IEC 61204-7

Edition 2.0 2016-11

EXTENDED VERSION

colour inside

This Extended version of IEC 61204-7:2016 includes the provisions of the general rules of IEC 62477-1:2012

Low-voltage switch mode power supplies –
Part 7: Safety requirements

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IEC 61204-7:2016-11 EXV(en)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCH MODE POWER SUPPLIES –

Part 7: Safety requirements

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This Extended version is intended only to provide the user with a comprehensive content consisting of a product standard and its reference document. An Extended version is not an official IEC Standard. Only the current versions of the related standards are to be considered the official documents.

This Extended version of IEC 61204-7:2016 includes the provisions of the general rules dealt with in IEC 62477-1:2012. Clauses and subclauses of IEC 62477-1:2012 that are applicable in IEC 61204-7:2016 have been introduced in the content in red text.

International Standard IEC 61204-7 has been prepared by subcommittee 22E: Stabilized power supplies, of IEC technical committee 22: Power electronic systems and equipment.

This second edition cancels and replaces the first edition published in 2006. This edition constitutes a complete technical revision.

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

a) use of IEC 62477-1 as reference document, instead of IEC 60950-1;
b) modification of the title by deleting the wording “DC output-“ and adding “switch mode”.

IEC 61204-7 has the status of a product standard.

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

FDIS	Report on voting
22E/175/FDIS	22E/177/RVD

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

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

A list of all parts in the IEC 61204 series, published under the general title *Low-voltage power supplies, d.c. output*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

This International Standard is to be read in conjunction with IEC 62477-1:2012.

NOTE A consolidated version is under consideration.

Subclauses that are numbered starting from 100 are additional to those in IEC 62477-1:2012.

Additional tables and figures in this document are numbered starting from 100.

New annexes in this document are lettered AA, AB, AC, etc.

The wordings ***SMPS*** and "power supply" are considered to be identical throughout this document.

References of the reference document to clauses or tables, which have been modified in this document, shall be read as reference to the relevant clauses or tables of this document.

Refer to 3.100 for further information on how to read this document.

In this document, the following print types are used:

– Requirements proper and normative annexes: in roman type.
– Notes and other informative matter: in smaller roman type.
– Normative conditions within tables: in smaller roman type.
– Terms that are defined in clause 3 or IEC 62477-1:2012: ***Bold Italic***.

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The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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.

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INTRODUCTION

IEC 62477-1:2012, used by this document as a reference, relates to products that include power electronic converters, with a rated system voltage not exceeding 1 000 V AC or 1 500 V DC. It specifies requirements to reduce risks of fire, electric shock, thermal, energy and mechanical hazards, except functional safety as defined in IEC 61508 (all parts). The objectives of this standard are to establish a common terminology and basis for the safety requirements of products that contain power electronic converters across several IEC technical committees.

IEC 62477-1:2012 was developed with the intention

– to be used as a reference document for product committees inside IEC technical committee 22: Power electronic systems and equipment in the development of product standards for power electronic converter systems and equipment,

– to replace IEC 62103 as a product family standard providing minimum requirements for safety aspects of power electronic converter systems and equipment in apparatus for which no product standard exists, and

NOTE The scope of IEC 62103 contains reliability aspects, which are not covered by this document.

– to be used as a reference document for product committees outside TC 22 in the development of product standards of power electronic converter systems and equipment intended for renewable energy sources. TC 82, TC 88, TC 105 and TC 114, in particular, have been identified as relevant technical committees at the time of publication.

As such, IEC technical sub-committee 22E: Stabilized switched-mode power supplies carefully considered the relevance of each paragraph of IEC 62477-1:2012 for the SMPS and referenced, added, replaced or modified requirements as relevant. This is because product-specific topics not covered by the reference document are the responsibility of the technical committee using the reference document.

The reference document, being a group safety standard, will not take precedence over this product-specific standard according to IEC Guide 104. IEC Guide 104 provides information about the responsibility of product committees to use group safety standards for the development of their own product standards.

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LOW-VOLTAGE SWITCH MODE POWER SUPPLIES –

Part 7: Safety requirements

0 Principles of safety

Safety principles of this document follow the concepts of IEC Guide 116 and Annex D of CENELEC Guide 32:2014.

NOTE The principles of safety are mainly adopted from IEC 60950-1:2005/AMD1:2009/AMD2:2013.

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0.1 General

The following principles have been adopted by IEC technical committee 22E in the development of this document. These principles do not cover performance or functional characteristics of equipment.

It is essential that designers understand the underlying principles of safety requirements in order that they can engineer safe equipment.

These principles are not an alternative to the detailed requirements of this document, but are intended to provide designers with an appreciation of the basis of these requirements. Where the equipment involves technologies, components and materials or methods of construction not specifically covered, the design of the equipment should provide a level of safety not less than that described in these principles of safety.

NOTE The need for additional detailed requirements to cope with a new situation is brought promptly to the attention of the appropriate committee.

Designers will take into account not only normal operating conditions of the equipment but also likely fault conditions, consequential faults, foreseeable misuse and external influences such as temperature, altitude, pollution, moisture, overvoltages on the ***mains supply*** and ***non-mains supply***.

Dimensioning of insulation spacings should take account of possible reductions by manufacturing tolerances, or where deformation could occur due to handling, shock and vibration likely to be encountered during manufacture, transport and normal operation.

The following priorities should be observed in determining what design measures to adopt:

– where possible, specify design criteria that will eliminate, reduce or guard against hazards;
– where the above is not practicable because the functioning of the equipment would be impaired, specify the use of protective means independent of the equipment, such as personal protective equipment (which is not specified in this document);
– where neither of the above measures is practicable, or in addition to those measures, specify the provision of markings and instructions regarding the residual risks.

There are two types of persons whose safety needs to be considered, ***operators*** (or ***users***) and ***service persons***.

Operator is the term applied to all persons other than ***service persons***. Requirements for protection should assume that ***operators*** are not trained to identify hazards, but will not intentionally create a hazardous situation. Consequently, the requirements will provide protection for cleaners and casual visitors as well as the assigned ***operators***. In general,

operators should not have access to hazardous parts, and to this end, such parts should only be in service access area or in equipment located in ***restricted access areas***.

When ***operators*** are admitted to ***restricted access areas (RAA)*** they shall be suitably instructed.

NOTE The term "restricted access area" (RAA) is also known as "restricted access location" (RAL).

Service persons are expected to use their training and skill to avoid possible injury to themselves and others due to obvious hazards that exist in service access areas of the equipment or on equipment located in ***restricted access areas***. However, ***service persons*** should be protected against unexpected hazards. This can be done by, for example, locating parts that need to be accessible for servicing away from electrical and mechanical hazards, providing shields to avoid accidental contact with hazardous parts, and providing labels or instructions to warn personnel about any residual risk.

Information about potential hazards can be marked on the equipment or provided with the equipment, depending on the likelihood and severity of injury, or made available for ***service persons***. In general, ***operators*** shall not be exposed to hazards likely to cause injury, and information provided for ***operators*** should primarily aim at avoiding misuse and situations likely to create hazards, such as connection to the wrong power source and replacement of fuses by incorrect types.

Moveable equipment is considered to present a slightly increased risk of shock, due to possible extra strain on the supply cord leading to rupture of the earthing conductor. With hand-held equipment, this risk is increased; wear on the cord is more likely, and further hazards could arise if the units were dropped. ***Transportable equipment*** introduces a further factor because it can be used and carried in any orientation; if a small metallic object enters an opening in the ***enclosure***, it can move around inside the equipment, possibly creating a hazard.

0.2 Hazards

0.2.1 General

Application of a safety standard is intended to reduce the risk of injury or damage due to the following:

– electric shock;
– energy related hazards;
– fire;
– heat related hazards;
– mechanical hazards;
– chemical hazards.

NOTE Radiation hazard are not included, as LEDs used for the purpose of indication and display only are not considered to cause hazardous radiation (e.g. like high intense lighting LEDs).

0.2.2 Electric shock

Electric shock is due to current passing through the human body. The resulting physiological effects depend on the value and duration of the current and the path it takes through the body. The value of the current depends on the applied voltage, the impedance of the source and the impedance of the body. The body impedance depends in turn on the area of contact, moisture in the area of contact and the applied voltage and frequency.

Currents of approximately half a milliamp can cause a reaction in persons in good health and may cause injury indirectly due to involuntary reaction. Higher currents can have more direct

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effects such as burn or muscle tetanisation leading to inability to let go or to ventricular fibrillation.

It is normal to provide two levels of protection for ***operators*** to prevent electric shock. Therefore, the operation of equipment under normal conditions and after a single fault, including any consequential faults, should not create a shock hazard.

Harm may result from

1) contact with hazardous-live-parts,
2) breakdown of insulation between ***hazardous-live-parts*** and accessible conductive parts,
3) contact with circuits above ***DVC As*** limits,
4) breakdown of ***operator*** accessible insulation, and
5) ***touch current*** (leakage current) flowing from ***hazardous-live-parts*** to accessible parts, or failure of a ***protective earthing*** connection. ***Touch current*** may include current due to EMC filter components.

0.2.3 Energy related hazards

Injury or fire may result from a short-circuit between adjacent poles of high current supplies or high capacitance circuits, causing

– burns,
– arcing, and
– ejection of molten metal.

Even circuits whose voltages are safe to touch may be hazardous in this respect.

Examples of measures to reduce risks include:

– separation;
– shielding;
– provision of safety interlocks.

NOTE Safety interlocks are not described within this document.

