,5
200	1,5	1,5	1,5	2	2,5	2,8	3,2	3,2
250	1,5	1,5	1,8	2,5	3,2	3,6	4	4
320	1,5	1,6	2,2	3,2	4	4,5	5	5
400	1,5	2	2,8	4	5	5,6	6,3	6,3
500	1,5	2,5	3,6	5	6,3	7,1	8,0	8,0
630	1,8	3,2	4,5	6,3	8	9	10	10
800	2,4	4	5,6	8	10	11	12,5	a
1 000	3,2	5	7,1	10	12,5	14	16	
1 250	4,2	6,3	9	12,5	16	18	20	
1 600	5,6	8	11	16	20	22	25	

NOTE 1 The CTI values refer to the values obtained in accordance with IEC 60112:2003, method A, for the insulating material used.

NOTE 2 Values taken from IEC 60664-1, but maintaining a minimum value of 1,5 mm.

a Insulation of material group IIIb is not recommended for use in pollution degree 3 above 630 V.

b As an exception, for rated insulation voltages 127, 208, 415, 440, 660/690 and 830 V, creepage distances corresponding to the lower values 125, 200, 400, 630 and 800 V may be used.

c Material groups are classified as follows, according to the range of values of the comparative tracking index (CTI) (see 3.6.16):

- 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 $100 \leq \text{CTI} < 175$

Table 3 – Cross-sectional area of a copper protective conductor (8.4.3.2.2)

Rated operational current I_e	Minimum cross-sectional area of a protective conductor
A	mm ²
$I_e \leq 20$	S^a
$20 < I_e \leq 25$	2,5
$25 < I_e \leq 32$	4
$32 < I_e \leq 63$	6
$63 < I_e$	10

^a S is the cross-sectional area of the phase conductor (mm²).

Table 4 – Conductor selection and installation requirements (8.6.4)

Type of conductor	Requirements
Bare conductors or single-core conductors with basic insulation, for example cables according to IEC 60227-3	Mutual contact or contact with conductive parts shall be avoided, for example by use of spacers
Single-core conductors with basic insulation and a maximum permissible conductor operating temperature of at least 90 °C, for example cables according to IEC 60245-3, or heat-resistant thermo-plastic (PVC) insulated cables according to IEC 60227-3	Mutual contact or contact with conductive parts is permitted where there is no applied external pressure. Contact with sharp edges shall be avoided. These conductors may only be loaded such that an operating temperature of 80 % of the maximum permissible conductor operating temperature is not exceeded
Conductors with basic insulation, for example cables according to IEC 60227-3, having additional secondary insulation, for example individually covered cables with shrink sleeving or individually run cables in plastic conduits	No additional requirements
Conductors insulated with a very high mechanical strength material, for example Ethylene Tetrafluoro Ethylene (ETFE) insulation, or double-insulated conductors with an enhanced outer sheath rated for use up to 3 kV, for example cables according to IEC 60502	
Single or multi-core sheathed cables, for example cables according to IEC 60245-4 or IEC 60227-4	

Table 5 – Minimum terminal capacity for copper protective conductors (PE, PEN) (8.8)

Cross-sectional area of phase conductors S mm ²	Minimum cross-sectional area of the corresponding protective conductor (PE, PEN) S_p^a mm ²
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S \leq 400$	$S/2$
$400 < S \leq 800$	200
$800 < S$	$S/4$

^a Current in the neutral may be influenced where there are significant harmonics in the load. See 8.6.1.

Table 6 – Temperature-rise limits (9.2)

Parts of ASSEMBLIES	Temperature rise K
Built-in components ^a	In accordance with the relevant product standard requirements for the individual components or, in accordance with the component manufacturer's instructions ^f , taking into consideration the temperature in the ASSEMBLY
Terminals for external insulated conductors	70 ^b
Busbars and conductors	Limited by ^f : <ul style="list-style-type: none"> – mechanical strength of conducting material ^g; – possible effect on adjacent equipment; – permissible temperature limit of the insulating materials in contact with the conductor; – effect of the temperature of the conductor on the apparatus connected to it; – for plug-in contacts, nature and surface treatment of the contact material
Manual operating means: <ul style="list-style-type: none"> – of metal – of insulating material 	15 ^c 25 ^c
Accessible external enclosures and covers: <ul style="list-style-type: none"> – metal surfaces – insulating surfaces 	30 ^d 40 ^d
Discrete arrangements of plug and socket-type connections	Determined by the limit for those components of the related equipment of which they form part ^e
<p>NOTE 1 The 105 K relates to the temperature above which annealing of copper is likely to occur. Other materials may have a different maximum temperature rise.</p> <p>NOTE 2 The temperature rise limits given in this table apply for a mean ambient air temperature up to 35 °C under service conditions (see 7.1). During verification a different ambient air temperature is permissible (see 10.10.2.3.4).</p>	
<p>^a The term "built-in components" means:</p> <ul style="list-style-type: none"> – conventional switchgear and controlgear; – electronic sub-assemblies (e.g. rectifier bridge, printed circuit); – parts of the equipment (e.g. regulator, stabilized power supply unit, operational amplifier). <p>^b The temperature-rise limit of 70 K is a value based on the conventional test of 10.10. An ASSEMBLY used or tested under installation conditions may have connections, the type, nature and disposition of which will not be the same as those adopted for the test, and a different temperature rise of terminals may result and may be required or accepted. Where the terminals of the built-in component are also the terminals for external insulated conductors, the lower of the corresponding temperature-rise limits shall be applied. The temperature rise limit is the lower of the maximum temperature rise specified by the component manufacturer and 70 K. In the absence of manufacturer's instructions it is the limit specified by the built-in component product standard but not exceeding 70 K.</p> <p>^c Manual operating means within ASSEMBLIES which are only accessible after the ASSEMBLY has been opened, for example draw-out handles which are operated infrequently, are allowed to assume a 25 K increase on these temperature-rise limits.</p> <p>^d Unless otherwise specified, in the case of covers and enclosures, which are accessible but need not be touched during normal operation, a 10 K increase on these temperature-rise limits is permissible. External surfaces and parts over 2 m from the base of the ASSEMBLY are considered inaccessible.</p> <p>^e This allows a degree of flexibility in respect of equipment (e.g. electronic devices) which is subject to temperature-rise limits different from those normally associated with switchgear and controlgear.</p> <p>^f For temperature-rise tests according to 10.10, the temperature-rise limits have to be specified by the original manufacturer taking into account any additional measuring points and limits imposed by the component manufacturer.</p> <p>^g Assuming all other criteria listed are met a maximum temperature rise of 105 K for bare copper busbars and conductors shall not be exceeded.</p>	

Table 7 – Values for the factor n^a (9.3.3)

r.m.s. value of short-circuit current kA	$\cos \varphi$	n
$I \leq 5$	0,7	1,5
$5 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2
$20 < I \leq 50$	0,25	2,1
$50 < I$	0,2	2,2

^a Values of this table represent the majority of applications. In special locations, for example in the vicinity of transformers or generators, lower values of power factor may be found, whereby the maximum prospective peak current may become the limiting value instead of the r.m.s. value of the short-circuit current.

Table 8 – Power-frequency withstand voltage for main circuits (10.9.2)

Rated insulation voltage U_i (line to line a.c. or d.c.) V	Dielectric test voltage a.c. r.m.s. V	Dielectric test voltage ^b d.c. V
$U_i \leq 60$	1 000	1 415
$60 < U_i \leq 300$	1 500	2 120
$300 < U_i \leq 690$	1 890	2 670
$690 < U_i \leq 800$	2 000	2 830
$800 < U_i \leq 1 000$	2 200	3 110
$1 000 < U_i \leq 1 500^a$	-	3 820

^a For d.c. only.
^b Test voltages based on 6.1.3.4.1, fifth paragraph, of IEC 60664-1.

Table 9 – Power-frequency withstand voltage for auxiliary and control circuits (10.9.2)

Rated insulation voltage U_i (line to line) V	Dielectric test voltage a.c. r.m.s. V
$U_i \leq 12$	250
$12 < U_i \leq 60$	500
$60 < U_i$	See Table 8

Table 10 – Impulse withstand test voltages (10.9.3)

Rated impulse withstand voltage U_{imp} kV	Test voltages and corresponding altitudes during test									
	$U_{1,2/50}$ a.c. peak and d.c. kV					a.c. r.m.s. kV				
	Sea level	200 m	500 m	1 000 m	2 000 m	Sea level	200 m	500 m	1 000 m	2 000 m
2,5	2,95	2,8	2,8	2,7	2,5	2,1	2,0	2,0	1,9	1,8
4,0	4,8	4,8	4,7	4,4	4,0	3,4	3,4	3,3	3,1	2,8
6,0	7,3	7,2	7,0	6,7	6,0	5,1	5,1	5,0	4,7	4,2
8,0	9,8	9,6	9,3	9,0	8,0	6,9	6,8	6,6	6,4	5,7
12,0	14,8	14,5	14,0	13,3	12,0	10,5	10,3	9,9	9,4	8,5

Table 11 – Copper test conductors for rated currents up to 400 A inclusive (10.10.2.3.2)

Range of rated current ^a		Conductor cross-sectional area ^{b, c}	
A		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
85	100	35	3
100	115	35	2
115	130	50	1
130	150	50	0
150	175	70	00
175	200	95	000
200	225	95	0000
225	250	120	250
250	275	150	300
275	300	185	350
300	350	185	400
350	400	240	500

^a The value of the rated 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 test conductors than those given for a stated rated current may be used.

^c Either of the two conductors specified may be used.

**Table 12 – Copper test conductors for rated currents
from 400 A to 4 000 A (10.10.2.3.2)**

Range of rated current ^a	Test conductors			
	Cables		Copper bars ^b	
	Quantity	Cross-sectional area mm ²	Quantity	Dimensions mm (W × D)
400 to 500	2	150	2	30 × 5
500 to 630	2	185	2	40 × 5
630 to 800	2	240	2	50 × 5
800 to 1 000			2	60 × 5
1 000 to 1 250			2	80 × 5
1 250 to 1 600			2	100 × 5
1 600 to 2 000			3	100 × 5
2 000 to 2 500			4	100 × 5
2 500 to 3 150			3	100 × 10
3 150 to 4 000			4	100 × 10

^a The value of the rated current shall be greater than the first value and less than or equal to the second value.

^b Bars are assumed to be arranged with their long faces (W) vertical. Arrangements with long faces horizontal may be used if specified by the manufacturer. Bars may be painted.

**Table 13 – Short-circuit verification by comparison with a reference design:
check list (10.5.3.3, 10.11.3 and 10.11.4)**

Item No.	Requirements to be considered	YES	NO
1	Is the short-circuit withstand rating of each circuit of the ASSEMBLY to be assessed, less than or equal to, that of the reference design?		
2	Is the cross-sectional dimensions of the busbars and connections of each circuit of the ASSEMBLY to be assessed, greater than or equal to, those of the reference design?		
3	Is the center line spacing of the busbars and connections of each circuit of the ASSEMBLY to be assessed, greater than or equal to, those of the reference design?		
4	Are the busbar supports of each circuit of the ASSEMBLY to be assessed of the same type, shape and material and have, the same or smaller center line spacing, along the length of the busbar as the reference design? And is the mounting structure for the busbar supports of the same design and mechanical strength?		
5	Are the material and the material properties of the conductors of each circuit of the ASSEMBLY to be assessed the same as those of the reference design?		
6	Are the short-circuit protective devices of each circuit of the ASSEMBLY to be assessed equivalent, that is of the same make and series ^a with the same or better limitation characteristics (I^2t , I_{pk}) based on the device manufacturer's data, and with the same arrangement as the reference design?		
7	Is the length of unprotected live conductors, in accordance with 8.6.4, of each non-protected circuit of the ASSEMBLY to be assessed less than or equal to those of the reference design?		
8	If the ASSEMBLY to be assessed includes an enclosure, did the reference design include an enclosure when verified by test?		

Item No.	Requirements to be considered	YES	NO
9	Is the enclosure of the ASSEMBLY to be assessed of the same design, type and have at least the same dimensions to that of the reference design?		
10	Are the compartments of each circuit of the ASSEMBLY to be assessed of the same mechanical design and at least the same dimensions as those of the reference design?		
'YES' to all requirements – no further verification required.			
'NO' to any one requirement – further verification is required.			
^a Short-circuit protective devices of the same manufacturer but of a different series may be considered equivalent where the device manufacturer declares the performance characteristics to be the same or better in all relevant respects to the series used for verification, e.g. breaking capacity and limitation characteristics (I^2t , I_{pk}), and critical distances.			

Table 14 – Relationship between prospective fault current and diameter of copper wire

Diameter of copper wire mm	Prospective fault current in the fusible element circuit A
0,1	50
0,2	150
0,3	300
0,4	500
0,5	800
0,8	1 500

Annex A (normative)

Minimum and maximum cross-section of copper conductors suitable for connection to terminals for external conductors (see 8.8)

Table A.1 below applies for the connection of one copper cable per terminal.

**Table A.1 – Cross-section of copper conductors suitable for connection
to terminals for external conductors**

Rated current	Solid or stranded conductors		Flexible conductors	
	Cross-sections		Cross-sections	
	min.	max.	min.	max.
A	mm ²		mm ²	
6	0,75	1,5	0,5	1,5
8	1	2,5	0,75	2,5
10	1	2,5	0,75	2,5
13	1	2,5	0,75	2,5
16	1,5	4	1	4
20	1,5	6	1	4
25	2,5	6	1,5	4
32	2,5	10	1,5	6
40	4	16	2,5	10
63	6	25	6	16
80	10	35	10	25
100	16	50	16	35
125	25	70	25	50
160	35	95	35	70
200	50	120	50	95
250	70	150	70	120
315	95	240	95	185

If the external conductors are connected directly to built-in apparatus, the cross-sections indicated in the relevant specifications are valid.