0.2.4 Fire

Risk of fire may result from excessive temperatures either under normal operating conditions or due to overload, component failure, insulation breakdown or loose connections. Fires originating within the equipment should not spread beyond the immediate vicinity of the source of the fire, nor cause damage to the surroundings of the equipment.

Examples of measures to reduce risks include:

– providing overcurrent protection;
– using constructional materials having appropriate flammability properties for their purpose;
– selection of parts, components and consumable materials to avoid high temperature which might cause ignition;
– limiting the quantity of combustible materials used;
– shielding or separating combustible materials from likely ignition sources;
– using ***enclosures*** or barriers to limit the spread of fire within the equipment;
– using suitable materials for ***enclosures*** so as to reduce the likelihood of fire spreading from the equipment.

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0.2.5 Heat related hazards

Injury may result from high temperatures under normal operating conditions, causing

- burns due to contact with hot accessible parts,
- degradation of insulation and of safety-critical components, and
- ignition of flammable liquids.

Examples of measures to reduce risks include:

- taking steps to avoid high temperature of accessible parts;
- avoiding temperatures above the ignition point of liquids;
- provision of markings to warn ***operators*** where access to hot parts is unavoidable.

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0.2.6 Mechanical hazards

Injury may result from

- sharp edges and corners,
- moving parts that have the potential to cause injury,
- equipment instability,
- sonic pressure, and
- flying particles from exploding components (like electrolytic capacitors).

Examples of measures to reduce risks include:

- rounding of sharp edges and corners;
- guarding;
- providing sufficient stability to free-standing equipment;
- selecting suitable components, for example electrolytic capacitors with integral pressure relief to avoid explosion;
- provision of markings to warn ***operators*** where access is unavoidable.

0.2.7 Chemical hazards

Injury may result from contact with some chemicals or from inhalation of their vapours and fumes.

Examples of measures to reduce risks include:

- avoiding the use of constructional and consumable materials likely to cause injury by contact or inhalation during intended and normal conditions of use;
- avoiding conditions likely to cause leakage or vaporization;
- provision of markings to warn ***operators*** about the hazards.

0.3 Materials and components

Materials and components used in the construction of equipment should be so selected and arranged that they can be expected to perform in a reliable manner for the anticipated life of the equipment without creating a hazard, and would not contribute significantly to the development of a serious fire hazard. Components should be selected so that they remain within their manufacturers' ratings under normal operating conditions, and do not create a hazard under fault conditions.

1 Scope

1.1 Equipment covered by this document

This part of IEC 61204 specifies the safety requirements for ***switch mode power supply*** (***SMPS***) units supplied by source voltages up to 1 000 V AC or 1 500 V DC providing AC and/or DC output(s), except inverter output(s) establishing AC mains (see exceptions in 1.2).

NOTE 1 This document by definition covers DC-DC converters.

NOTE 2 Power supplies may provide accessory AC mains socket outlets, when such outputs are supplied from the AC mains.

This product standard covers both ***stand-alone*** and ***component SMPS*** as defined in this document. ***DC power and distribution equipment*** which provides, distributes, monitors, and controls isolated ***secondary circuit*** power to other equipment typically used in information and communication technology equipment installations (refer to Annex AC).

Equipment which is within the scope of Annex AC consists of some or all of the following:

– distribution panelboards, powerboards, disconnects, and overcurrent protective devices;
– control and monitoring equipment;
– assemblies consisting of: racks, shelves, and enclosures which could contain any of the above components, interconnecting hardware, ***power supplies*** (such as rectifiers, converters, and inverters), batteries, and any other related peripheral devices.

Where no standards exist, use of this document for other applications is not precluded.

1.2 Exclusions

This document does not cover:

– functional safety aspects as covered by for example IEC 61508 (all parts);
– reliability and risk considerations (e.g. related to power loss);
– information and communication technology equipment other than ***SMPS*** to such apparatus;
– electrical equipment and systems for railways applications and electric vehicles.
– motor-generator sets;
– uninterruptible power supplies (UPS);
– direct plug-in power units;
– power supplies according to IEC 61558 (all parts) covering linear power supply units incorporating safety isolating transformers providing ***SELV*** or ***PELV*** output(s) in accordance with IEC 60364-4-41 and ***SMPS*** for use with household and other consumer products;
– transformers covered by IEC 61558-1;
– step-down converters covered by IEC 60146-1-1;
– ***SMPS*** and converters for use with or in products covered by IEC 61347-2-2;
– ***AC or DC mains supply*** distribution equipment which is part of the building wiring system and not an integral part of the equipment used in ***DC power and distribution equipment***, batteries, the design or installation of ***DC power and distribution*** conductors and other building installation wiring (not covered by Annex AC).

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1.3 Additional requirements

Requirements additional to those specified in this document may be necessary for

- ***SMPS*** which comply with this document and satisfy the requirements of ***SMPS*** for use in or with other equipment, when referenced in such end product standards,
- ***SMPS*** intended for operation in special environments (for example, extremes of temperature; excessive dust, moisture or vibration (e.g. earth quake zones); flammable gases; and corrosive or explosive atmospheres),
- ***SMPS*** intended to be used in vehicles, on board ships or aircraft, or in tropical countries, and
- ***SMPS*** intended for use where ingress of water is possible; for guidance on such requirements and on relevant testing, see IEC 60529.

NOTE Attention is drawn to the fact that authorities in some countries impose additional requirements for health, environmental and similar reasons.

2 Normative references

Clause 2 of IEC 62477-1:2012 applies with the following exceptions/additions:

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

IEC 60227 (all parts), *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V*

IEC 60245 (all parts), *Rubber insulated cables – Rated voltages up to and including 450/750 V*

IEC 60320 (all parts), *Appliance couplers for household and similar general purposes*

IEC 60384-14:2013, *Fixed capacitors for use in electronic equipment – Part 14: Sectional specification: Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

IEC 60417:2002 [online database], *Graphical symbols for use on equipment* [viewed 2016-06-24]. Available at *http://www.graphical-symbols.info/*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 60695-11-5, *Fire hazard testing Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

IEC 60695-11-20:1999, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test methods*

IEC 60730-1:2010, *Automatic electrical controls – Part 1: General requirements*

IEC 60738-1:2009, *Thermistors – Directly heated positive temperature coefficient – Part 1: Generic specification*

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IEC 60747-5-5:2007, *Semiconductor devices – Discrete devices – Part 5-5: Optoelectronic devices – Photocouplers*

IEC 60799, *Electrical accessories – Cord sets and interconnection cord sets*

IEC 60851-3:2009, *Winding wires – Test methods – Part 3: Mechanical properties*

IEC 60851-5:2008, *Winding wires – Test methods – Part 5: Electrical properties*

IEC 60851-6:1996, *Winding wires – Test methods – Part 6: Thermal properties*

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

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60990:1999, *Methods of measurement of touch current and protective conductor current*

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

IEC 61058-1:2000, *Switches for appliances - Part 1: General requirements*
IEC 61058-1:2000/AMD1:2001
IEC 61058-1:2000/AMD2:2007

IEC 61293:1994, *Marking of electrical equipment with ratings related to electrical supply – Safety requirements*

IEC 61558-1:2005, *Safety of power transformers, power supplies, reactors and similar products – Part 1: General requirements and tests*
IEC 61558-1:2005/AMD1:2009

IEC 61558-2 (all parts), *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V*

IEC 61810-1:2008, *Electromechanical elementary relays – Part 1: General requirements*

IEC 62368-1:2014, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

IEC 62477-1:2012, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

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3 Terms and definitions

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

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

3.1
adjacent circuit
circuit next to the circuit under consideration having a requirement for functional, simple or protective *insulation*

3.2
basic insulation
insulation applied to *hazardous live parts* to provide *basic protection* against electric shock

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

3.3
basic protection
protection against electric shock under fault-free conditions

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

3.4
commissioning test
test on a device or equipment performed on site, to prove the correctness of installation and operation

[SOURCE: IEC 60050-411:1996, 411-53-06, modified]

3.5
decisive voltage class
DVC
classification of voltage range used to determine the protective measures against electric shock and the requirements of *insulation* between circuits

3.6
double insulation
insulation comprising both *basic insulation* and *supplementary insulation*

[SOURCE: IEC 60050-826:2004, 826-12-16]

3.7
DVC As
secondary circuit providing only safe to touch voltage, under normal and fault conditions and limited overvoltages

Note 1 to entry: For limits refer to Table 5.

Note 2 to entry: The limitation of overvoltage is not related to electric shock, but necessary due to interconnection of circuitry and possible affect to insulation relied on for safety.

3.8
DVC Ax
DVC Ax is the general *DVC* value used for *DVC A*, *DVC A1*, *DVC A2* or *DVC A3*

Note 1 to entry: Only ***DVC As*** is used within this document (refer to 3.100.5).

Note 2 to entry: Wherever IEC 62477-1:2012 uses the definition ***DVC Ax***, it shall be read as ***DVC As*** in context with this document.

3.9
electrical breakdown
failure of *insulation* under electric stress when the discharge completely bridges the *insulation*, thus reducing the voltage between the electrodes almost to zero

[SOURCE: IEC 60664-1:2007, 3.20]

3.10
(electrical) insulation
electrical separation between circuits or conductive parts provided by clearance or creepage distance or solid *insulation* or combinations of them

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3.11
(electronic) (power) conversion
change of one or more of the characteristics of an electric power *system* essentially without appreciable loss of power by means of *power semiconductor devices*

Note 1 to entry: Characteristics are, for example, voltage, number of phases and frequency, including zero frequency.

[SOURCE: IEC 60050-551:1998, 551-11-02, modified]

3.12
enclosure
housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: This standard provides requirement for the *enclosure* according to IEC 60529 as well as additional requirement for mechanical and environmental impact. The purpose of the additional requirement is to ensure the *enclosures* ability to provide *basic protection* under the environmental conditions specified by the manufacturer.

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

3.13
enhanced protection
protective provision having a reliability of protection not less than that provided by two independent protective provisions

3.14
expected lifetime
design duration for which the performance characteristics are valid at rated conditions of operation

3.15
extra-low voltage
ELV
voltage not exceeding the relevant voltage limit of band I specified in IEC 60449

Note 1 to entry: In IEC 60449, band I is defined as not exceeding 50 V a.c. r.m.s. and 120 V d.c. Other product committees may have defined *ELV* with different voltage levels.

Note 2 to entry: In this standard, protection against electric shock is dependent on the *decisive voltage classification*.

[SOURCE: IEC 60050-826:2004, 826-12-30, modified]

3.16
fault protection
protection against electric shock under single-fault conditions

Note 1 to entry: For low-voltage *installations*, *systems* and equipment, *fault protection* generally corresponds to protection against indirect contact as used in IEC 60364-4-41, mainly with regard to failure of *basic insulation*.

[SOURCE: IEC 60050-195:1998, Amendment 1:1998, 195-06-02]

3.17
field wiring terminal
terminal provided for connection of external conductors to the *SMPS*

3.18
fire enclosure
part of the equipment intended to minimize the spread of fire or flames from within

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3.19
functional insulation
insulation between conductive parts within a circuit that is necessary for the proper functioning of the circuit, but which does not provide protection against electric shock

Note 1 to entry: *Functional insulation* may, however, reduce the likelihood of ignition and fire.

3.20
hazardous-live-part
live part which, under certain conditions, can give a harmful electric shock

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

3.21
installation
equipment or equipments including at least the SMPS

Note 1 to entry: The word installation is also used in this standard to denote the process of installing a *SMPS*. In these cases, the word does not appear in italics.

3.22
live part
conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a *protective earth conductor* or *protective earth* neutral

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

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

3.23
low voltage
LV
set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V a.c. or 1 500 V d.c.

[SOURCE: IEC 60050-601:1985, 601-01-26, modified]

3.24
mains supply
power distribution system that is either an AC ***mains supply*** or a DC ***mains supply***

3.25
muscular reaction (inability to let go)
physiological reaction due to a minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary contraction of a muscle, such as inability to let go from an electrode, but not including *startle reaction*

[SOURCE: IEC/TR 60479-5:2007, 3.3.2, modified]

3.26
non-mains supply
electrical circuit that is not energized directly from the *mains supply*, but is, for example, isolated by a transformer or supplied by a battery, generator, or similar sources not directly connected to the a.c. power distribution *system*

3.27
open type
product intended for incorporation within *enclosure* or assembly that will provide protection against hazards

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3.28
output short circuit current
available current r.m.s or d.c. that flows at the output of the *SMPS* when a short circuit is applied by a conductor of negligible impedance

3.29
PELV (system)
electric system in which the voltage cannot exceed the value of *extra low voltage*:

– under normal conditions; and
– under *single fault conditions*, except earth faults in other electric circuits

Note 1 to entry: PELV is the abbreviation for protective *extra low voltage*.

[SOURCE: IEC 60050-826:2004, 826-12-32]

3.30
permanently connected (equipment)
equipment that is intended for connection to the building *installation* wiring using screw terminals or other reliable means

3.31
pluggable equipment type A
equipment that is intended for connection to the *mains supply* via a non-industrial plug and socket-outlet or a non-industrial appliance coupler, or both

3.32
pluggable equipment type B
equipment that is intended for connection to the *mains supply* via an industrial plug and socket-outlet or an appliance coupler, or both, complying with IEC 60309 or with a comparable national standard

3.33
port
access to a device or network where electromagnetic energy or signals may be supplied or received or where the device or network variables may be observed or measured

[SOURCE: IEC 60050-131:2002, 131-12-60]

3.34
power semiconductor device
semiconductor device used for *electronic power conversion*

3.35
prospective short circuit current
available current that flows when a short circuit is applied by a conductor of negligible impedance

3.36
protective-equipotential-bonding
equipotential bonding for purposes of safety (e.g. protection against electric shock)

[SOURCE: IEC 60050-195:1998, 195-01-15, modified]

3.37
protective class I
equipment in which protection against electric shock does not rely on *basic insulation* only, but which includes an additional safety precaution in such a way that means are provided for

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the connection of accessible conductive parts to the *protective (earthing) conductor* in the fixed wiring of the *installation*, so that accessible conductive parts cannot become live in the event of a failure of the *basic insulation*

3.38
protective class II
equipment in which protection against electric shock does not rely on *basic insulation* only, but in which additional safety precautions such as *supplementary insulation* or *reinforced insulation* are provided, there being no provision for *protective earthing* or reliance upon *installation* conditions

3.39
protective class III
equipment in which protection against electric shock relies on supply at ***DVC As*** and in which voltages higher than those of ***DVC As*** are not generated and there is no provision for ***protective earthing***

3.40
protective earthing
PE
earthing of a point in a *system*, or equipment, for protection against electric shock in case of a fault

3.41
PE conductor
conductor in the building *installation* wiring, or in the power supply cord, connecting a main *protective earthing* terminal in the equipment to an earth point in the building *installation* for safety purposes

3.42
protective impedance
impedance connected between *hazardous live parts* and accessible conductive parts, of such value that the current, in normal use and under likely fault conditions, is limited to a safe value, and which is so constructed that its ability is maintained throughout the life of the equipment

[SOURCE: IEC 60050-442:1998, 442-04-24, modified]

3.43
(electrically) protective screening
separation of circuits from hazardous live-parts by means of an interposed conductive screen, connected to the means of connection for a *PE conductor,* either directly or via *protective equipotential bonding*

3.44
(electrically) protective separation
separation of one electric circuit from another by means of:

– *double insulation* or

– *basic insulation* and electrically *protective screening* or

– *reinforced insulation*

[SOURCE: IEC 60050-195:1998, Amendment 1:1998, 195-06-19]

3.45
power electronic converter
PEC
device or part thereof for the purpose of *electronic power conversion*, including signalling, measurement, control circuitries and other parts, if essential for the *power* conversion function

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3.46
power electronic converter *system*
PECS
one or more *power electronic converters* intended to work together with other equipment

3.47
reinforced insulation
insulation of *hazardous-live-parts* which provides a degree of protection against electric shock equivalent to *double insulation*

[SOURCE: IEC 60664-1:2007, 3.17.5]

3.48
restricted access area
area accessible only to electrically skilled persons and electrically instructed persons with the proper authorization

Note 1 to entry: An electrically skilled person is a person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

Note 2 to entry: An electrically instructed person is a person adequately advised or supervised by electrically skilled persons to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-195:1998, 195-04-04, modified]

3.49
routine test
test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

[SOURCE: IEC 60050-411:1996, 411-53-02, modified]

3.50
sample test
test on a number of devices taken at random from a batch

3.51
SELV (system)
electric system in which the voltage cannot exceed the value of *extra-low voltage*:

– under normal conditions; and
– under *single fault conditions*, including earth faults in other electric circuits

NOTE SELV is the abbreviation for safety *extra low voltage*.

[SOURCE: IEC 60050-826:2004, 826-12-31, modified]

3.52
short circuit backup protection
protection that is intended to operate when other protective measures within a *system* or equipment fail to clear a fault

3.53
simple separation
separation between electric circuits or between an electric circuit and local earth by means of *basic insulation*

[SOURCE: IEC 60050-826:2004, 826-12-28]

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3.54
single fault condition
condition in which one failure is present which could cause a hazard covered by this standard

Note 1 to entry: If a *single fault condition* results in other subsequent failures, the set of failures is considered as one *single fault condition*.

Note 2 to entry: Examples of hazards include, but are not limited to electric shock, fire, energy, mechanical, sonic pressure etc.

3.55
startle reaction
physiological reaction due to a minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary muscular contraction to the person through which it is flowing

[SOURCE: IEC/TR 60479-5:2007, 3.3.1, modified]

3.56
supplementary insulation
independent *insulation* applied in addition to *basic insulation* for *fault protection*

Note 1 to entry: *Basic* and *supplementary insulation* are separate, each designed for *simple separation* against electric shock.

[SOURCE: IEC 60664-1: 2007, 3.17.3, modified]

3.57
surge protective device
SPD
device that contains at least one non-linear component that is intended to limit surge voltages and divert surge currents

Note 1 to entry: An SPD is a complete assembly, having appropriate connecting means.

[SOURCE: IEC 61643-11:2011, 3.1.1]

3.58
system
set of interrelated and/or interconnected independent elements

Note 1 to entry: A *system* is generally defined with the view of achieving a given objective, for example by performing a definite function.

3.59
system voltage
voltage used to determine *insulation* requirements

Note 1 to entry: See 4.4.7.1.6 for further consideration of *system voltage*.

3.60
temporary overvoltage
overvoltage at power frequency of relatively long duration

[SOURCE: IEC 60664-1:2007, 3.7.1]

3.61
touch current
electric current passing through a human body or through an animal body when it touches one or more accessible parts of an electrical installation or electrical equipment

[SOURCE: IEC 60050-826:2004, 826-11-12]

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3.62
type test
test of one or more devices made to a certain design to show that the design meets certain specifications

[SOURCE: IEC 60050-811:1991, 811-10-04]

3.63
ventricular fibrillation
cardiac fibrillation, limited to the ventricles, leading to ineffective circulation and then to heart failure

Note 1 to entry: Ventricular fibrillation stops blood circulation.