In cases where it is necessary to provide for conductors other than those specified in the table, special agreement shall be reached between the ASSEMBLY manufacturer and the user.

Annex B (normative)

Method of calculating the cross-sectional area of protective conductors with regard to thermal stresses due to currents of short duration

The following formula shall be used to calculate the cross-section of the protective conductors necessary to withstand the thermal stresses due to currents with a duration of the order of 0,2 s to 5 s.

$$S_p = \frac{\sqrt{I^2 t}}{k}$$

where

S_p is the cross-sectional area, in square millimetres;

I is the value (r.m.s.) of a.c. fault current for a fault of negligible impedance which can flow through the protective device, in amperes;

t is the operating time of the disconnecting device, in seconds;

NOTE Account should be taken of the current-limiting effect of the circuit impedances and the limiting capability (Joule integral) of the protective device.

k is the factor dependent on the material of the protective conductor, the insulation and other parts and the initial and final temperatures, see Table B.1.

Table B.1 – Values of k for insulated protective conductors not incorporated in cables, or bare protective conductors in contact with cable covering

	Insulation of protective conductor or cable covering		
	Thermo-plastic (PVC)	XLPE EPR Bare conductors	Butyl rubber
Final temperature	160 °C	250 °C	220 °C
	Factor k		
Material of conductor:			
Copper	143	176	166
Aluminium	95	116	110
Steel	52	64	60
The initial temperature of the conductor is assumed to be 30 °C.			

More detailed information is to be found in IEC 60364-5-54.

Annex C (informative)

User information template

This annex is intended as a template for the identification of items necessary for the ASSEMBLY manufacturer which is to be provided by the user.

It is intended to be used and developed in the relevant ASSEMBLY standards.

Table C.1 – Template

Characteristics	Reference clause or subclause	Default arrangement ^b	Options listed in standard	User requirement ^a
Electrical system				
Earthing system	5.6, 8.4.3.1, 8.4.3.2.3, 8.6.2, 10.5, 11.4	Manufacturer's standard, selected to suit local requirements	TT / TN-C / TN-C-S / IT, TN-S	
Nominal voltage (V)	3.8.9.1, 5.2.1, 8.5.3	Local, according to installation conditions	max 1 000 V a.c. or 1 500 V d.c.	
Transient overvoltages	5.2.4, 8.5.3, 9.1, Annex G	Determined by the electrical system	Overvoltage category I / II / III / IV	
Temporary overvoltages	9.1	Nominal system voltage + 1 200 V	None	
Rated frequency f_n (Hz)	3.8.12, 5.5, 8.5.3, 10.10.2.3, 10.11.5.4	According to local installation conditions	d.c./50 Hz/60 Hz	
Additional on site testing requirements: wiring, operational performance and function	11.10	Manufacturer's standard, according to application	None	
Short-circuit withstand capability				
Prospective short-circuit current at supply terminals I_{cp} (kA)	3.8.7	Determined by the electrical system	None	
Prospective short-circuit current in the neutral	10.11.5.3.5	Max. 60 % of phase values	None	
Prospective short-circuit current in the protective circuit	10.11.5.6	Max. 60 % of phase values	None	
SCPD in the incoming functional unit requirement	9.3.2	According to local installation conditions	Yes / No	
Co-ordination of short-circuit protective devices including external short-circuit protective device details.	9.3.4	According to local installation conditions	None	
Data associated with loads likely to contribute to the short-circuit current	9.3.2	No loads likely to make a significant contribution allowed for	None	
Protection of persons against electric shock in accordance with IEC 60364-4-41				

Characteristics	Reference clause or subclause	Default arrangement ^b	Options listed in standard	User requirement ^a
Type of protection against electric shock – Basic protection (protection against direct contact)	8.4.2	Basic protection	According to local installation regulations	
Type of protection against electric shock – Fault protection (protection against indirect contact)	8.4.3	According to local installation conditions	Automatic disconnection of supply / Electrical separation / Total insulation	
Installation environment				
Location type	3.5, 8.1.4, 8.2	Manufacturer's standard, according to application	Indoor / outdoor	
Protection against ingress of solid foreign bodies and ingress of water	8.2.2, 8.2.3	Indoor (enclosed): IP 2X Outdoor (min.): IP 23	IP 00, 2X, 3X, 4X, 5X, 6X After removal of removable parts: As for connected position / Reduced protection to manufacturer's standard	
External mechanical impact (IK)	8.2.1, 10.2.6	None	None	
Resistance to UV radiation (applies for outdoor assemblies only unless specified otherwise)	10.2.4	Indoor: Not applicable. Outdoor: Temperate climate	None	
Resistance to corrosion	10.2.2	Normal Indoor/Outdoor arrangements	None	
Ambient air temperature – Lower limit	7.1.1	Indoor: –5 °C Outdoor: –25 °C	None	
Ambient air temperature – Upper limit	7.1.1	40 °C	None	
Ambient air temperature – Daily average maximum	7.1.1, 9.2	35 °C	None	
Maximum relative humidity	7.1.2	Indoor: 50 % at 40 °C Outdoor: 100 % at 25 °C	None	
Pollution degree (of the installation environment)	7.1.3	Industrial: 3	1, 2, 3, 4	
Altitude	7.1.4	≤ 2 000 m	None	
EMC environment (A or B)	9.4, 10.12, Annex J	A/B	A/B	
Special service conditions (e.g. vibration, exceptional condensation, heavy pollution, corrosive environment, strong electric or magnetic fields, fungus, small creatures, explosion hazards, heavy vibration and shocks, earthquakes)	7.2, 8.5.4, 9.3.3 Table 7	No special service conditions	None	

Characteristics	Reference clause or subclause	Default arrangement ^b	Options listed in standard	User requirement ^a
Installation method				
Type	3.3, 5.6	Manufacturer's standard	Various e.g. floor standing / wall mounted	
Stationary/Movable	3.5	Stationary	Stationary / movable	
Maximum overall dimensions and weight	5.6, 6.2.1	Manufacturer's standard, according to application	None	
External conductor type(s)	8.8	Manufacturer's standard	Cable / Busbar Trunking System	
Direction(s) of external conductors	8.8	Manufacturer's standard	None	
External conductor material	8.8	Copper	Copper / aluminium	
External phase conductor, cross sections, and terminations	8.8	As defined within the standard	None	
External PE, N, PEN conductors cross sections, and terminations	8.8	As defined within the standard	None	
Special terminal identification requirements	8.8	Manufacturer's standard	None	
Storage and handling				
Maximum dimensions and weight of transport units	6.2.2, 10.2.5	Manufacturer's standard	None	
Methods of transport (e.g. forklift, crane)	6.2.2, 8.1.6	Manufacturer's standard	None	
Environmental conditions different from the service conditions	7.3	As service conditions	None	
Packing details	6.2.2	Manufacturer's standard	None	
Operating arrangements				
Access to manually operated devices	8.4		Authorized persons / Ordinary persons	
Location of manually operated devices	8.5.5	Easily accessible	None	
Isolation of load installation equipment items	8.4.2, 8.4.3.3, 8.4.6.2	Manufacturer's standard	Individual / groups / all	
Maintenance and upgrade capabilities				
Requirements related to accessibility in service by ordinary persons; requirement to operate devices or change components while the ASSEMBLY is energised	8.4.6.1	Basic protection	None	
Requirements related to accessibility for inspection and similar operations	8.4.6.2.2	No requirements for accessibility	None	
Requirements related to accessibility for maintenance in service by authorized persons	8.4.6.2.3	No requirements for accessibility	None	
Requirements related to accessibility for extension in service by authorized persons	8.4.6.2.4	No requirements for accessibility	None	

Characteristics	Reference clause or subclause	Default arrangement ^b	Options listed in standard	User requirement ^a
Method of functional units connection	8.5.1, 8.5.2	Manufacturer's standard	None	
Protection against direct contact with hazardous live internal parts during maintenance or upgrade (e.g. functional units, main busbars, distribution busbars)	8.4	No requirements for protection during maintenance or upgrade	None	
Current carrying capability				
Rated current of the ASSEMBLY I_{nA} (amps)	3.8.9.1, 5.3, 8.4.3.2.3, 8.5.3, 8.8, 10.10.2, 10.10.3, 10.11.5, Annex E	Manufacturer's standard, according to application	None	
Rated current of circuits I_{nc} (amps)	5.3.2	Manufacturer's standard, according to application	None	
Rated diversity factor	5.4, 10.10.2.3, Annex E	As defined within the standard	RDF for groups of circuits / RDF for whole ASSEMBLY	
Ratio of cross section of the neutral conductor to phase conductors: phase conductors up to and including 16 mm ²	8.6.1	100 %	None	
Ratio of cross section of the neutral conductor to phase conductors: phase conductors above 16 mm ²	8.6.1	50 % (min. 16 mm ²)	None	
<p>a For exceptionally onerous applications, the user may need to specify more stringent requirements to those in the standard.</p> <p>b In some cases information declared by the ASSEMBLY manufacturer may take the place of an agreement.</p>				

Annex D (informative)

Design verification

Table D.1 – List of design verifications to be performed

No.	Characteristic to be verified	Clauses or subclauses	Verification options available		
			Testing	Comparison with a reference design	Assessment
1	Strength of material and parts:	10.2			
	Resistance to corrosion	10.2.2	YES	NO	NO
	Properties of insulating materials:	10.2.3			
	Thermal stability	10.2.3.1	YES	NO	NO
	Resistance to abnormal heat and fire due to internal electric effects	10.2.3.2	YES	NO	YES
	Resistance to ultra-violet (UV) radiation	10.2.4	YES	NO	YES
	Lifting	10.2.5	YES	NO	NO
	Mechanical impact	10.2.6	YES	NO	NO
	Marking	10.2.7	YES	NO	NO
2	Degree of protection of enclosures	10.3	YES	NO	YES
3	Clearances	10.4	YES	NO	NO
4	Creepage distances	10.4	YES	NO	NO
5	Protection against electric shock and integrity of protective circuits:	10.5			
	Effective continuity between the exposed conductive parts of the ASSEMBLY and the protective circuit	10.5.2	YES	NO	NO
	Short-circuit withstand strength of the protective circuit	10.5.3	YES	YES	NO
6	Incorporation of switching devices and components	10.6	NO	NO	YES
7	Internal electrical circuits and connections	10.7	NO	NO	YES
8	Terminals for external conductors	10.8	NO	NO	YES
9	Dielectric properties:	10.9			
	Power-frequency withstand voltage	10.9.2	YES	NO	NO
	Impulse withstand voltage	10.9.3	YES	NO	YES
10	Temperature-rise limits	10.10	YES	YES	YES
11	Short-circuit withstand strength	10.11	YES	YES	NO
12	Electromagnetic compatibility (EMC)	10.12	YES	NO	YES
13	Mechanical operation	10.13	YES	NO	NO

Annex E

(informative)

Rated diversity factor

E.1 General

All circuits within an ASSEMBLY are individually capable of carrying their rated current, in accordance with 5.3.2, continuously but, the current carrying capacity of any circuit may be influenced by adjacent circuits. Thermal interaction can result in heat being imported from, or exported to, circuits in close proximity. Cooling air available to a circuit may be at a temperature well in excess of the ambient due to the influence of other circuits.

In practise, not all circuits within an ASSEMBLY are normally required to carry rated current continuously and simultaneously. Within a typical application the type and nature of loads differ appreciably. Some circuits will be rated on the basis of inrush currents and intermittent or short duration loads. A number of circuits may be heavily loaded while others are lightly loaded or switched off.

To provide ASSEMBLIES in which all circuits can be operated at rated current continuously is therefore unnecessary and would be an inefficient use of materials and resources. This standard recognises the practical requirements of ASSEMBLIES through the assignment of a rated diversity factor as defined in 3.8.11.

By stating a rated diversity factor, the ASSEMBLY manufacturer is specifying the 'average' loading conditions for which the ASSEMBLY is designed. The rated diversity factor confirms the per unit value of rated current to which all the outgoing circuits, or a group of outgoing circuits, within the ASSEMBLY, can be continuously and simultaneously loaded. In ASSEMBLIES where the total of the rated currents of the outgoing circuits operating at rated diversity factor exceeds the capacity of the incoming circuit, the diversity factor applies to any combination of outgoing circuits used to distribute the incoming current.