[SOURCE: IEC 60050-891:1998, 891-01-16]

3.64
working voltage
voltage, at rated supply conditions (without tolerances) and worst case operating conditions, that occurs by design in a circuit or across *insulation*

Note 1 to entry: The *working voltage* can be d.c. or a.c. Both the r.m.s. and recurring peak values are used.

3.65
zone of equipotential bonding
zone where all simultaneously accessible conductive parts are electrically connected to prevent hazardous voltages appearing between them

Note 1 to entry: For equipotential bonding, it is not necessary for the parts to be earthed.

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3.100 General

The terms and definitions of ***SELV/PELV*** circuits are inconsistent throughout the standards. Therefore the definition for ***DVC*** circuits has been introduced. Where references are made of this document to clauses of the IEC 62477-1:2012 containing requirements for ***SELV*** and ***PELV*** circuits, such requirements shall be disregarded. Refer also to 4.4.6.4.2 for further details.

3.100.1
abnormal operation conditions
temporary operating condition that is not a normal operating condition and is not a single fault condition of the equipment itself

Note 1 to entry: An abnormal operating condition may be introduced by the equipment or by a person and may result in a failure of a component, a device or insulation.

3.100.2
AC mains supply
low voltage AC power distribution system for supplying power to AC equipment

3.100.3
DC mains supply
a DC power distribution system, with or without batteries, external to the equipment, for supplying power to DC powered equipment at hazardous energy level (> 240 VA after 60 s)

3.100.4
DC power and distribution equipment
equipment to supply DC power to information and communication technology equipment

Note 1 to entry: Normally consisting of batteries, power supplies, control and monitoring circuits, and distribution panels all interconnected to provide isolated secondary circuit power to information and communication technology equipment loads. Components within this system are normally installed in racks, cabinets, or other structures

3.100.5
DVC B
secondary circuit which stays in certain voltage limits under normal and fault conditions

Note 1 to entry: Refer to Table 5.

3.100.6
DVC C
any circuit not meeting the separation requirements or voltage limits for ***DVC B*** or ***DVC As***

3.100.7
electric strength
dielectric strength
ability of the insulation against the effects of the electric field as investigated by electric strength tests

Note 1 to entry: Any reference to electric strength tests made within this document refers to both an impulse voltage test and an AC and DC voltage test.

Note 2 to entry: An AC and DC voltage test can be used alternatively to an impulse voltage test as described in 5.2.3.3, see 5.2.3.4 for details.

3.100.8
auxiliary socket-outlet
mains socket-outlet
AC output which is either directly connected or via EMC filtering components, AC switches or fuses to the ***AC mains supply***

3.100.9
moveable equipment
equipment that is either

– 18 kg or less in mass and not fixed in place, or
– provided with wheels, casters, or other means to facilitate movement by an ordinary person as required to perform its intended use

3.100.10
operator
user
any person, other than a ***service person***

3.100.11
secondary circuit
circuit that has no direct connection to a AC mains circuit and derives its power from a transformer, converter or equivalent isolation device, from a battery or DC mains

3.100.12
service person
person having appropriate technical training and experience necessary to be aware of hazards to which that person may be exposed in performing a task and of measures to minimize the risks to that person or other persons

3.100.13
stand-alone switch-mode power supply
switch mode power supply (SMPS) that in itself is an end use product

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3.100.14
stationary equipment

– fixed equipment, or
– permanently connected equipment, or
– equipment that, due to its physical characteristics, is normally not moved

Note 1 to entry: Stationary equipment is neither movable equipment nor transportable equipment.

3.100.15
switch-mode power supply
SMPS
an electrical or electronic device, incorporating a switching regulator to efficiently convert electrical power, transforming electrical power into single or multiple power outputs

Note 1 to entry: It may also isolate, regulate and/or convert the power. This may consist of one or more individual ***SMPS*** with associated circuitry and hardware.

3.100.16
component SMPS
switch mode power supply (SMPS) which may not comply with some of the requirements of the standard such as ***enclosure*** requirements

Note 1 to entry: This type of ***SMPS*** is intended for incorporation within an end product, which in turn complies with all the requirements of the end product standard.

3.100.17
transportable equipment
equipment that is intended to be routinely carried

4 Protection against hazards

The provisions of Clause 4 of IEC 62477-1:2012 apply, except as follows.

4.1 General

Replacement:

Clause 4 defines the minimum requirements for the design and construction of a SMPS, to ensure its safety during installation, normal operating conditions and maintenance for the expected lifetime of the SMPS. Consideration is also given to minimising hazards resulting from reasonably foreseeable misuse.

Protection against hazards shall be maintained under normal and single fault conditions, as specified in this document.

Components compliant with a relevant IEC product standard which provides similar safety requirements as the requirement of this document do not require separate evaluation.

Components or assemblies of components, for which no relevant product standard exists, shall be tested according to the requirements of this document.

Where the SMPS is intended to be used together with specific auxiliary equipment, the safety evaluation and test shall include this auxiliary equipment unless it can be shown that it does not affect the safety of either equipment.

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Addition:

4.1.100 Constructions not specifically covered

Where the equipment involves technologies and materials or methods of construction not specifically covered in this document, the equipment shall provide a level of safety not less than that generally afforded by this document and the principles of safety contained herein.

NOTE The need for additional detailed requirements to cope with a new situation is brought promptly to the attention of the appropriate committee.

4.1.101 Orientation during transport and use

4.1.101.1 General

Where it is clear that the orientation of the equipment is likely to have a significant effect on the application of the requirements or the results of tests, all orientations of use permitted in the installation or operating instructions shall be taken into account. For ***transportable equipment***, all orientations of transport and use shall be taken into account.

4.1.101.2 Choice of criteria

Where the standard permits a choice between different criteria for compliance, or between different methods or conditions of test, the choice is specified by the manufacturer.

4.1.101.3 Conductive liquids

For the electrical requirements of this document, conductive liquids shall be treated as conductive parts.

4.2 Fault and abnormal conditions

Replacement:

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

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

This analysis shall include situations where a failure of the component or any insulation other than ***double*** or ***reinforced insulation*** would result in

– an impact on the decisive voltage classification voltage limits (Table 5),
– a risk of electric shock due to an impact on any of the methods for protection against electric shock according to 4.4,
– a risk of energy hazard according to 4.5,
– a risk of degradation due to emission of flame, burning particles or molten metal of the fire according to 4.6,
– a risk of thermal hazard due to high temperature according to 4.6, and
– a risk of mechanical hazard according to 4.7.

The effects of short circuit and open-circuit conditions of the component or between components or between printed wiring board (PWB) traces shall be considered. Testing is necessary unless analysis can conclusively show that no hazard will result in case of the these failure modes. Compliance shall be checked by investigation or test of 5.2.4.6.

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The evaluation of components shall be based on the expected stress occurring in the expected lifetime of the SMPS including, but not limited to

– specified climatic and mechanical conditions according to 4.9 (temperature, humidity, vibration, etc.),
– electrical characteristics according to 4.4.7 (expected impulse voltage, working voltage, temporary overvoltage, etc.), and
– micro environment according to 4.4.7 (pollution degree, humidity, etc.).

Components shall meet the requirements of Clause 7.

Clearance and creepage distances, dimensioned to 4.4.7.4 and 4.4.7.5 and/or solid insulation dimensioned to 4.4.7.8 for ***double*** or ***reinforced insulation*** does not need to be faulted.

Functional insulation on PWB and between legs of components assembled on PWBs not fulfilling the requirements for clearance and creepage distance in 4.4.7.4 and 4.4.7.5 shall meet the requirement of 4.4.7.7.

Addition:

4.2.100 Application of faults and abnormal conditions

A single fault consists of a single failure of any insulation (excluding ***double insulation*** or ***reinforced insulation***) or a single failure of any component (excluding components with ***double insulation*** or ***reinforced insulation***).

The equipment construction, circuit diagrams, component specifications, including ***functional insulation*** are examined to determine those ***single fault conditions*** that might reasonably be expected. In particular:

– short-circuits and open circuits of semiconductor devices and capacitors;
– faults causing continuous dissipation in resistors designed for intermittent dissipation;
– internal faults in integrated circuits causing excessive dissipation;
– failure of ***functional*** or ***basic insulation***, where this might affect
  - accessible conductive parts;
  - earthed conductive screens;
  - parts of ***DVC As*** circuits;
  - parts of limited current circuits described in clause 4.4.5.102.
– as a minimum, the following examples of abnormal operating conditions shall be considered, as applicable:
  - for equipment with controls accessible to an user, adjustment of the controls, both individually and collectively, for worst-case operating conditions;
  - applicable testing as indicated in Table 22;
– fault conditions as described in IEC 60990:1999, 6.2.2.
– any other faults or conditions that might affect the safety of the power supply.

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4.3 Short circuit and overload protection

4.3.1 General

The *SMPS* shall not present a hazard, under short circuit or overload conditions at any *port*, including phase to phase, phase to earth and phase to neutral. Adequate information shall be provided in the documentation to allow proper selection of external wiring and protective devices (see 6.3.7.6 and 6.3.7.7).

Protective *systems* or devices shall be provided or specified in sufficient quantity and location so as to detect and to interrupt or limit the current flowing in any possible fault current path between conductors or from conductors to earth.

NOTE 1 In this standard, the term overcurrent covers both short circuit and overload.

NOTE 2 Local *installation* codes will still usually require provision of such protection for the purposes of protecting the input wiring in the *installation.*

Protection against overcurrents shall be provided for all input circuits, and for output circuits that do not comply with the requirements for limited power sources in 4.6.5.

If the *SMPS* complies with all normal, abnormal and fault test conditions in this standard without such protection provided, provision or specification of overcurrent protection for input circuits is not necessary for the protection of the *SMPS*.

No protection is required against overcurrent to earth in equipment that either

– has no connection to earth; or
– has *double insulation* or *reinforced insulation* between *live parts* and all parts connected to earth.

NOTE 3 Under a *single fault condition* in an IT system no short circuit current or a limited short circuit current will flow. The interruption of the short circuit current in an IT system (see 4.4.7.1.4) is done when a second fault occurs. Typically only detection is done after the first fault in an IT *system*.

NOTE 4 Where *double insulation* or *reinforced insulation* is provided, a short circuit to earth would be considered to be two faults.

For *pluggable equipment type A*, the protective device is provided in the *installation* and shall not require any specific characteristics other than that required in IEC 60364 or other local *installation* codes.

For *pluggable equipment type B* or fixed installed equipment, this protection may be provided by devices external to the equipment, in which case the installation instructions shall state the need for the protection to be provided in the *installation* and shall include the specifications for the required short circuit and/or overload protection (see 6.3.7).

NOTE 5 IEC 60364 provides requirements for short circuit and overload protection of the input wiring in the *installation.*The above requirement ensures that the user is informed about any special characteristics of the protective devices for the protection of the *SMPS*, in addition to the requirements in IEC 60364 or other local *installation* codes.

If a protective device interrupts the neutral conductor, it shall also simultaneously interrupt all other supply conductors of the same circuit. It is permissible for the protective device to interrupt the neutral conductor after the other supply conductors of the same circuit.

Compliance shall be checked by inspection and where necessary, by simulation of *single fault conditions* (see 4.2) and by the tests of 5.2.4.4 and 5.2.4.5.

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4.3.2 Specification of input short-circuit withstand strength and output short circuit current ability

4.3.2.1 General

The interrupting capability of the overcurrent protective device shall be equal or greater than the *prospective short circuit current* of the *mains supply*.

For *pluggable equipment type A*, either the *SMPS* shall be designed so that the building *installation* provides *short circuit backup protection*, or additional *short circuit backup protection* shall be provided as part of the equipment.

For *permanently connected equipment* or *pluggable equipment type B*, it is permitted for *short circuit backup protection* to be in the building *installation*.

4.3.2.2 Input *ports* short-circuit withstand strength

The input *prospective short circuit current* ratings apply to *ports* intended to be connected to battery circuits, external *mains supply*, *non-mains* a.c. or d.c. sources, and to other *ports* for which overcurrent protection is necessary.

For co-ordination and selection of internal or external protective devices, the *SMPS* manufacturer shall specify:

– a maximum allowable *prospective short circuit current* for each input *port* of the *SMPS*; and

– a minimum required *prospective short circuit current* in order to ensure proper operation of the protective device

NOTE 1 This requirement is especially applicable to fuses, which are not specified to be operated below a certain fault current value.

NOTE 2 The maximum allowable and minimum required *prospective short circuit current* are used to ensure a proper coordination between the *prospective short circuit current and a suitable protective device* at the location of the electrical *installation*.

If external protective devices are specified or provided the characteristics of those shall be specified by the manufacturer.

See 6.2 for marking.

4.3.2.3 Output short circuit current ability

The *output short circuit current* ratings appliy to a.c. and d.c. power output *ports* and to other *ports* for which overcurrent protection is necessary.

For all output *ports*, short circuit evaluation to determine the minimum and maximum *output short circuit current* shall be performed according to 5.2.4.4 and the *output short circuit current* available from the *SMPS* shall be specified as in 5.2.4.4 and 6.2.

Internal electronic output short circuit protection is considered acceptable as an output short circuit protection device of the *SMPS*, when compliance is shown by test in 5.2.4.4.

4.3.2.4 Combined input and output *ports*

For *ports* which are both input and output *ports* the applicable requirements of both 4.3.2.1 and 4.3.2.3 apply.

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4.3.3 Short-circuit coordination (backup protection)

Protective devices provided or specified shall have adequate breaking capability to interrupt the maximum *prospective short circuit current* specified for the *port* to which they are connected.

If internal protection of the *SMPS* is not rated for the *prospective short circuit current,* the installation instructions shall specify an upstream protective device, rated for this *prospective short circuit current* of that *port*, which shall be used to provide backup protection. Analysis shall ensure the protection coordination between the external and internal protective device.

NOTE IEC 60364 provides requirements for upstream protective devices of the backup protection in the *installation.* The above requirement ensures that the user is informed about any special characteristics of the upstream protective devices for the backup protection of the *SMPS*, in addition to the requirements in IEC 60364 or other local *installation* codes.

Compliance shall be checked by inspection and by the tests of 5.2.4.4 and 5.2.4.5.

4.3.4 Protection by several devices

Where protective devices that require manual replacement or resetting are used in more than one pole of a supply to a given load, those devices shall be located together. It is permitted to combine two or more protective devices in one component.

Compliance shall be checked by inspection.

4.4 Protection against electric shock

4.4.1 General

Protection against electric shock depends on the *decisive voltage class* from 0 and *insulation* requirements from 4.4.2.3, and is to be provided by at least one of the following measures:

– *basic protection* from 4.4.3 and *fault protection* from 4.4.4;

– *enhanced protection* from 4.4.5

Protection under normal conditions is provided by *basic protection*, and protection under *single fault conditions* is provided by *fault protection*.

Enhanced protection provides protection under both conditions.

Additional protection can be provided by residual current-operated protective devices (RCD). For further information, see 4.4.8.

NOTE In this standard, 4.4.1 to 4.4.6 have been harmonized with the concepts of the horizontal standard IEC 61140 for protection against electrical shock. *Basic protection*, *fault protection*, *enhanced protection* and the combination of those measures has been implemented.

4.4.2 Decisive voltage class

4.4.2.1 General

Replacement:

No access protection is required if under normal operation and under ***single fault condition*** the ***DVC As*** limits, derived from Table 5, are not exceeded in this document. Values of ***DVC B*** are not allowed to be touchable by the test finger, except for connectors of telecommunication circuits. ***DVC C*** is not allowed to be touched, and clearance requirements to the test finger do apply.

NOTE Refer to Table A.4, row 4 for examples on clearance requirements.

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4.4.2.2 Determination of decisive voltage class

4.4.2.2.1 General

The provisions of clause 4.4.2.2.1 of IEC 62477-1:2012 do not apply.

NOTE The considerations related to ***SMPS*** regarding their application and environment lead to the conclusion to only use the DVC A voltage levels for dry hand and DVC A2 for water wet environments.

Addition:

4.4.2.2.1.100 Additional DVC considerations

The manufacturer defines the ***DVC*** for the individual output circuits and provides the information with the accompanying documentation.

Inputs/output circuits with rated voltages within the limits of ***DVC As*** are investigated as ***DVC As*** circuits, except they are differently specified by the manufacturer (see 6.2.101) and only intended to be accessed by a ***service person***.

SELV and ***PELV*** circuits have to be ***DVC*** classified in order to apply the proper requirements. ***DVC*** circuits can be earthed or unearthed.

NOTE SELV and PELV circuits are covered as DVC As or DVC B depending on working voltage. The maximum DVC B voltage is limited to the ELV limits as defined in IEC 61140 (same as SELV and PELV) under normal and single fault condition and is used for example. as interface to SELV/PELV circuits.

For determination of transients of any other external circuit, 5.4.2.3.2.4 and Table 14 of the IEC 62368-1:2014 can be used.

4.4.2.2.1.101 DVC As levels for water wet locations

Accessible parts and ***DVC As*** outputs of ***SMPS*** designed for usage in water wet locations shall comply with reduced voltage levels as defined in Table 5.

4.4.2.2.2 Selection tables for contact area and skin humidity condition

The provisions of 4.4.2.2.2 of IEC 62477-1:2012 do not apply.

4.4.2.2.3 Limits of the working voltage for the DVC

Replacement:

The provisions of clause 4.4.2.2.3 of IEC 62477-1:2012 are replaced by:

Limits for the ***working voltage*** regarding the ***DVC*** for normal operation and during fault and abnormal operation are given in Table 5.

Table 5 of IEC 62477-1:2012 is replaced by Table 5 of this document.

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Table 5 – Voltage limits

DVC	Limits of working voltage during normal operation V				Limits of working voltage during fault and abnormal conditions V	
	AC voltage (RMS) U_{AC}	**AC voltage (peak)** U_{peak}	**DC voltage (mean)** U_{DC}	**Limit for overvoltage** U_{peak}	**Voltage (peak AC or DC) up to 200 ms**[a,d]	**Voltage (peak AC or DC) after 1 000 ms**[a,d]
As	30/12[c]	42,4/17[c]	60/28[c]	1 500[e]	120	NOPL[b]
B	50	71	120	1 500[e]		
C	all circuits not meeting DVC As or DVC B			N/A	N/A	

[a] Linear interpolation is allowed between 200 ms and 1 000 ms.

[b] Relevant normal operation limit (NOPL), as described in this table, corresponding to the appropriate voltage type.

[c] Limits for water wet location applications.

[d] Single pulses relate to DC voltage limits and repetitive pulses relate to AC voltage limits.

[e] Maximum transients with the 1,2/50 µs impulse characteristic.

NOTE DVC A1 and A3 limits are not used.

For testing, see 5.2.4.

4.4.2.3 Requirements for protection against electric shock

Replacement:

The provisions of clause 4.4.2.3 of IEC 62477-1:2012 are replaced by:

User and service persons shall be protected against electric shock by the methods for ***enhanced protection*** outlined in 4.4.5.