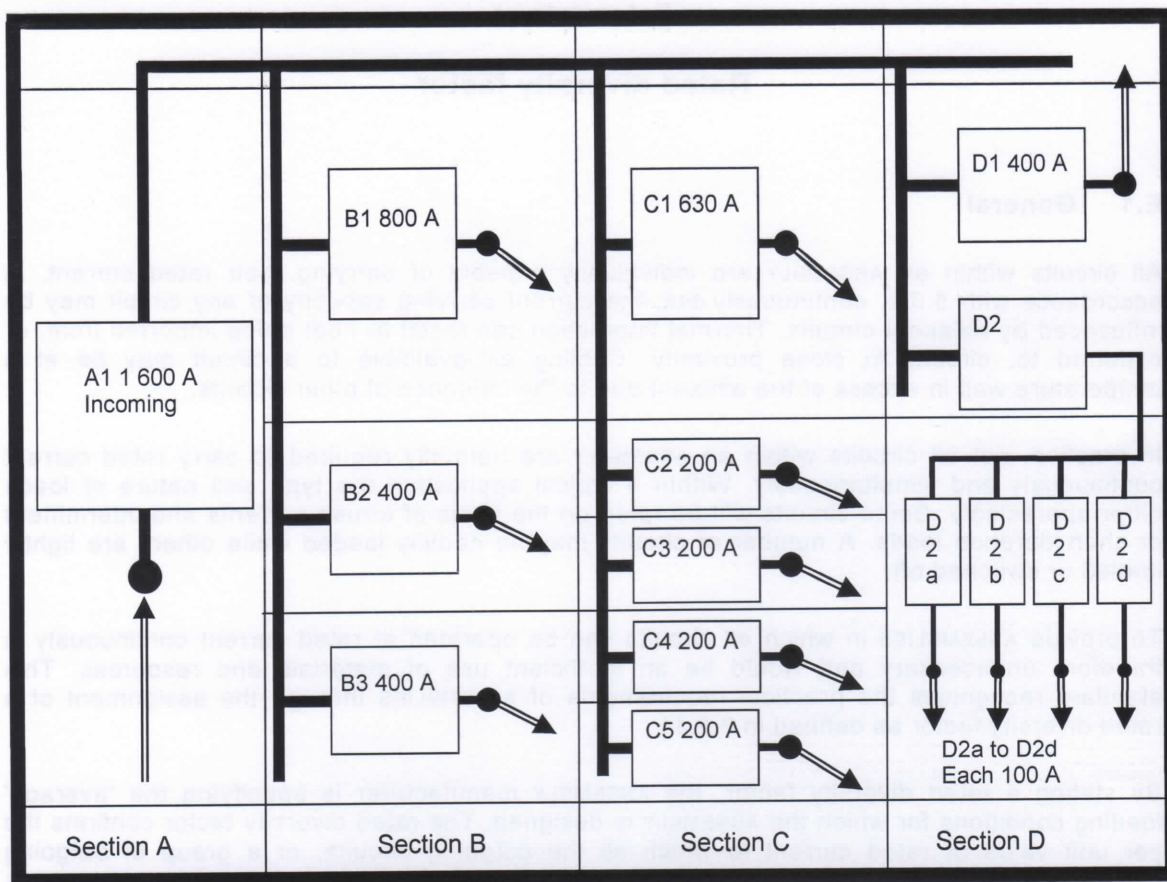
E.2 Rated diversity factor of an ASSEMBLY

The rated diversity factor of an ASSEMBLY is specified in 5.4. For the typical ASSEMBLY shown in Figure E.1, examples of the multitude of loading arrangements for a diversity factor of 0,8 are given in Table E.1 and shown in Figures E.2 to E.5.

E.3 Rated diversity factor of a group of outgoing circuits

In addition to stating the rated diversity factor for a complete ASSEMBLY, an ASSEMBLY manufacturer may specify a different diversity factor for a group of related circuits within an ASSEMBLY. Subclause 5.4 specifies the rated diversity factor for a group of outgoing circuits.

Tables E.2 and E.3 give examples of a diversity factor of 0,9 for a section and subdistribution board within the typical ASSEMBLY shown in Figure E.1.



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Functional unit – Rated current (I_n) shown ^a

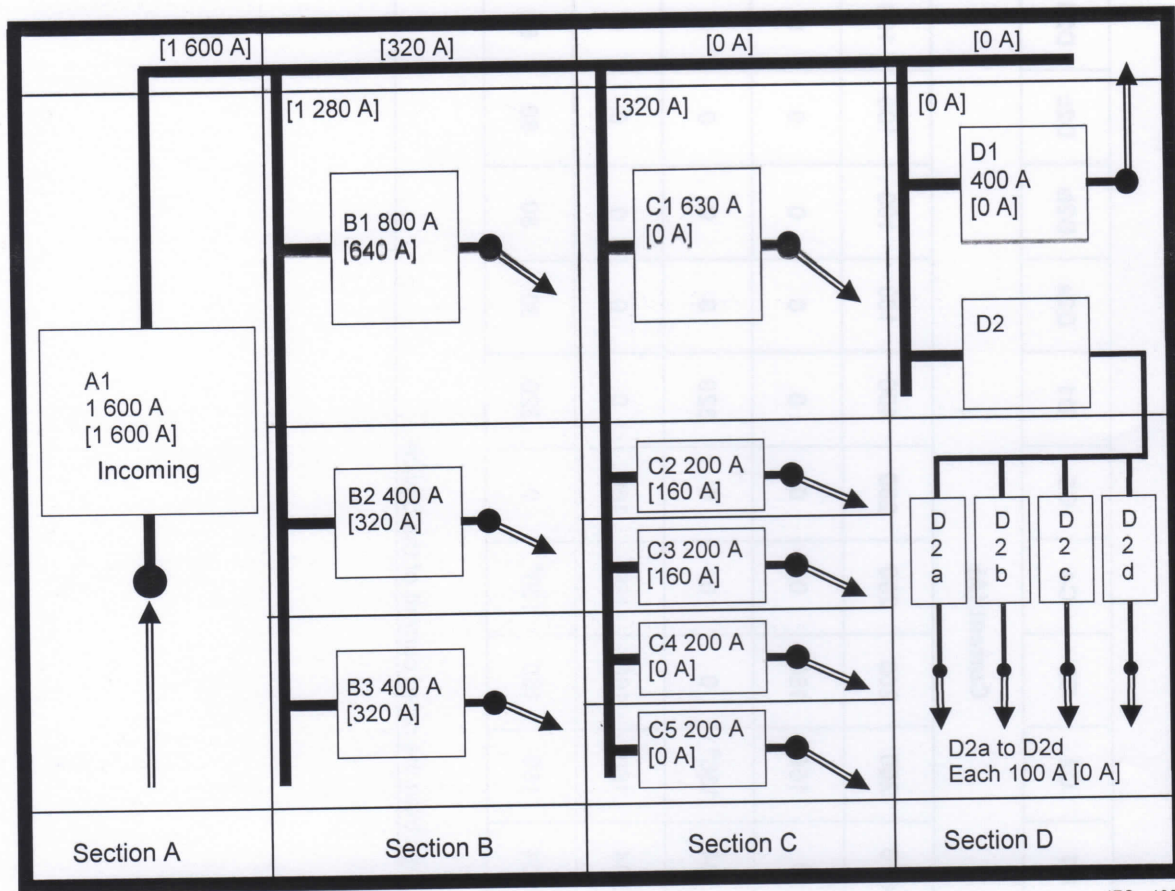
- ^a The rated current of the functional unit (the circuit) in the ASSEMBLY may be less than the rated current of the device.

Figure E.1 – Typical ASSEMBLY

Table E.1 – Examples of loading for an ASSEMBLY with a rated diversity factor of 0,8

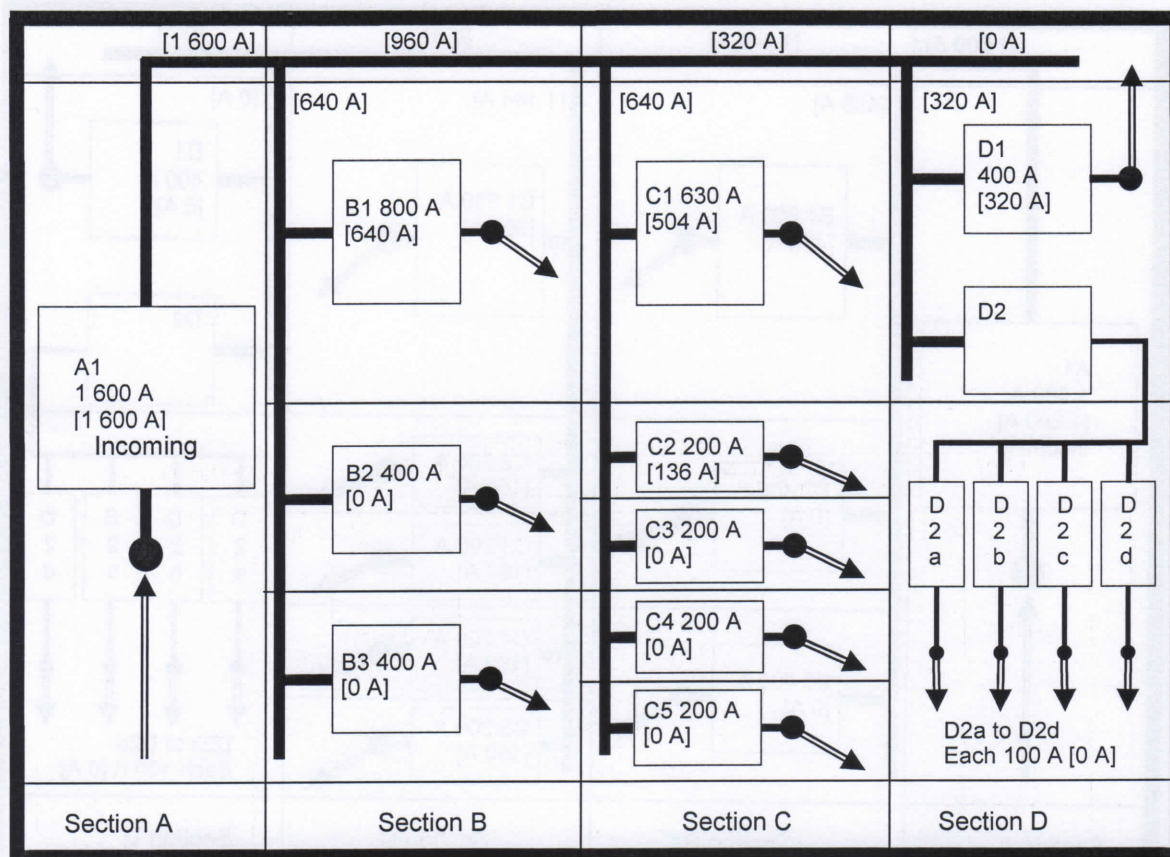
Functional unit	A1	B1	B2	B3	C1	C2	C3	C4	C5	D1	D2a	D2b	D2c	D2d
	Current (A)													
Functional unit - rated current (I_n) ^b (See Figure E.1)	1 600	800	400	400	630	200	200	200	200	400	100	100	100	100
Functional unit loading for an ASSEMBLY with a rated diversity factor of 0,8	Example 1 Figure E.2	1 600	640	320	320	0	160	0	0	0	0	0	0	0
	Example 2 Figure E.3	1 600	640	0	0	504	136 ^a	0	0	320	0	0	0	0
	Example 3 Figure E.4	1 600	456 ^a	0	0	504	160	160	160	0	0	0	0	0
	Example 4 Figure E.5	1 600	0	0	0	504	160	136 ^a	0	320	80	80	80	80

^a Balance current to load incoming circuit to its rated current.^b The rated current of the functional unit (the circuit) in the ASSEMBLY may be less than the rated current of the device.



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Figure E.2 – Example 1: Table E.1 – Functional unit loading for an ASSEMBLY with a rated diversity factor of 0,8

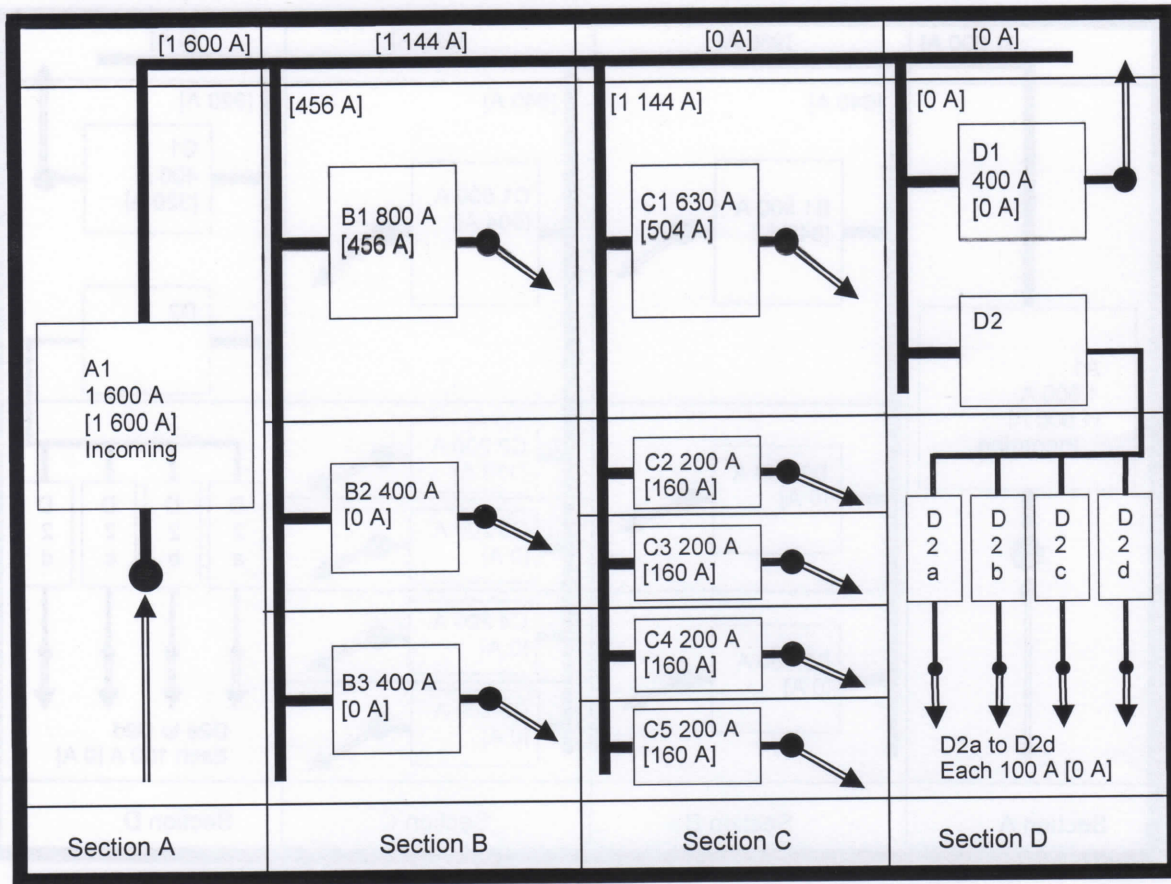


IEC 1854/11

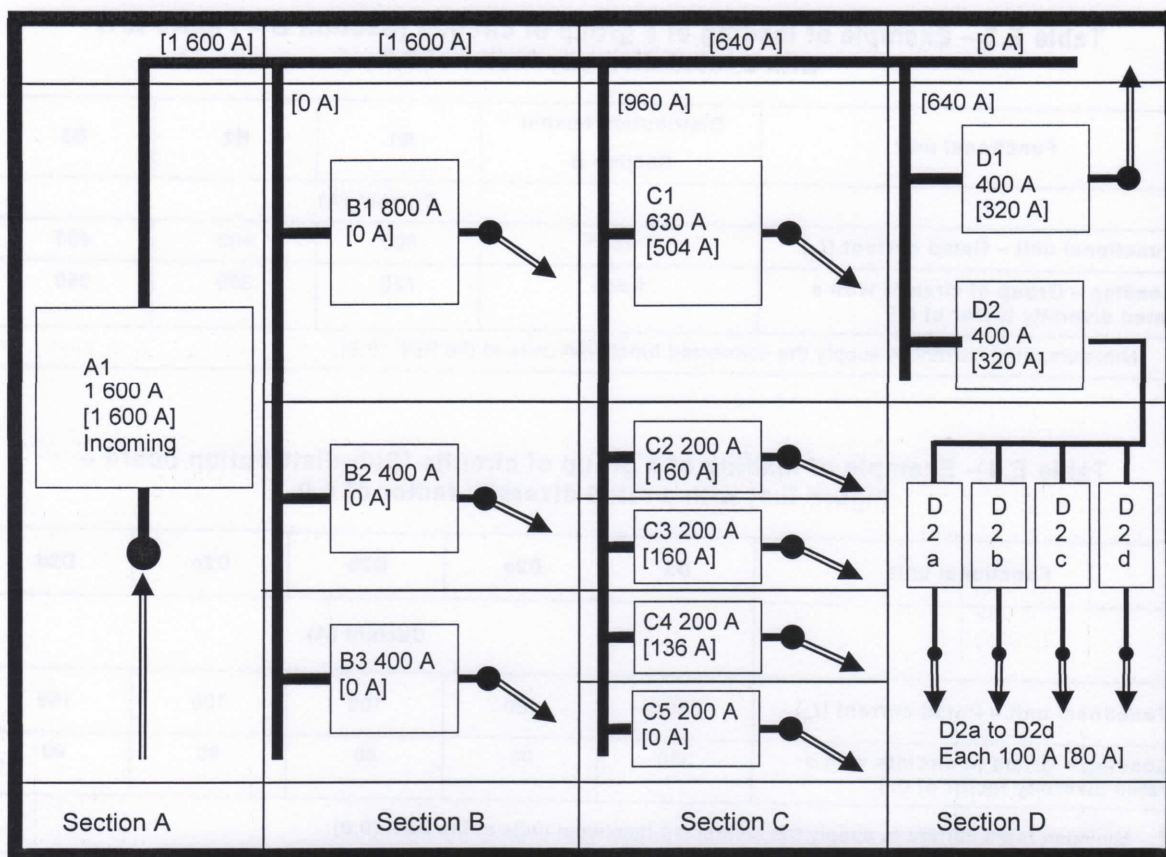
Actual loading is indicated by the figures in brackets e.g. [640 A].

Busbar section loading is indicated by the figure in brackets e.g. [320 A].

Figure E.3 – Example 2: Table E.1 – Functional unit loading for an ASSEMBLY with a rated diversity factor of 0,8



Actual loading is indicated by the figures in brackets e.g. [640 A].
 Busbar section loading is indicated by the figure in brackets e.g. [320 A].
**Figure E.4 – Example 3: Table E.1 – Functional unit loading for an ASSEMBLY
 with a rated diversity factor of 0,8**



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Actual loading is indicated by the figures in brackets e.g. [640 A].

Busbar section loading is indicated by the figure in brackets e.g. [320 A].

Figure E.5 – Example 4: Table E.1 – Functional unit loading for an ASSEMBLY with a rated diversity factor of 0,8

Table E.2 – Example of loading of a group of circuits (Section B – Figure E.1) with a rated diversity factor of 0,9

Functional unit	Distribution busbar Section B	B1	B2	B3
Current (A)				
Functional unit – Rated current (I_n)	1 440 ^a	800	400	400
Loading – Group of circuits with a rated diversity factor of 0,9	1 440	720	360	360

^a Minimum rated current to supply the connected functional units at the RDF (0,9).

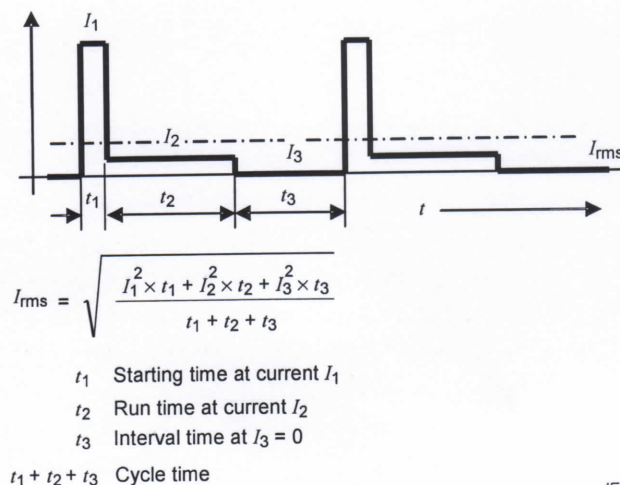
Table E.3 – Example of loading of a group of circuits (Sub-distribution board – Figure E.1) with a rated diversity factor of 0,9

Functional unit	D2	D2a	D2b	D2c	D2d
Current (A)					
Functional unit – Rated current (I_n)	360 ^a	100	100	100	100
Loading – Group of circuits with a rated diversity factor of 0,9	360	90	90	90	90

^a Minimum rated current to supply the connected functional units at the RDF (0,9).

E.4 Rated diversity factor and intermittent duty

The dissipated heat of circuits built from components with Joule losses is proportional to the true r.m.s value of the current. An equivalent r.m.s current representing the thermal effect of the real intermittent current can be calculated by the formula given below. This enables the thermal equivalent true r.m.s current (I_{eff}) in case of intermittent duty to be determined and thus the permissible load pattern for a given RDF. Care should be taken with ON-times > 30 min since small devices could already reach the thermal equilibrium.



IEC 1857/11

Figure E.6 – Example of average heating effect calculation

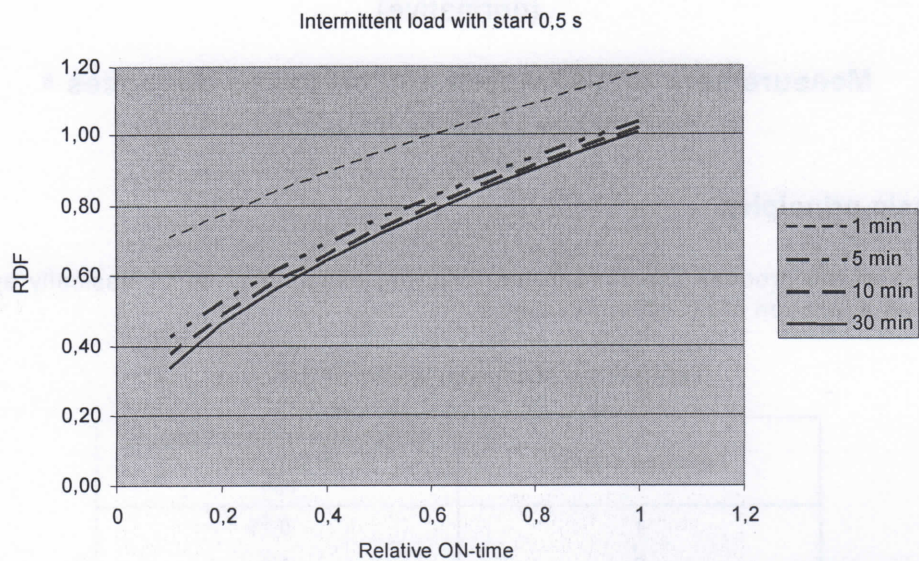


Figure E.7 – Example graph for the relation between the equivalent RDF and the parameters at intermittent duty at $t_1 = 0,5$ s, $I_1 = 7 \cdot I_2$ at different cycle times

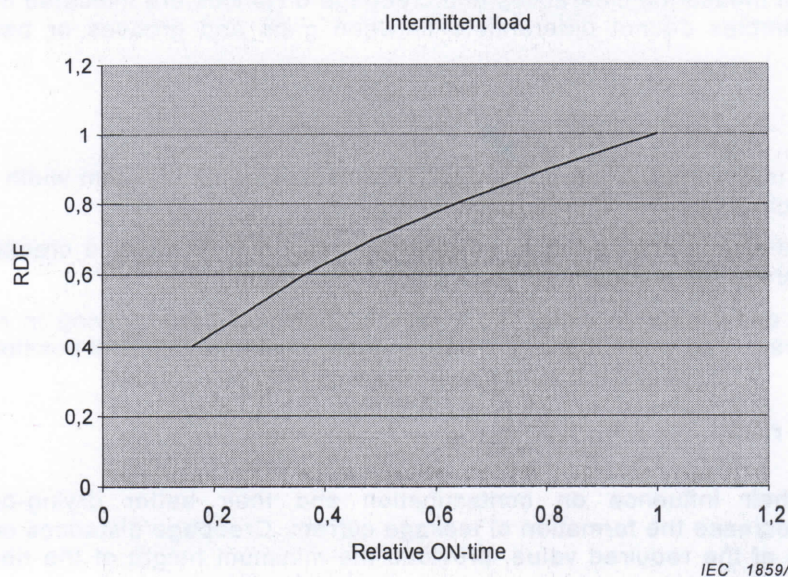


Figure E.8 – Example graph for the relation between the equivalent RDF and the parameters at intermittent duty at $I_1 = I_2$ (no starting overcurrent)

Annex F (normative)

Measurement of clearances and creepage distances ⁶

F.1 Basic principles

The width X of the grooves specified in the following examples 1 to 11 basically apply to all examples as a function of pollution as follows:

Table F.1 – Minimum width of grooves

Pollution degree	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 be reduced to one-third of this clearance.

The methods of measuring clearances and creepage distances are indicated in examples 1 to 11. 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 example 3);
- where the distance across the top of a groove is X mm or more, a creepage distance is measured along the contours of the grooves (see example 2);
- clearances and creepage distances measured between parts moving in relation to each other are measured when these parts are in their most unfavourable positions.

F.2 Use of ribs

Because of their influence on contamination and their better drying-out effect, ribs considerably decrease the formation of leakage current. Creepage distances can therefore be reduced to 0,8 of the required value, provided the minimum height of the ribs is 2 mm, see Figure F.1.

⁶ This Annex F is based on IEC 60664-1:2007.

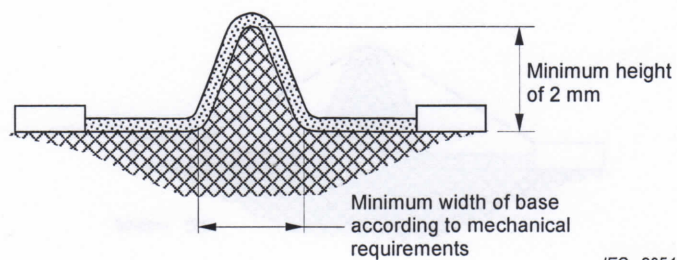
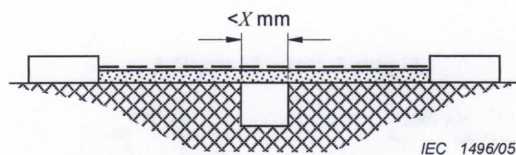


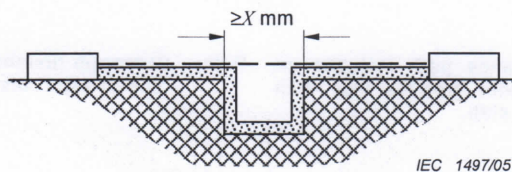
Figure F.1 a) – Measurement of ribs: examples



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 clearances are measured directly across the groove as shown.

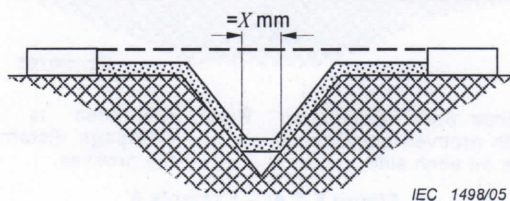
Figure F.1 b) – Example 1



Condition: This creepage distance path includes a parallel-sided groove of any depth and 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 F.1 c) – Example 2



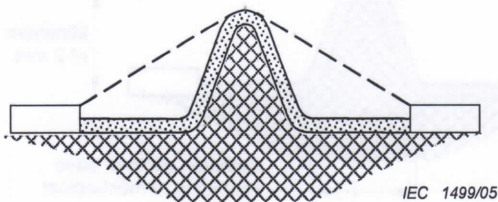
Condition: This creepage distance path includes a V-shaped groove with a width greater than X mm

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 F.1 d) – Example 3

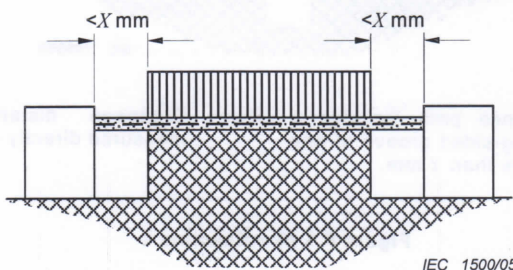
----- Clearance

Creepage distance



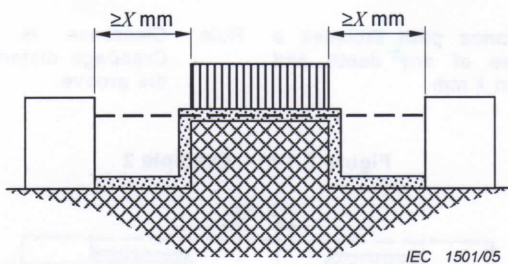
Condition: This creepage distance path includes a rib. Rule: Clearance is the shortest air path over the top of the rib. Creepage path follows the contour of the rib.