The requirement of this document for protection against electric shock to be provided by Table 6 unless other insulation means are provided, in which case failure analysis and testing shall show that the requirements of 4.1 and 4.4 are met.

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Table 6 – Separation requirements for circuit under consideration

Circuit under consideration[e]	To operator accessible parts and parts not reliably connected to PE[a]	To service accessible parts	To service accessible parts in RAL	To PE and conductive parts reliably connected to PE	DVC As	DVC B	DVC C
DVC As	None[b]	None[b]	None[b]	None[b]	None[b,c]	PS	PS
DVC B	SS[d]	SS	None[b]	None[b]		None[b,c]	PS
DVC C	PS[d]	PS	PS	SS			None[b,c]

NOTE This table describes the separation requirements between different galvanically separated circuits.

SS: Simple separation

PS: Protective separation

[a] For example. functionally earthed.

[b] Protection is not necessary for safety, but may be required for functional reasons according to 4.4.7.3. For DVC As circuits located in different environments, SS shall be used.

[c] PS is needed, if a single insulation fault between circuits leads to a violation of the individual circuits DVC classification.

[d] SS to tip of test finger and PS to enclosure contact point of test finger. See row 4 of Table A.4.

[e] For water-wet environmental conditions, DVC As circuits for dry environment (higher limits of Table 5) and DVC B are to be read as DVC C circuits (in this table only) to determine the separation requirements.

NOTE Refer to Annex AD for further explanation.

4.4.3 Provision for basic protection

4.4.3.1 General

Replacement:

Basic protection is employed to establish a first level of protection to prevent persons from touching ***hazardous-live-parts***.

It shall be provided by means of basic insulation of ***live parts*** in 4.4.3.2.

NOTE 1 Basic protection itself is considered insufficient for protection of users, as basic protection can be damaged or faulted.

NOTE 2 Refer to Annex AD for further explanation.

4.4.3.2 Protection by means of basic insulation of live parts

Replacement:

Basic insulation may be provided by solid insulation or air clearance.

The insulation shall be rated according to the impulse voltage, temporary overvoltage or working voltage (see 4.4.7.2.1), whichever gives the most severe requirement. It shall not be possible to remove the insulation without the use of a tool or key.

An accessible conductive part is considered to be conductive if its surface is bare or is covered by an insulating layer that does not comply with the requirements of at least basic insulation.

Basic insulation has to be provided as required by Table 6.

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The basic insulation shall be designed and tested to withstand the impulse voltages and temporary overvoltages for the circuits to which they are connected. See 5.2.3.2 and 5.2.3.4 for tests.

Clause A.7 provides examples of the use of elements of protective measures.

4.4.3.3 Protection by means of enclosures or barriers

Replacement:

Refer to clause 4.4.5.100.

4.4.3.4 Protection by means of limitation of touch current and charge

Replacement:

Refer to clause 4.4.5.102 or 4.4.5.103 as relevant.

4.4.3.5 Protection by means of limited voltages

The provisions of clause 4.4.3.5 of IEC 62477-1:2012 do not apply.

NOTE Requirements regarding limited voltages are located in 4.4.5.101.

4.4.4 Provision for fault protection

4.4.4.1 General

Replacement:

Fault protection is employed to establish a second level of protection to prevent persons from touching ***hazardous-live-parts***. Fault protection requires basic protection first and shall be provided in addition by one or more of the following measures:

a) protective equipotential bonding in 4.4.4.2 in combinations with the PE conductor in 4.4.4.3;
b) automatic disconnection of supply in 4.4.4.4;
c) ***supplementary insulation*** in 4.4.4.5;
d) electrically protective screening in 4.4.4.7.

Addition:

4.4.4.1.100 Additional measures for protection

In addition to the measures outlined in 4.4.4.1, it can be necessary in an electrical circuitry to provide additional measures to prevent from a risk of electric shock resulting from ***single fault*** or ***abnormal operating condition*** as investigated according to 4.2.

These additional measures, consisting of components or insulation, shall be carefully selected to ensure operation over the product lifetime.

NOTE 1 An example would be voltages on the secondary side of an isolating transformer in a SMPS, which exceed the voltage limits of DVC As, but additional components in the secondary side ensure that the output voltage of the SMPS meets the limits of DVC As under normal and fault conditions.

NOTE 2 Functional safety according to IEC 61508 (all parts) or IEC 60730-1 can be used to achieve an acceptable level of safety by means of electronics (e.g. integrated circuits, ASICs, FPGAs) with or without software. However, this document does not provide any guidance on selection of an acceptable risk level. A SMPS can be also investigated according to this document by disabling or extensive simulation of faults on such safety means.

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Two output circuits have to be separated by protective separation, if fault testing of combinations of circuits, according to 4.2, leads to an excess of the relevant circuit limits.

4.4.4.2 Protective equipotential bonding

4.4.4.2.1 General

Protective equipotential bonding shall be provided between accessible conductive parts of the equipment and the means of connection for the *PE conductor*, except:

a) accessible conductive parts that are protected by one of the measures in 4.4.6.4; or

b) when accessible conductive parts are separated from *live parts* using *double* or *reinforced insulation*.

Electrical contact to the means of connection of the *PE conductor* shall be achieved by one or more of the following means:

– through direct metallic contact;

– through other accessible conductive parts or other metallic components which are not removed when the *SMPS* is used as intended;

– through a dedicated *protective equipotential bonding* conductor.

When painted surfaces (in particular powder painted surfaces) are joined together, masking of paint, paint piercing methods or a separate connection shall be made to ensure reliable contact.

Where electrical equipment is mounted on lids, doors, or cover plates, continuity of the *protective equipotential bonding* circuit shall be ensured by a dedicated conductor or equivalent means complying with the requirements for *protective equipotential bonding*. If fasteners, hinges or sliding contacts do not provide and guarantee low enough impedance, sufficient parallel bonding is required.

Electrical connections of *protective equipotential bonding* circuit shall be designed so that contact pressure is not transmitted through insulating material, unless there is sufficient resilience in the metallic parts to compensate for any possible shrinkage or distortion of the insulating material.

Unless specified by the manufacturer and in compliance with 4.4.4.2.2 metal ducts of flexible or rigid construction and metallic cable sheaths shall not be used as *protective equipotential bonding* means. Nevertheless, such metal ducts and the metal sheathing of all connecting cables (for example cable armouring, lead sheath) shall be connected to the *protective equipotential bonding* circuit.

The *protective equipotential bonding* circuit shall not incorporate a component such as switch or overcurrent protective devices which may open the circuit.

The electrical connection points of the *protective equipotential bonding* shall be corrosion-resistant.

Figure 4 shows an example of a *SMPS* assembly and its associated *protective equipotential bonding*.

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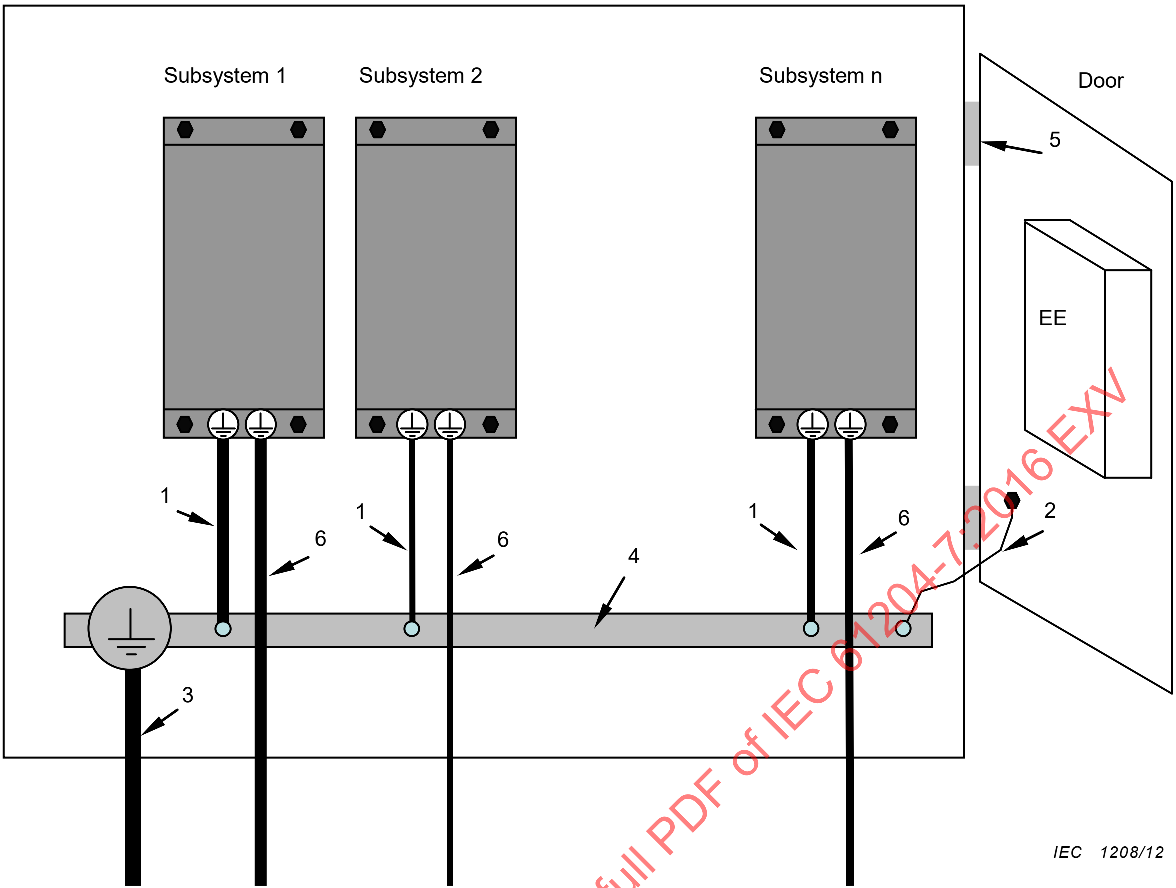

Key

1 *protective equipotential bonding* of subsystems or *SMPS PE conductor* (dimensioned according to *SMPS* requirements)

2 *protective equipotential bonding*

3 *PE conductor* (dimensioned according to *SMPS* requirements) to *installation* earthing point

4 *earth* bar

5 hinge

6 PE conductor to the load

EE other electrical equipment (bonded as relevant for that equipment)

Figure 4 – Example of a *SMPS* assembly and its associated *protective equipotential bonding*

Figure 5 shows an example of a *SMPS* assembly and its associated *protective equipotential bonding* through direct metallic contact.