Figure F.1 e) – 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 paths are the "line-of-sight" distance shown.

Figure F.1 f) – Example 5

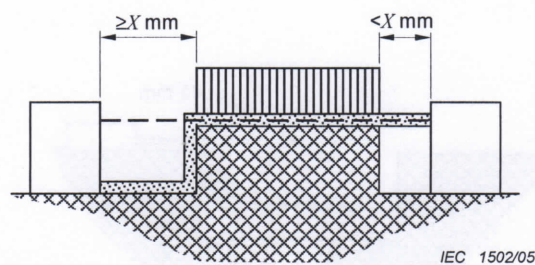


Condition: This creepage distance path includes an uncemented joint with grooves equal to or more than X mm wide on each side. Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the grooves.

Figure F.1 g) – Example 6

----- Clearance

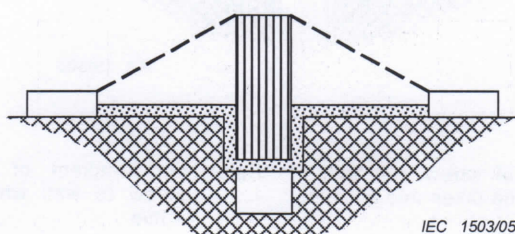
===== Creepage distance



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: Clearances and creepage distance paths are as shown.

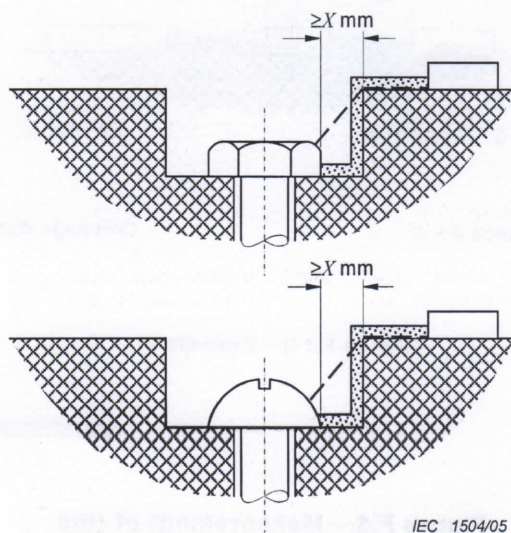
Figure F.1 h) – Example 7



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 F.1 i) – Example 8



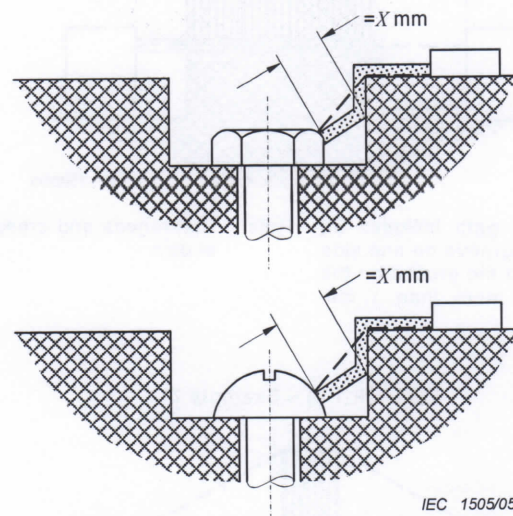
Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

Rule: Clearances and creepage distance paths are as shown.

Figure F.1 j) – Example 9

----- Clearance

Creepage distance

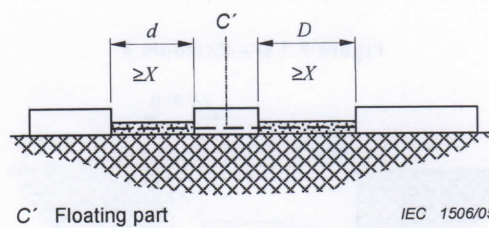


IEC 1505/05

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 F.1 k) – Example 10



C' Floating part

IEC 1506/05

Clearance is the distance $d + D$

Creepage distance is also $d + D$

Figure F.1 l) – Example 11

----- Clearance

Creepage distance

Figure F.1 – Measurement of ribs

Annex G

(normative)

Correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of the equipment⁷

This annex is intended to give the necessary information concerning the choice of equipment for use in a circuit within an electrical system or part thereof.

Table G.1 provides examples of the correlation between nominal supply system voltages and the corresponding rated impulse withstand voltage of the equipment.

The values of rated impulse voltage given in Table G.1 are based on 4.3.3 of IEC 60664-1:2007. Further information about criteria for the selection of an appropriate overvoltage category and overvoltage protection (if necessary) is given in IEC 60364-4-44:2007, Clause 443.

It should be recognized that control of overvoltages with respect to the values in Table G.1 can also be achieved by conditions in the supply system such as the existence of a suitable impedance or cable feed.

⁷ This annex is based on Annex H of IEC 60947-1:2007.

Table G.1 – Correspondence between the nominal voltage of the supply system and the equipment rated impulse withstand voltage

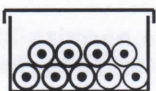


Maximum value of rated operational voltage to earth, a.c. r.m.s. or d.c. V	Nominal voltage of the supply system (≤ rated insulation voltage of the equipment) V			Preferred values of rated impulse withstand voltage (1,2/50 µs) at 2 000 m kV			
	AC r.m.s.	AC r.m.s.	AC r.m.s. or d.c.	IV Origin of installation (service entrance) level	III Distribution circuit level	II Load (appliance, equipment) level	I Specially protected level
50	–	–	AC r.m.s. or d.c.	1,5	0,8	0,5	0,33
100	66/115	66	12,5, 24, 25, 30, 42, 48	2,5	1,5	0,8	0,5
150	120/208 127/220	115, 120 127	110, 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	6	4	2,5	1,5
600	347/600, 380/660 400/690, 415/720 480/830	347, 380, 400 415, 440, 480 500, 577, 600	480	8	6	4	2,5
1 000	–	660 690, 720 830, 1 000	1 000	12	8	6	4

Annex H (informative)

Operating current and power loss of copper conductors

The following tables provide guidance values for conductor operating currents and power losses under ideal conditions within an ASSEMBLY. The calculation methods used to establish these values are given to enable values to be calculated for other conditions.

**Table H.1 – Operating current and power loss of single-core copper cables
with a permissible conductor temperature of 70 °C
(ambient temperature inside the ASSEMBLY: 55 °C)**

Conductor arrangement							
		Single-core cables in a cable trunking on a wall, run horizontally. 6 of the cables (2 three-phase circuits) continuously loaded		Single-core cables, touching free in air or on a perforated tray. 6 cables (2 three-phase circuits) continuously loaded		Single-core cables, spaced horizontally in free air	
Cross-sectional area of conductor	Resistance of conductor at 20 °C, R_{20}^a	Max. operating current I_{max}^b	Power-losses per conductor P_v	Max. operating current I_{max}^c	Power-losses per conductor P_v	Max. operating current I_{max}^d	Power-losses per conductor P_v
mm ²	mΩ/m	A	W/m	A	W/m	A	W/m
1,5	12,1	8	0,8	9	1,3	15	3,2
2,5	7,41	10	0,9	13	1,5	21	3,7
4	4,61	14	1,0	18	1,7	28	4,2
6	3,08	18	1,1	23	2,0	36	4,7
10	1,83	24	1,3	32	2,3	50	5,4
16	1,15	33	1,5	44	2,7	67	6,2
25	0,727	43	1,6	59	3,0	89	6,9
35	0,524	54	1,8	74	3,4	110	7,7
50	0,387	65	2,0	90	3,7	134	8,3
70	0,268	83	2,2	116	4,3	171	9,4
95	0,193	101	2,4	142	4,7	208	10,0
120	0,153	117	2,5	165	5,0	242	10,7
150	0,124			191	5,4	278	11,5
185	0,099 1			220	5,7	318	12,0
240	0,075 4			260	6,1	375	12,7

a Values from IEC 60228:2004, Table 2 (stranded conductors).
b Current carrying capacity I_{30} for one three-phase circuit from IEC 60364-5-52:2009, Table B.52.4, col. 4 (Method of installation: Item 6 in Table B.52.3). $k_2=0,8$ (Item 1 in Table B.52.17, two circuits).
c Current carrying capacity I_{30} for one three-phase circuit from IEC 60364-5-52:2009, Table B.52.10, col. 5 (Method of installation: Item F in Table B.52.1). Values for cross-sections less than 25 mm² calculated following Annex D of IEC 60364-5-52:2009. $k_2=0,88$ (item 4 in Table B.52.17, two circuits).
d Current carrying capacity I_{30} for one three-phase circuit from IEC 60364-5-52, Table B.52.10, col. 7 (Method of installation: item G in Table B.52.1). Values for cross-sections less than 25 mm² calculated following Annex D of IEC 60364-5-52:2009. ($k_2=1$)

$$I_{\max} = I_{30} \times k_1 \times k_2 \quad P_v = I_{\max}^2 \times R_{20} \times [1 + \alpha \times (T_c - 20 \text{ °C})]$$

where

- k_1 reduction factor for air temperature inside the enclosure around the conductors (IEC 60364-5-52:2009, Table B.52.14)
 $k_1 = 0,61$ for conductor temperature 70 °C, ambient temperature 55 °C
 k_1 for other air temperatures: see Table H.2;
- k_2 reduction factor for groups of more than one circuit (IEC 60364-5-52:2009, Table B.52.17) ;
- α temperature coefficient of resistance, $\alpha = 0,004 \text{ K}^{-1}$;
- T_c conductor temperature.

Table H.2 – Reduction factor k_1 for cables with a permissible conductor temperature of 70 °C (extract from IEC 60364-5-52:2009, Table B.52.14)

Air temperature inside the enclosure around the conductors °C	Reduction factor k_1
20	1,12
25	1,06
30	1,00
35	0,94
40	0,87
45	0,79
50	0,71
55	0,61
60	0,50

NOTE If the operating current in Table H.1 is converted for other air temperatures using the reduction factor k_1 , then also the corresponding power losses must be calculated using the formula given above.

Annex I

(Void)

Annex J (normative)

Electromagnetic compatibility (EMC)

J.1 General

The subclause numbering within this annex aligns with that of the body of the standard.

J.2 Terms and definitions

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

(See Figure J.1)

J.3.8.13.1

port

particular interface of the specified apparatus with external electromagnetic environment

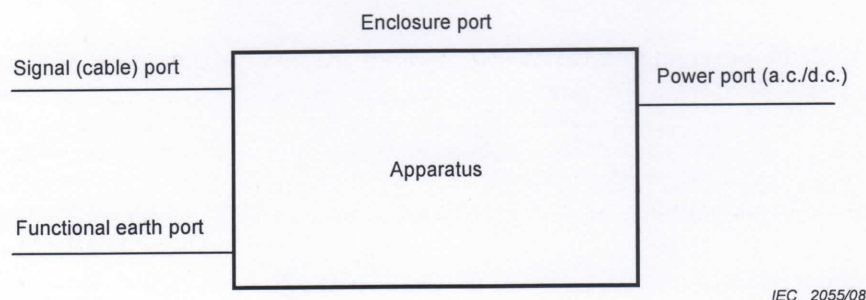


Figure J.1 – Examples of ports

J.3.8.13.2

enclosure port

physical boundary of the apparatus through which electromagnetic fields may radiate or impinge on

J.3.8.13.3

functional earth port

port other than signal, control or power port, intended for connection to earth for purposes other than electrical safety

J.3.8.13.4

signal port

port at which a conductor or cable intended to carry signals is connected to the apparatus

NOTE Examples are analogue inputs, outputs and control lines; data busses; communication networks etc.

[3.4 of IEC 61000-6-1:2005]

J.3.8.13.5

power port

port at which a conductor or cable carrying the primary electrical power needed for the operation (functioning) of an apparatus or associated apparatus is connected to the apparatus

J.9.4 Performance requirements

J.9.4.1 General

For the majority of ASSEMBLIES applications falling within the scope of this standard, two sets of environmental conditions are considered and are referred to as

- a) Environment A;
- b) Environment B.

Environment A: relates to a power network supplied from a high or medium voltage transformer dedicated to the supply of an installation feeding manufacturing or similar plant, and intended to operate in or in proximity to industrial locations, as described below. This standard applies also to apparatus which is battery operated and intended to be used in industrial locations.

The environments encompassed are industrial, both indoor and outdoor.

Industrial locations are in addition characterised by the existence of one or more of the following examples:

- industrial, scientific and medical (ISM) apparatus (as defined in CISPR 11);
- heavy inductive or capacitive loads are frequently switched;
- currents and associated magnetic fields are high.

NOTE 1 Environment A is covered by the generic EMC standards IEC 61000-6-2 and IEC 61000-6-4.

Environment B: relates to low-voltage public mains networks or apparatus connected to a dedicated DC source which is intended to interface between the apparatus and the low-voltage public mains network. It applies also to apparatus which is battery operated or is powered by a non-public, but non-industrial, low voltage power distribution system if this apparatus is intended to be used in the locations described below.

The environments encompassed are residential, commercial and light-industrial locations, both indoor and outdoor. The following list, although not comprehensive, gives an indication of locations which are included:

- residential properties, for example houses, apartments;
- retail outlets, for example shops, supermarkets;
- business premises, for example offices, banks;
- areas of public entertainment, for example cinemas, public bars, dance halls; outdoor locations, for example petrol stations, car parks, amusement and sports centres;
- light-industrial locations, for example workshops, laboratories, service centres.

Locations which are characterised by being supplied directly at low voltage from the public mains network are considered to be residential, commercial or light-industrial.

NOTE 2 Environment B is covered by the generic EMC standards IEC 61000-6-1 and IEC 61000-6-3.

The environmental condition A and/or B for which the ASSEMBLY is suitable shall be stated by the ASSEMBLY manufacturer.

J.9.4.2 Requirement for testing

ASSEMBLIES are in most cases manufactured or assembled on a one-off basis, incorporating a more or less random-combination of devices and components.

No EMC immunity or emission tests are required on final ASSEMBLIES if the following conditions are fulfilled:

- a) the incorporated devices and components are in compliance with the requirements for EMC for the stated environment (see J.9.4.1) as required by the relevant product or generic EMC standard.
- b) the internal installation and wiring is carried out in accordance with the devices and components manufacturer's instructions (arrangement with regard to mutual influences, cable, screening, earthing etc.)

In all other cases the EMC requirements are to be verified by tests as per J.10.12.

J.9.4.3 Immunity

J.9.4.3.1 ASSEMBLIES not incorporating electronic circuits

Under normal service conditions, ASSEMBLIES not incorporating electronic circuits are not sensitive to electromagnetic disturbances and therefore no immunity tests are required.

J.9.4.3.2 ASSEMBLIES incorporating electronic circuits

Electronic equipment incorporated in ASSEMBLIES shall comply with the immunity requirements of the relevant product or generic EMC standard and shall be suitable for the specified EMC environment stated by the ASSEMBLY manufacturer.

In all other cases the EMC requirements are to be verified by tests as per J.10.12.

Equipment utilizing electronic circuits in which all components are passive (for example diodes, resistors, varistors, capacitors, surge suppressors, inductors) are not required to be tested.

The ASSEMBLY manufacturer shall obtain from the device and or component manufacturer the specific performance criteria of the product based on the acceptance criteria given in the relevant product standard.

J.9.4.4 Emission

J.9.4.4.1 ASSEMBLIES not incorporating electronic circuits

For ASSEMBLIES not incorporating electronic circuits, electromagnetic disturbances can only be generated by equipment during occasional switching operations. The duration of the disturbances is of the order of milliseconds. The frequency, the level and the consequences of these emissions are considered as part of the normal electromagnetic environment of low-voltage installations. Therefore, the requirements for electromagnetic emission are deemed to be satisfied, and no verification is necessary.

J.9.4.4.2 ASSEMBLIES incorporating electronic circuits

Electronic equipment incorporated in the ASSEMBLY shall comply with the emission requirements of the relevant product or generic EMC standard and shall be suitable for the specific EMC environment stated by the ASSEMBLY manufacturer.

ASSEMBLIES incorporating electronic circuits (such as switched mode power supplies, circuits incorporating microprocessors with high-frequency clocks) may generate continuous electromagnetic disturbances.

For such emissions, these shall not exceed the limits specified in the relevant product standard, or the requirements of IEC 61000-6-4 for environment A and/or IEC 61000-6-3 for environment B shall apply. Tests are to be carried out as detailed in the relevant product standard, if any, otherwise according to J.10.12.

J.10.12 Tests for EMC

Functional units within ASSEMBLIES which do not fulfil the requirements of J.9.4.2 a) and b) shall be subjected to the following tests, as applicable.

The emission and immunity tests shall be carried out in accordance with the relevant EMC standard. However, the ASSEMBLY manufacturer shall specify any additional measures necessary to verify the criteria of performance for the ASSEMBLIES if necessary (e.g. application of dwell times).

J.10.12.1 Immunity tests

J.10.12.1.1 ASSEMBLIES not incorporating electronic circuits

No tests are necessary; see J.9.4.3.1.

J.10.12.1.2 ASSEMBLIES incorporating electronic circuits

Tests shall be made according to the relevant environment A or B. The values are given in Tables J.1 and/or J.2 except where a different test level is given in the relevant specific product standard and justified by the electronic components manufacturer.

Performance criteria shall be stated by the ASSEMBLIES manufacturer based on the acceptance criteria in Table J.3.

J.10.12.2 Emission tests

J.10.12.2.1 ASSEMBLIES not incorporating electronic circuits

No tests are necessary; see J.9.4.4.1.

J.10.12.2.2 ASSEMBLIES incorporating electronic circuits

The ASSEMBLIES manufacturer shall specify the test methods used; see J.9.4.4.2.

The emission limits for environment A are given in IEC 61000-6-4:2006, Table 1.

The emission limits for environment B are given in IEC 61000-6-3:2006, Table 1.

If the assembly incorporates telecommunication ports, the emission requirements of CISPR 22, relevant to that port and to the selected environment, shall apply.

Table J.1 – Tests for EMC immunity for environment A
(see J.10.12.1)

Type of test	Test level required	Performance criterion ^c
Electrostatic discharge immunity test IEC 61000-4-2	± 8 kV / air discharge or ± 4 kV / contact discharge	B
Radiated radio-frequency electromagnetic field immunity test IEC 61000-4-3 at 80 MHz to 1 GHz and 1,4 GHz to 2 GHz	10 V/m on enclosure port	A
Electrical fast transient/burst immunity test IEC 61000-4-4	± 2 kV on power ports ± 1 kV on signal ports including auxiliary circuits and functional earth	B
1,2/50 µs and 8/20 µs surge immunity test IEC 61000-4-5 ^a	± 2 kV (line to earth) on power ports, ± 1 kV (line to line) on power ports, ± 1 kV (line to earth) on signal ports	B
Conducted radio-frequency immunity test IEC 61000-4-6 at 150 kHz to 80 MHz	10 V on power ports, signal ports and functional earth	A
Immunity to power-frequency magnetic fields IEC 61000-4-8	30 A/m ^b on enclosure port	A
Immunity to voltage dips and interruptions IEC 61000-4-11 ^d	30 % reduction for 0,5 cycles 60 % reduction for 5 and 50 cycles >95 % reduction for 250 cycles	B C C
Immunity to harmonics in the supply IEC 61000-4-13	No requirements	
^a For equipment and/or input/output ports with a rated d.c. voltage of 24 V or less tests are not required. ^b Applicable only to apparatus containing devices susceptible to magnetic fields. ^c Performance criteria are independent of the environment. See Table J.3. ^d Applicable only to mains input power ports.		

**Table J.2 – Tests for EMC immunity for environment B
(see J.10.12.1)**

Type of test	Test level required	Performance criterion ^c
Electrostatic discharge immunity test IEC 61000-4-2	± 8 kV / air discharge or ± 4 kV / contact discharge	B
Radiated radio-frequency electromagnetic field immunity test IEC 61000-4-3 at 80 MHz to 1 GHz and 1,4 GHz to 2 GHz	3 V/m on enclosure port	A
Electrical fast transient/burst immunity test IEC 61000-4-4	± 1 kV on power ports ± 0,5 kV on signal ports including auxiliary circuits and functional earth	B
1,2/50 µs and 8/20 µs surge immunity test IEC 61000-4-5 ^a	± 0,5 kV (line to earth) for signal and power ports except for mains supply input port where ±1 kV applies (line to earth) ± 0,5 kV (line to line)	B
Conducted radio-frequency immunity test IEC 61000-4-6 at 150 kHz to 80 MHz	3 V on power ports, signal ports and functional earth	A
Immunity to power-frequency magnetic fields IEC 61000-4-8	3 A/m ^b on enclosure port	A
Immunity to voltage dips and interruptions IEC 61000-4-11 ^d	30 % reduction for 0,5 cycles 60 % reduction for 5 cycles >95 % reduction for 250 cycles	B C C
Immunity to harmonics in the supply IEC 61000-4-13	No requirements	
^a For equipment and/or input/output ports with a rated d.c. voltage of 24 V or less tests are not required. ^b Applicable only to apparatus containing devices susceptible to magnetic fields. ^c Performance criteria are independent of the environment. See Table J.3. ^d Applicable only to mains input power ports.		

Table J.3 – Acceptance criteria when electromagnetic disturbances are present

Item	Acceptance criteria (performance criteria during tests)		
	A	B	C
Overall performance	No noticeable changes of the operating characteristic Operating as intended	Temporary degradation or loss of performance which is self-recoverable	Temporary degradation or loss of performance which requires operator intervention or system reset ^a
Operation of power and auxiliary circuits	No unwanted operation	Temporary degradation or loss of performance which is self-recoverable ^a	Temporary degradation or loss of performance which requires operator intervention or system reset ^a
Operation of displays and control panels	No changes to visible display information Only slight light intensity fluctuation of LEDs, or slight movement of characters	Temporary visible changes or loss of information Undesired LED illumination	Shut down or permanent loss of display. Wrong information and/or unpermitted operating mode, which should be apparent or an indication should be provided. Not self-recoverable
Information processing and sensing functions	Undisturbed communication and data interchange to external devices	Temporarily disturbed communication, with possible error reports of the internal and external devices	Erroneous processing of information Loss of data and/or information Errors in communication Not self-recoverable

^a Specific requirements shall be detailed in the product standard.

Annex K **(normative)**

Protection by electrical separation

K.1 General

Electrical separation is a protective measure in which:

- basic protection (protection against direct contact) is provided by basic insulation between hazardous live parts and exposed conductive parts of a separated circuit, and
- fault protection (protection against indirect contact) is provided:
 - by simple separation of the separated circuit from other circuits and from earth;
 - by an earth-free protective equipotential bonding interconnecting exposed equipment parts of the separated circuit where more than one item of equipment is connected to the separated circuit.

Intentional connection of exposed conductive parts to a protective conductor or to an earth conductor is not permitted.

K.2 Electrical separation

K.2.1 General

Protection by electrical separation shall be ensured by compliance with all the requirements of K.2.2 to K.2.5.

K.2.2 Supply source

The circuit shall be supplied through a source that provides separation i.e.

- an isolating transformer, or
- a source of current providing a degree of safety equivalent to that of the isolating transformer specified above, for example a motor generator with windings providing equivalent isolation.

NOTE Ability to withstand a particularly high test voltage is recognized as a means of ensuring the necessary degree of isolation.

Mobile sources of supply connected to a supply system shall be selected in accordance with Clause K.3 (class II equipment or equivalent insulation).

Fixed sources of supply shall be either:

- selected in accordance with Clause K.3, or
- such that the output is separated from the input and from the enclosure by an insulation satisfying the conditions of Clause K.3; if such a source supplies several items of equipment, the exposed conductive parts of that equipment shall not be connected to the metallic enclosure of the source.

K.2.3 Selection and installation of supply source

K.2.3.1 Voltage

The voltage of the electrically separated circuit shall not exceed 500 V.

K.2.3.2 Installation

K.2.3.2.1 Live parts of the separated circuit shall not be connected at any point to another circuit or to earth.

To avoid the risk of a fault to earth, particular attention shall be given to the insulation of such parts from earth, especially for flexible cables and cords.

Arrangements shall ensure electrical separation not less than that between the input and output of an isolating transformer.

NOTE In particular the electrical separation is necessary between the live parts of electrical equipment such as relays, contactors, auxiliary switches and any part of another circuit.

K.2.3.2.2 Flexible cables and cords shall be visible throughout any part of their length liable to mechanical damage.

K.2.3.2.3 For separated circuits, the use of separate wiring systems is necessary. If the use of conductors of the same wiring system for the separated circuits and other circuits is unavoidable, multi-conductor cables without metallic covering, or insulated conductors in insulating conduit, ducting or trunking shall be used, provided that their rated voltage is not less than the highest voltage likely to occur, and that each circuit is protected against overcurrent.

K.2.4 Supply of a single item of apparatus

Where a single item of apparatus is supplied, the exposed conductive parts of the separated circuit shall not be connected either to the protective conductor or exposed conductive parts of other circuits.

NOTE If the exposed conductive parts of the separated circuit are liable to come into contact, either intentionally or fortuitously, with the exposed conductive parts of other circuits, protection against electric shock no longer depends solely on protection by electrical separation but on the protective measures to which the latter exposed conductive parts are subject.

K.2.5 Supply of more than one item of apparatus

If precautions are taken to protect the separated circuit from damage and insulation failure, a source of supply, complying with K.2.2, may supply more than one item of apparatus provided that all the following requirements are fulfilled.

- a) The exposed-conductive-parts of the separated circuit shall be connected together by insulated non-earthed equipotential bonding conductors. Such conductors shall not be connected to the protective conductors or exposed-conductive-parts of other circuits or to any extraneous conductive parts.

NOTE If the exposed-conductive-parts of the separated circuit are liable to come into contact, either intentionally or fortuitously, with the exposed-conductive-parts of other circuits, protection against electric shock no longer depends solely on protection by electrical separation but on the protective measures to which the latter exposed-conductive-parts are subject.

- b) All socket-outlets shall be provided with protective contacts which shall be connected to the equipotential bonding system provided in accordance with item a).
- c) Except where supplying class II equipment, all flexible cables shall embody a protective conductor for use as an equipotential bonding conductor.

It shall be ensured that if two faults affecting two exposed conductive parts occur and these are fed by conductors of different polarity, a protective device shall disconnect the supply in a disconnecting time conforming to Table K.1.

Table K.1 – Maximum disconnecting times for TN systems

U_0^a V	Disconnecting time s
120	0,8
230	0,4
277	0,4
400	0,2
>400	0,1
^a Values based on IEC 60038.	

For voltages which are within the tolerance band stated in IEC 60038, the disconnecting time appropriate to the nominal voltage applies.

For intermediate values of voltage, the next higher value in the above table is to be used.

K.3 Class II equipment or equivalent insulation

Protection shall be provided by electrical equipment of the following types:

- Electrical equipment having double or reinforced insulation (class II equipment)
- ASSEMBLIES having total insulation see 8.4.3.3.

This equipment is marked with the symbol .

NOTE This measure is intended to prevent the appearance of dangerous voltage on the accessible parts of electrical equipment through a fault in the basic insulation.

Annex L (informative)

Clearances and creepage distances for North American region

Table L.1 – Minimum clearances in air

Rated operational voltage V	Minimum clearances mm	
	Phase to phase	Phase to earth
(150) ^a 125 or less	12,7	12,7
(151) ^a 126-250	19,1	12,7
251-600	25,4	25,4
^a Values in brackets are applicable in Mexico.		