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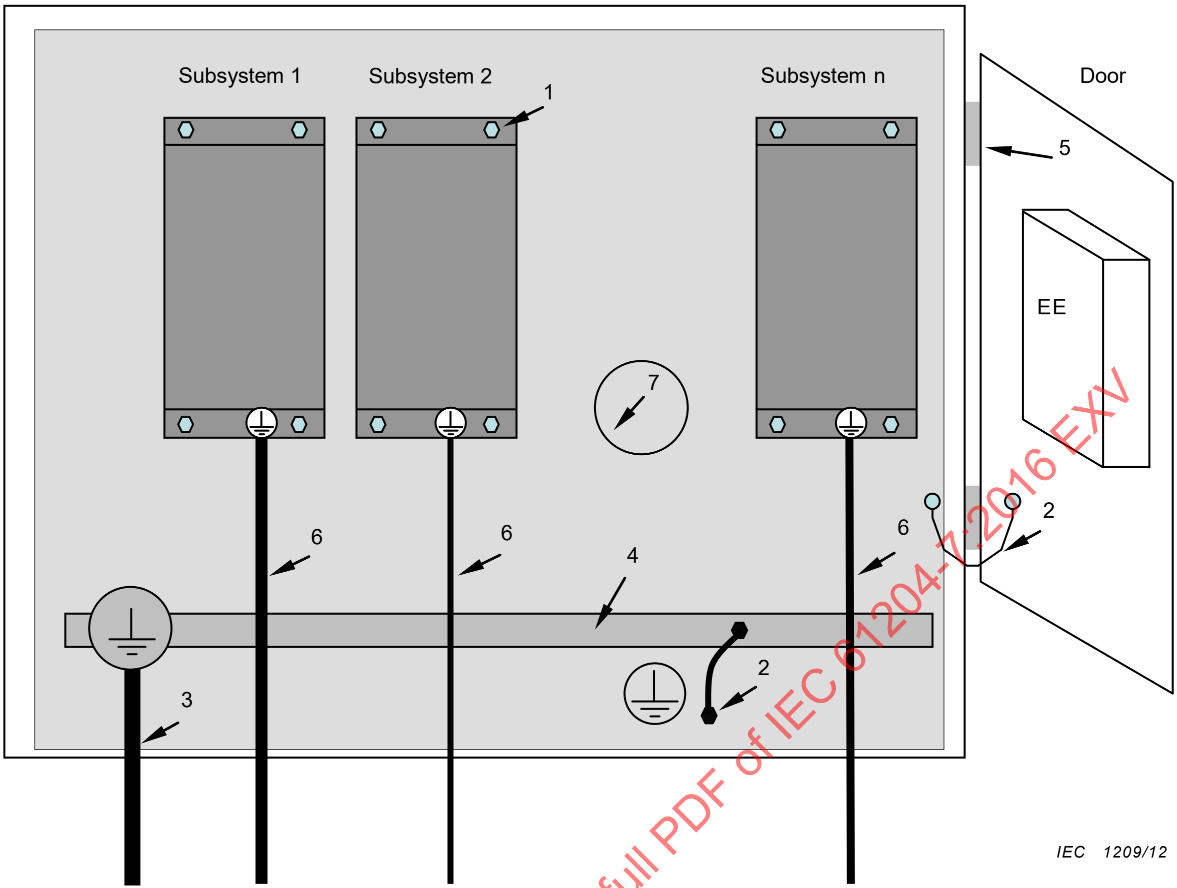

Key

1 *protective equipotential bonding* of subsystems through direct metallic contact (paint removed)

2 *protective equipotential bonding*

3 *PE conductor* (dimensioned according to *SMPS* requirements) to *installation* earthing point

4 *earth* bar

5 hinge

6 *PE conductor* to the load

7 metal subplate

EE other electrical equipment (bonded as relevant for that equipment)

Figure 5 – Example of a *SMPS* assembly and its associated *protective equipotential bonding*

4.4.4.2.2 Rating of protective equipotential bonding

Protective equipotential bonding shall either be:

a) sized in accordance with the requirements for the *PE conductor* in 4.4.4.3 and the means of connection for the *PE conductor* in 4.4.4.3.2 to ensure no voltage drop exceeding the values from 4.4.2.2.3 during a fault; or

b) sized

- to withstand the highest stresses that can occur to the *SMPS* item(s) concerned when they are subjected to a fault connecting to accessible conductive parts; and
- to remain effective for as long as a fault to the accessible conductive parts persists or until an upstream protective device removes power from the part; and
- to ensure no voltage drop exceeding the values from 4.4.2.2.3 during normal operation and during a fault.

Compliance shall be checked with the *type tests* in 5.2.3.11.

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4.4.4.3 PE conductor

4.4.4.3.1 General

A *PE conductor* shall be connected at all times when power is supplied to the *SMPS*, unless the *SMPS* complies with the requirements of *protective class II* (see 4.4.6.3) or *protective class III*. Unless local wiring regulations state otherwise, the *PE conductor* cross-sectional area shall be determined from Table 7 or by calculation according to 543.1 of IEC 60364-5-54:2011.

If the *PE conductor* is routed through a plug and socket, or similar means of disconnection, it shall not be possible to disconnect it unless power is simultaneously removed from the part to be protected.

Table 7 – *PE conductor* cross-section[a]

Cross-sectional area of phase conductors of the *SMPS* S mm²	Minimum cross-sectional area of the corresponding *PE conductor* S_p mm²
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S$	$S/2$

[a] These values are valid only if the *PE conductor* is made of the same material as the phase conductors.In case of different materials the cross-sectional area of the *PE conductor* shall be determined in a manner which produces a conductance equivalent to that which results from the application of this table.

The cross-sectional area of every *PE conductor* that does not form part of the supply cable or cable *enclosure* shall, in any case, be not less than:

- 2,5 mm² if mechanical protection is provided; or
- 4 mm² if mechanical protection is not provided.

Provisions within cord-connected equipment shall be made so that the *PE conductor* in the cord shall, in the case of failure of the strain-relief mechanism, be the last conductor to be interrupted.

For special *system* topologies, the *SMPS* designer shall verify the *PE conductor* cross-section required.

4.4.4.3.2 Means of connection for the PE conductor

SMPS shall have a means of connection for the *PE conductor*, located near the terminals for the respective live conductors. The means of connection shall be corrosion-resistant and shall be suitable for the connection of conductors according to Table 7 and of cables in accordance with the wiring rules applicable at the *installation*. The means of connection for the *PE conductor* shall not be used as a part of the mechanical assembly of the equipment or for other connections. Connection and bonding points shall be designed so that their current-carrying capacity is not impaired by mechanical, chemical, or electrochemical influences.

Where enclosures and/or conductors of aluminium or aluminium alloys are used, particular attention should be given to the problems of electrolytic corrosion.

Compliance shall be checked by inspection.

Annex K provides further information about electrochemical corrosion.

See 6.3.7.3.2 for marking requirements.

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The marking shall not be placed on or fixed by screws, washers or other parts which might be removed when conductors are being connected.

4.4.4.3.3 Requirements for reliable earthing

NOTE The header of this subclause has been changed for easier understanding.

The requirements of this subclause shall be satisfied to prevent accessible conductive parts to become dangerous in case of damage to or disconnection of the *PE conductor*.

For *pluggable type A* equipment, the *touch current* shall not exceed the limits specified in 4.4.3.4.

For all other *SMPS*, one or more of the following measures shall be applied, unless the *touch current* can be shown to be less than the limits specified in 4.4.3.4:

a) Use of a fixed connection and

- a cross-section of the *PE conductor* of at least 10 mm^2 Cu or 16 mm^2 Al; or
- automatic disconnection of the supply in case of discontinuity of the *PE conductor*; or
- provision of an additional terminal for a second *PE conductor* of the same cross-sectional area as the original *PE conductor*;

or

b) Use of a *pluggable type B* connection with a minimum *PE conductor* cross-section of 2,5 mm^2 as part of a multi-conductor power cable. Adequate strain relief shall be provided.

For marking requirements, see 6.3.7.4.

Compliance is checked by inspection and by test of 5.2.3.7.

For equipment which may be energized from multiple sources of supply, the *touch current* limits above apply in all possible intended *installation* configurations and combinations of sources that may be energized at the same time, unless one of the measures in a) or b) above is used.

When it is intended and allowed to interconnect two or more *SMPS* using one common *PE conductor*, the above *touch current* requirements apply to the maximum number of *SMPS* to be interconnected, unless one of the measures in a) or b) above is used. The maximum number of interconnected *SMPS* is used in the testing and has to be stated in the installation manual.