Table L.2 – Minimum creepage distances

Rated operational voltage V	Minimum creepage distances mm	
	Phase to phase	Phase to earth
(150) ^a 125 or less	19,1	12,7
(151) ^a 126-250	31,8	12,7
251-600	50,8	25,4
^a Values in brackets are applicable in Mexico.		

NOTE This is not a complete and exhaustive listing of all regulations that are specific to the North American marketplace.

Annex M (informative)

North American temperature rise limits

The temperature rise limitation permitted in North America are based upon the allowable rises permitted for the devices connected (wire connectors, cables, circuit breakers, etc.). In order to maintain the proper and safe performance of the entire electrical system, these must be taken into account. These requirements are mandated by the National Electrical Code, NFPA 70, Article 110.14-C, "Temperature Limitations". This document is published by the National Fire Protection Association, Quincy, Massachusetts, USA. In Mexico these requirements are mandated by NOM-001-SEDE.

Table M.1 – North American temperature rise limits

Parts of ASSEMBLIES	Temperature rise K
Unplated busbars	50
Plated busbars	65
Terminals except as covered below	50
Terminals for devices marked for use with 90 °C conductors, based upon 75 °C ampacity (current carrying capacity)	60
Terminals for devices rated 110 A and less, if marked for use with 75 °C conductors	65





Annex N (normative)

Operating current and power loss of bare copper bars

The following tables provide values for conductor operating currents and power losses under ideal conditions within an ASSEMBLY (see 10.10.2.2.3, 10.10.4.2.1 and 10.10.4.3.1). This annex does not apply to conductors verified by test.

The calculation methods used to establish these values are given to enable values to be calculated for other conditions.

Table N.1 – Operating current and power loss of bare copper bars with rectangular cross-section, run horizontally and arranged with their largest face vertical, frequency 50 Hz to 60 Hz (ambient temperature inside the ASSEMBLY: 55 °C, temperature of the conductor 70 °C)

Height x thickness of bars	Cross-sectional area of bar	One bar per phase			Two bars per phase (spacing = thickness of bars)		
							
		k_3	Operating current	Power-losses per phase conductor P_v	k_3	Operating current	Power-losses per phase conductor P_v
mm × mm	mm ²		A	W/m		A	W/m
12 × 2	23,5	1,00	70	4,5	1,01	118	6,4
15 × 2	29,5	1,00	83	5,0	1,01	138	7,0
15 × 3	44,5	1,01	105	5,4	1,02	183	8,3
20 × 2	39,5	1,01	105	6,1	1,01	172	8,1
20 × 3	59,5	1,01	133	6,4	1,02	226	9,4
20 × 5	99,1	1,02	178	7,0	1,04	325	11,9
20 × 10	199	1,03	278	8,5	1,07	536	16,6
25 × 5	124	1,02	213	8,0	1,05	381	13,2
30 × 5	149	1,03	246	9,0	1,06	437	14,5
30 × 10	299	1,05	372	10,4	1,11	689	18,9
40 × 5	199	1,03	313	10,9	1,07	543	17,0
40 × 10	399	1,07	465	12,4	1,15	839	21,7
50 × 5	249	1,04	379	12,9	1,09	646	19,6
50 × 10	499	1,08	554	14,2	1,18	982	24,4
60 × 5	299	1,05	447	15,0	1,10	748	22,0
60 × 10	599	1,10	640	16,1	1,21	1118	27,1
80 × 5	399	1,07	575	19,0	1,13	943	27,0
80 × 10	799	1,13	806	19,7	1,27	1372	32,0
100 × 5	499	1,10	702	23,3	1,17	1125	31,8
100 × 10	999	1,17	969	23,5	1,33	1612	37,1
120 × 10	1200	1,21	1131	27,6	1,41	1859	43,5

$$P_v = \frac{I^2 \times k_3}{\kappa \times A} \times [1 + \alpha \times (T_c - 20 \text{ °C})]$$

where

P_v is the power loss per metre;

I is the operating current;

k_3 is the current displacement factor;

- κ is the conductivity of copper, $\kappa = 56 \frac{\text{m}}{\Omega \times \text{mm}^2}$;
- A is the cross-sectional area of bar;
- α is the temperature coefficient of resistance, $\alpha = 0,004 \text{ K}^{-1}$;
- T_c is the temperature of the conductor.

The operating currents may be converted for other ambient air temperatures inside the ASSEMBLY and/or for a conductor temperature of 90 °C by multiplying the values of Table N.1 by the corresponding factor k_4 from Table N.2. Then the power losses shall be calculated using the formula given above accordingly.

Table N.2 – Factor k_4 for different temperatures of the air inside the ASSEMBLY and/or for the conductors

Air temperature inside the enclosure around the conductors °C	Factor k_4	
	Conductor temperature of 70 °C	Conductor temperature of 90 °C
20	2,08	2,49
25	1,94	2,37
30	1,82	2,26
35	1,69	2,14
40	1,54	2,03
45	1,35	1,91
50	1,18	1,77
55	1,00	1,62
60	0,77	1,48

It shall be considered that, dependent upon the design of the ASSEMBLY, quite different ambient and conductor temperatures can occur, especially with higher operating currents.

Verification of the actual temperature rise under these conditions shall be determined by test. The power losses may then be calculated by the same method as used for this Table N.2.

NOTE At higher currents additional eddy current losses may be significant which are not included in the values of Table N.1.

Annex O **(informative)**

Guidance on temperature rise verification

O.1 General

All ASSEMBLIES generate heat in service. Assuming the heat dissipation capability of the ASSEMBLY for local areas within the ASSEMBLY and for the ASSEMBLY as a whole, when operating on full load, exceeds the total heat produced then thermal equilibrium will be established; temperature will stabilize at a temperature rise above the ambient temperature surrounding the ASSEMBLY.

The purpose of temperature rise verification is to ensure temperatures stabilize at a value that will not result in:

- a) significant deterioration or ageing of the ASSEMBLY, or
- b) excessive heat being transferred to external conductors, such that the service capability of the external conductors and any equipment to which they are connected, may be impaired, or,
- c) people, operators or animals in the vicinity of an ASSEMBLY being burnt in normal operating circumstances.

O.2 Temperature-rise limits

It is the manufacture's responsibility to select the appropriate method for temperature rise verification. (See Figure O.1).

All the temperature rise limits given in the standard assume that the ASSEMBLY will be located in an environment where the daily average and peak ambient temperatures do not exceed 35 °C and 40 °C, respectively.

The standard also assumes that all outgoing circuits within an ASSEMBLY will not be loaded to their rated current at the same time. This recognition of the practical situation is defined by a 'rated diversity factor'. Subject to the loading of the incoming circuit not exceeding its rated current, diversity is the proportion of the individual rated currents that any combination of outgoing circuits can carry continuously and simultaneously, without the ASSEMBLY overheating. Diversity factor (assumed loading) is usually defined for the ASSEMBLY as a whole, but a manufacturer may choose to specify it for groups of circuits, for example the circuits in a section.

Temperature rise verification confirms two criteria, as follows:

- a) that each type of circuit is capable of carrying its rated current when it is incorporated in the ASSEMBLY. This takes into account the way in which the circuit is connected and enclosed within the ASSEMBLY, but excludes any heating affects that may result from adjacent circuits carrying current.
- b) the ASSEMBLY as a whole will not overheat when the incoming circuit is loaded to its rated current and, subject to the maximum current of the incoming circuit, any combination of outgoing circuits can be simultaneously and continuously loaded to their rated current multiplied by the rated diversity factor for the ASSEMBLY.

Temperature rise limits within the ASSEMBLY are the manufacturers' responsibility, they are essentially determined on the basis of operating temperature not exceeding the long term capability of the materials used within the ASSEMBLY. At interfaces between the ASSEMBLY and

the 'wider world', for example, cable terminals and operating handles, the standard defines temperature rise limits (see Table 6).

Within boundaries defined in the standard, temperature rise verification can be undertaken by test, calculation or design rules. It is permissible to use one or a combination of the verification methods set out in the standard to verify temperature rise performance of an ASSEMBLY. This allows the manufacturer to choose the most appropriate method for the ASSEMBLY, or part of an ASSEMBLY, being considered, taking into consideration volumes, the construction, design flexibility, current rating and size of the ASSEMBLY.

In typical applications involving some adaptation of a standard design it is highly likely more than one method will be used to cover various elements of the ASSEMBLY design.

O.3 Test

O.3.1 General

In order to avoid unnecessary testing the standard provides guidance on selecting groups of comparable functional units. It then details how to select the critical variant from the group for test. Design rules are then applied to assign ratings to other circuits that are 'thermally similar' to the critical variant tested.

Three options for verification by test are offered in this standard.

O.3.2 Method a) – Verification of the complete ASSEMBLY (10.10.2.3.5)

If several or all circuits of an ASSEMBLY are loaded simultaneously then the same circuit is only able to carry its rated current multiplied with the rated diversity factor (see 5.4), due to the thermal influence of the other circuits. Thus to verify the rated currents of all circuits a separate test for each type of circuit is necessary. To verify the rated diversity factor one additional test with simultaneous load on all circuits has to be done (see methods b) and c)).

To avoid the large number of tests that may be necessary 10.10.2.3.5 describes a verification method where only one test is made with simultaneous load on all circuits. Because with only one test the rated currents and the rated diversity factor of the circuits cannot be verified separately, it is assumed that the diversity factor is one. In this case the load currents are equal to the rated currents.

This is a quick and conservative approach to achieving a result for a particular arrangement of ASSEMBLY. It proves the rating of the outgoing circuits and the ASSEMBLY in the same test. The incoming circuit and busbars are loaded to their rated current and as many outgoing circuits in a group as are necessary to distribute the incoming current, are loaded to their individual rated currents when installed in the ASSEMBLY. For most installations this is an unrealistic situation since outgoing circuits are not normally loaded to unity diversity. If the group of functional units tested does not include one of each of the different types of outgoing circuit incorporated in the ASSEMBLY, then further tests are carried out considering different groups of outgoing circuits until one of each type has been tested.

Testing in this manner requires the minimum number of temperature rise tests, but the test arrangement is more onerous than necessary and the result is not applicable to a range of ASSEMBLIES.

O.3.3 Method b) – Verification considering individual functional units separately and the complete ASSEMBLY (10.10.2.3.6)

With this arrangement of testing each critical variant of outgoing circuit is tested separately to confirm its rated current and then the ASSEMBLY as whole is tested with the incoming circuit loaded to its rated current and groups of outgoing circuits, as necessary to distribute the

incoming current, loaded to their rated current multiplied by the diversity factor. The group tested should include one outgoing circuit of each critical variant to be incorporated in the ASSEMBLY. Where this is not practical, further groups are tested until all critical variants of outgoing circuit have been considered.

This test regime takes into account the diversity in the loading of outgoing circuits that is applicable in the majority of applications. However, as in method a) above, the result is only applicable to a specific arrangement of ASSEMBLY tested.

O.3.4 Method c) – Verification considering individual functional units and the main and distribution busbars separately as well as the complete ASSEMBLY (10.10.2.3.7)

This test method enables modular systems to be temperature rise verified without the need to test every conceivable combination of circuits. Temperature rise tests are carried out separately to prove the rating of:

- a) functional units,
- b) main busbars,
- c) distribution busbars,
- d) complete ASSEMBLY.

To verify the performance of the ASSEMBLY as a whole, these tests are then complimented by a test on a representative ASSEMBLY in which the incoming circuit is loaded to its rated current and the outgoing circuits are loaded to their rated current multiplied by the diversity factor.

Whilst this approach requires more testing than methods a) and b) it has the advantage that the modular system rather than a specific arrangement of ASSEMBLY is verified.

O.4 Calculation

O.4.1 General

Two methods of verifying temperature rise performance by calculation are included within the standard.

O.4.2 Single compartment assembly with a rated current not exceeding 630 A

A very simple method of temperature rise verification that requires confirmation that the total power loss of the components and conductors within the ASSEMBLY do not exceed the known power dissipation capability of the enclosure. The scope of this approach is very limited and in order that there are no difficulties with hot spots, all components must be de-rated to 80 % of their free air current rating.

O.4.3 assembly with rated currents not exceeding 1 600 A

Temperature rise verification is by calculation in accordance with IEC 60890 with additional margins. The scope of this approach is limited to 1 600 A, components are de-rated to 80 % of their free air rating or less and any horizontal partitions must have, as a minimum, a 50 % open area.

O.5 Design rules

The standard allows, in clearly defined circumstances, for the derivation of ratings from similar variants that have been verified by test. For example, if the current rating of a double lamination busbar has been established by test, it is acceptable to assign a rating equal to

50 % of the tested arrangement to a busbar comprising a single lamination with the same width and thickness as the tested laminations, when all other considerations are the same.

In addition, the rating of all circuits within a group of comparable functional units (all devices must be of the same frame size and belong to the same series) can be derived from a single temperature rise test on the critical variant within the group. An example of this may be to test a nominal 250 A outgoing circuit breaker and establish a rating for it in the ASSEMBLY. Then, assuming the same frame size breaker is being considered and other specified conditions are met, verify by calculation the rating of a nominal 160 A circuit breaker within the same enclosure.

Lastly, in respect of temperature rise, there are very strict design rules that permit the substitution of a device with a similar device from another series or even another make, without retesting. In this case, in addition to the physical arrangement being essentially the same, the power loss and terminal temperature rise of the substitute device, when it is tested in accordance with its own product standard, must not be higher than those of the original device.

NOTE When considering device substitution all other performance criteria, in particular that dealing with short circuit capability, should be considered and satisfied, in accordance with the standard, before an ASSEMBLY is deemed to be verified.

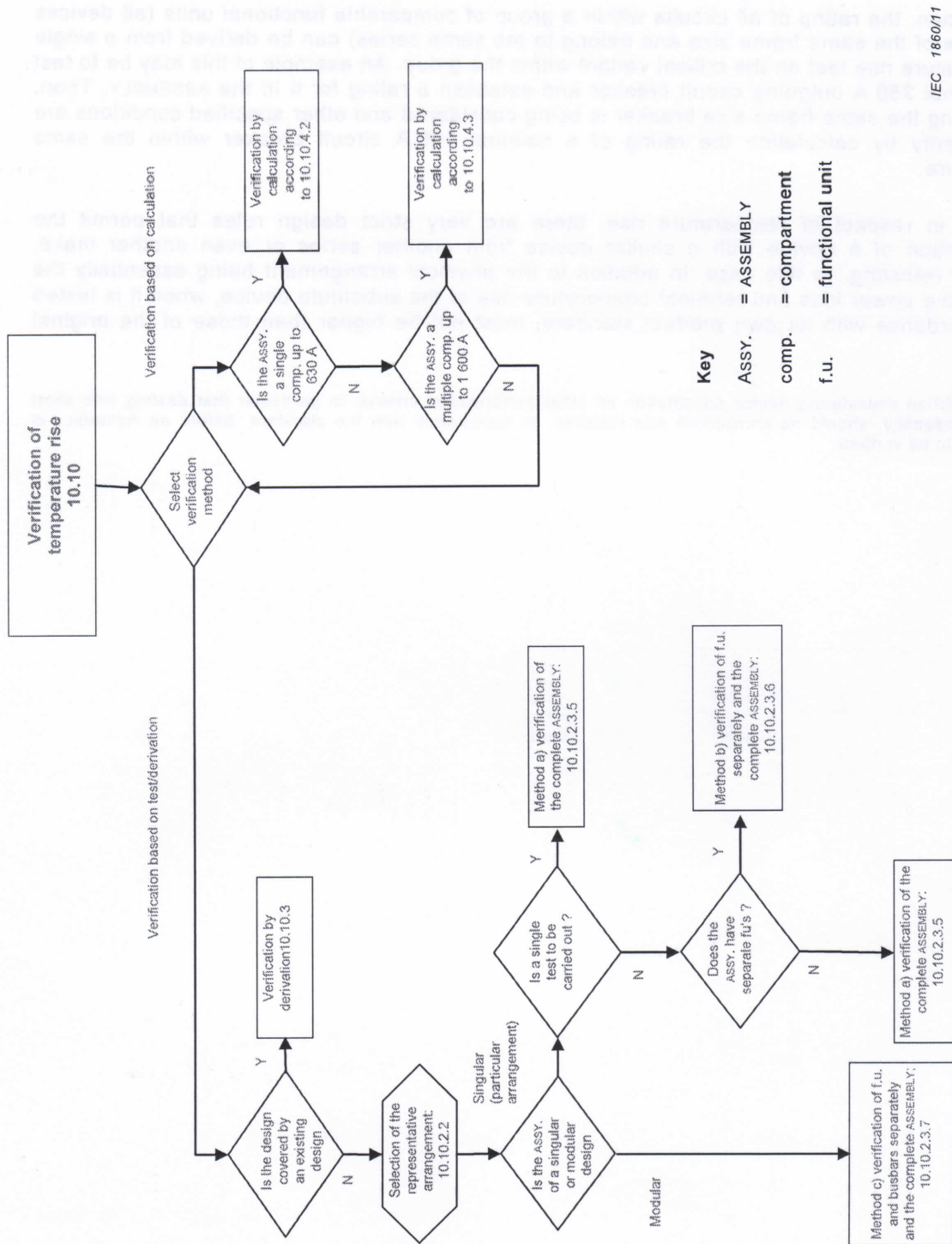


Figure O.1 – Temperature rise verification methods

Annex P (normative)

Verification of the short-circuit withstand strength of busbar structures by comparison with a tested reference design by calculation

P.1 General

This annex describes a method for assessing the short-circuit withstand strength of busbar structures of an ASSEMBLY by a comparison of the ASSEMBLY to be assessed with an ASSEMBLY already verified by test (see 10.11.5).

P.2 Terms and definitions

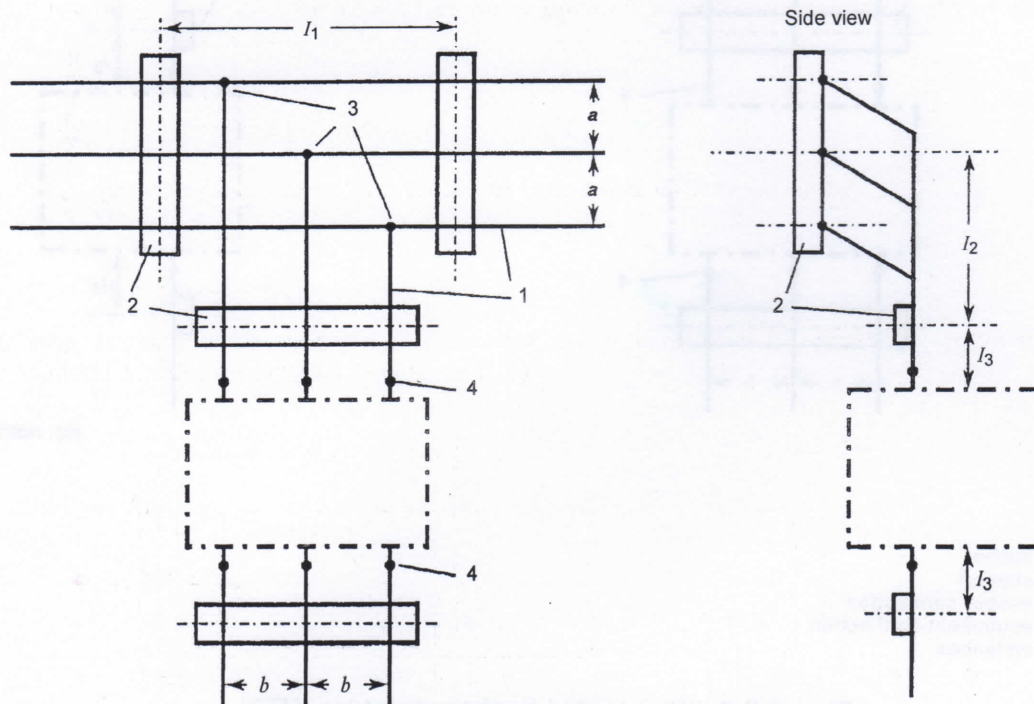
For the purposes of this annex, the following terms and definitions apply.

P.2.1

tested busbar structure

TS

structure whose arrangement and equipment are documented by drawings, parts lists and descriptions in the test certificate (Figure P.1)



IEC 1861/11

Key

- 1 busbar
- 2 support
- 3 busbar connection
- 4 equipment connection
- a, b, I distances

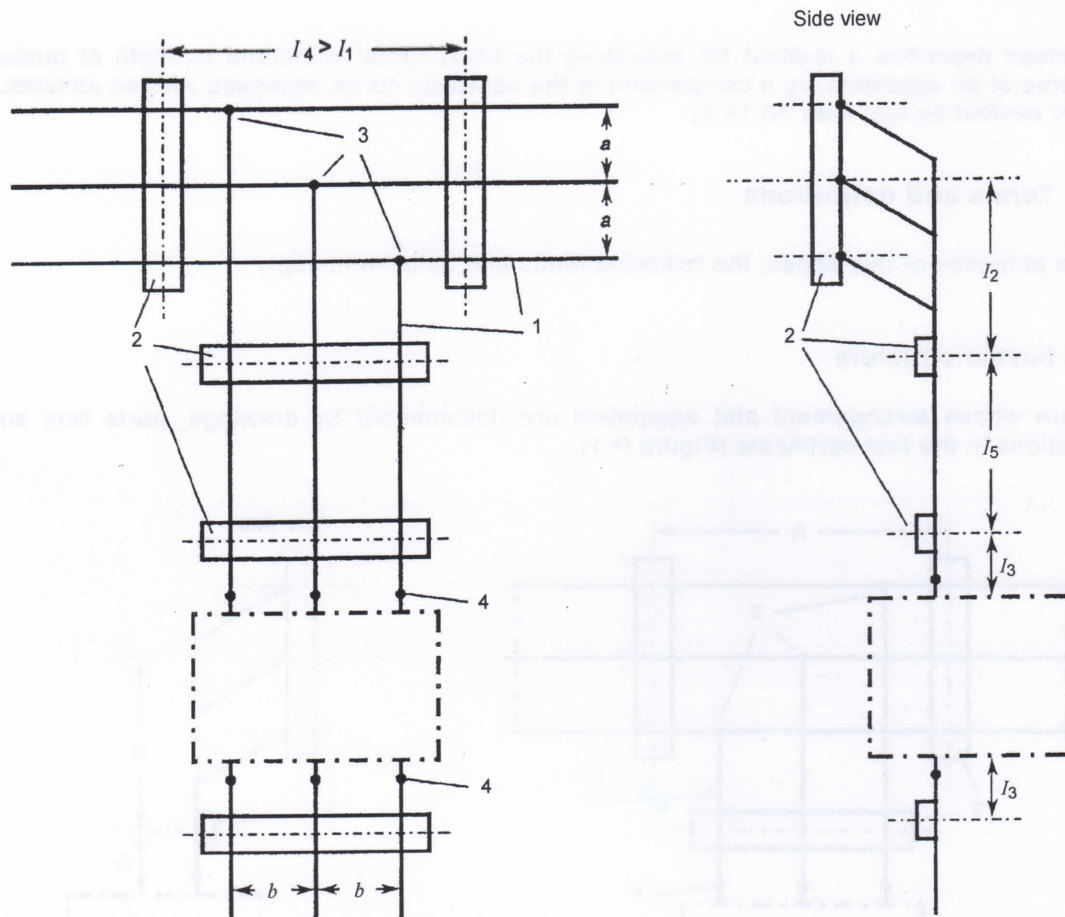
Figure P.1 – Tested busbar structure (TS)

P.2.2

non tested busbar structure

NTS

structure which requires verification of short-circuit withstand strength (Figure P.2)



IEC 1862/11

Key

- 1 busbar
- 2 support
- 3 busbar connection
- 4 equipment connection
- a, b, I distances

Figure P.2 – Non tested busbar structure (NTS)

P.3 Method of verification

The short-circuit withstand strength of a derived structure, i.e. an NTS, is verified from a tested structure (TS) by applying calculations according to IEC 60865-1 to both structures. The short-circuit withstand strength of the NTS is considered verified if the calculations show that the NTS does not have to withstand higher mechanical and thermal stresses than the tested structure.

P.4 Conditions for application

P.4.1 General

Changes of parameters, such as busbar clearances, busbar material, busbar cross-section and busbar configuration shown to be necessary by the calculation in conformity with IEC 60865-1 are permissible only in so far as the following conditions are adhered to.

P.4.2 Peak short-circuit current

The short-circuit current may be changed only to lower values.

P.4.3 Thermal short-circuit strength

The thermal short-circuit strength of an NTS shall be verified by calculations according to IEC 60865-1. The calculated temperature rise of the NTS shall not be higher than that of the TS.

P.4.4 Busbar supports

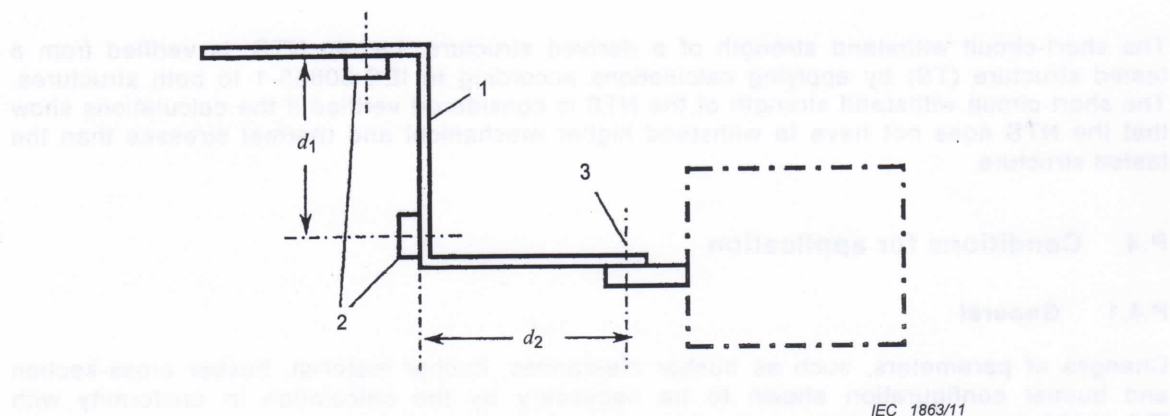
Changes of material or shape of supports taken from an ASSEMBLY verified by test are not permitted. However, other supports may be used but they shall have been previously tested for the required mechanical strength.

P.4.5 Busbar connections, equipment connections

The type of busbar and equipment connections shall have been previously verified by test.

P.4.6 Angular busbar configurations

IEC 60865-1 is applicable only to straight busbar configurations. Angular busbar configurations may be considered as a series of straight configurations when supports are provided at the corners (see Figure P.3).



Key

- 1 busbar
- 2 support
- 3 equipment connection
- d support distance

Figure P.3 – Angular busbar configuration with supports at the corners

P.4.7 Calculations with special regard to conductor oscillation

For calculations in conformity with IEC 60865-1 on the tested structure (TS), the following values of the factors V_{σ} , $V_{\sigma s}$ and V_F shall be used:

$$V_{\sigma} = V_{\sigma s} = V_F = 1,0$$

where

V_{σ} is the ratio between dynamic and static main conductor stress;

$V_{\sigma s}$ is the ratio between dynamic and static sub-conductor stress;

V_F is the ratio between dynamic and static force on support.

For the NTS,

$$V_{\sigma} = V_{\sigma s} = 1,0 \text{ and}$$

V_F is found from calculations in accordance with IEC 60865-1, but $V_F < 1,0$ is to be replaced by $V_F = 1,0$.

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