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4.4.4.4 Automatic disconnection of supply

For automatic disconnection of supply:

– a *protective equipotential bonding system* shall be provided; and

– a protective device operated by the fault current shall disconnect one or more of the line conductors supplying the equipment, *system* or *installation*, in case of a failure of *basic insulation*.

The protective device shall interrupt the fault current within a time as specified in Figure 1, Figure 2 or Figure 3 in 4.4.2.2.3 of 62477-1:2012.

4.4.4.5 Supplementary insulation

Supplementary insulation is an independent *insulation* applied in addition to *basic insulation* for *fault protection* and shall be dimensioned to withstand the same stresses as specified for *basic insulation*.

Addition:

4.4.4.5.100 Provision of supplementary insulation

Supplementary insulation has to be provided as required by Table 6.

4.4.4.6 Simple separation between circuits

Simple separation between a circuit and other circuits or earth shall be achieved by *basic insulation* throughout, rated for the highest voltage present.

If any component is connected between the separated circuits, that component shall withstand the electric stresses specified for the insulation which it bridges.

If any component is connected between a circuit and a circuit connected to earth, its impedance shall limit the current flow through the component to the steady-state *touch current* values indicated in 4.4.3.4.

4.4.4.7 Electrically protective screening

Electrically protective screening interposed between *hazardous live parts* of a *SMPS*, shall consist of a conductive screen connected to the *protective equipotential bonding* of the *SMPS* whereby the screen is separated from *live parts* by at least *simple separation*.

The protective screen and the connection to the *protective equipotential bonding system* of the *SMPS* and that interconnection shall comply with the requirements of 4.4.4.2.

4.4.5 Enhanced protection

4.4.5.1 General

Replacement:

The provisions of 4.4.5.1 of IEC 62477-1:2012 are replaced by:

Enhanced protection is generally acceptable to protect the user or service person. It consists of two levels of protection, or one reinforced level of protection considered equivalent to two levels of protection, to prevent persons from touching ***hazardous-live-parts***.

Enhanced protection is achieved by:

– protection by prevention of access, as described in 4.4.5.100; or
– protection by protective separation between circuits in 4.4.5.3, together with at least one of the following measures for:
  a) limitation of voltage, as described in 4.4.5.101;
  b) limitation of current, as described in 4.4.5.102;
  c) limitation of energy or charge, as described in 4.4.5.103;
  d) protective impedance, as described in 4.4.5.4.

Additional protection as described in 4.4.4.1.100 might be necessary to comply with these measures.

NOTE Refer to Annex AD for further explanation.

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4.4.5.2 Reinforced insulation

Reinforced insulation shall be so designed as to be able to withstand electric, thermal, mechanical and environmental stresses with the same reliability of protection as provided by *double insulation* (*basic insulation* and *supplementary insulation*, see 4.4.3.2 and 4.4.4.5).

4.4.5.3 Protective separation between circuits

Protective separation between a circuit and other circuits shall be achieved by one of the following means:

- *double insulation* (*basic insulation* and *supplementary insulation* in 4.4.3.2 and 4.4.4.5);
- *reinforced insulation* in 4.4.5.2;
- *electrically protective screening* in 4.4.4.7;
- a combination of these provisions.

If conductors of the separated circuit are contained together with conductors of other circuits in a multi-conductor cable or in another grouping of conductors, they shall be insulated, individually or collectively, for the highest voltage present, so that *double insulation* is achieved.

If any component is connected between the separated circuits, that component shall comply with the requirements for *protective impedance* devices (see 4.4.5.4)

4.4.5.4 Protection by means of protective impedance

Protective impedance shall be arranged so that under both normal and *single fault conditions* the current and discharge energy available shall be limited according to 4.4.3.4.

The *protective impedances* shall be designed and tested to withstand the impulse voltages and *temporary overvoltages* for the circuits to which they are connected. See 5.2.3.2 and 5.2.3.4 for tests.

Compliance with the requirement for the limitation of *touch current* is checked by test of 5.2.3.6.

Compliance with the requirement for the discharge energy shall be checked by performing calculations and/or measurements to determine the voltage and capacitance.

NOTE A *protective impedance* designed according to this subclause is not considered to be a galvanic connection.

Addition:

4.4.5.100 Protection by prevention of access

Operator access to parts or circuits other than ***DVC As*** shall be:

- arranged in ***enclosures*** or located behind ***enclosures*** or barriers, which meet at least the requirements of the protective type IPXXB according to Clause 7 of IEC 60529:1989;
- located under top surfaces of enclosures or barriers which are accessible when the equipment is energized fulfilling the test with the IP3X test probe of 5.2.2.2.

For ***moveable equipment*** with no defined top and bottom the test with the IP3X test probe of 5.2.2.2 applies to all sides.

If the ***SMPS*** is installed in a ***restricted access area***, IPXXB instead of the test with the IP3X test probe of 5.2.2.2 applies.

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Compliance is shown by test of 5.2.2.2.

It shall only be possible to open ***enclosures*** or remove barriers:

– with the use of a tool or key; or
– after de-energization of parts or circuits other than DVC As.

Where the ***enclosure*** is required to be opened and the ***SMPS*** energized during installation or maintenance:

a) parts or circuits other than ***DVC As*** shall be protected by at least IPXXA; and
b) parts or circuits other than ***DVC As*** that are likely to be touched when making adjustments shall be protected by at least IPXXB; and
c) it shall be ensured that persons are aware that parts or circuits other than ***DVC As*** are accessible.

Protection of a ***service person*** in ***restricted access areas*** can be alternatively achieved by:

a) means of ***basic insulation*** of ***live parts*** in 4.4.3.2 or below methods of b) and c);
b) prevention of contact parts or circuits other than ***DVC As*** or ***DVC B*** and
c) prevention of unintentional contact by usage of warning markings for non-obvious hazards (e.g. discharge of capacitors).

For marking requirements, see 6.3.7.1.

Enclosures of ***protective class I*** products have to meet 4.4.6.2 and ***enclosures*** of ***protective class II*** products have to meet 4.4.6.3.

4.4.5.101 Protection by limitation of voltage

Operator access is only allowed to parts/circuitry or simultaneously accessible parts/circuitry of DVC As except for connectors with DVC B for telecommunication circuits (see 4.4.2.1).Within this document a ***DVC As*** represents a safe to touch circuit, as it has to meet:

a) protective separation requirements as outlined in 4.4.5; and
b) voltage limits according to Table 5, during normal and fault conditions, with considerations according to 4.2 and testing to 5.2.4.

Service person access is allowed to parts/circuitry or simultaneously accessible parts/ circuitry up to voltages at ***DVC B.***

The ***DVC B*** circuit has to meet:

a) protective separation requirements as outlined in 4.4.5; and
b) voltage limits according to 4.4.2.2.3 Table 5, during normal and fault conditions, with considerations according to 4.2 and testing to 5.2.4.

4.4.5.102 Protection by limitation of current

Access to parts able to deliver currents over the limits of Table 100 shall be prevented under normal, fault and abnormal operation, except for conductive parts reliably connected to PE according to 4.4.4.3.3, if they are marked as described in 6.3.7.4.

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Table 100 – Limits for access of current

Frequency range	Normal operation limit[a,b]	Fault condition limit[a,b]
Direct current	2 mA	10 mA
Up to 1 kHz	0,5 mA RMS or 0,7 mA peak	3,5 mA RMS or 5 mA peak
1 kHz up to 100 kHz	0,5 mA RMS. x frequency in kHz or 0,7 mA peak. x frequency in kHz	3,5 mA RMS + 0,95 x frequency in kHz or 5 mA peak + 0,95 x frequency in kHz
Above 100 kHz	50 mA RMS or 70 mA peak	100 mA RMSA or 140 mA peak

[a] For non-sinusoidal waveforms, the peak values apply and the current is measured using the measuring network specified in Figure 4 of IEC 60990:1999, for currents up to 2 mA, or Figure 5 of IEC 60990:1999, for currents above.

[b] For sinusoidal waveforms and DC, the RMS values apply and the current may be measured using a 2 000 Ω resistor.

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The currents are measured according to 5.2.3.7 and 5.2.3.7.100.

When protective impedances are used to bridge any insulation 4.4.5.4 and 4.4.7.1.7 applies.

4.4.5.103 Protection by limitation of energy or charge

The limitation of energy or charge has to be investigated in unloaded condition.

Operator access to parts at an energy above 0,5 mJ shall be prevented under normal and under fault and abnormal operation. Additionally, the requirements for capacitor discharge of 4.4.9 and access with test finger to hazardous energy level of 4.5.1.1 apply.

NOTE 1 Voltage limits at a certain capacitance can be calculated over the formula $U = \sqrt[2]{\frac{E}{C}}$.

Service persons shall not have access to a stored charge above 50 µC, with the exception that there is no energy limit in ***restricted access areas***, if the preventions of 4.4.5.100 are used.

NOTE 2 Voltage limits at a certain capacitance can be calculated over the formula $U = \frac{Q}{C}$.

4.4.6 Protective measures

4.4.6.1 General

NOTE Refer to Annex AD for further explanation.

That part of a *SMPS* which meets the requirements of 4.4.6.2 is defined as *protective class I*.

That part of a *SMPS* which meets the requirements of 4.4.6.3 is defined as *protective class II*.

That part of a *SMPS* which meets the requirements of 4.4.6.4 is defined as *protective class III*.

Compliance shall be checked by satisfying the requirements for *protective class I*, *class II* or *class III*.

A.7 provides Examples of the use of elements of protective measures.

Equipment of protective *class I, II and III* shall be marked according to 6.3.7.3.

4.4.6.2 Protective measures for protective class I equipment

Protective class I equipment shall meet the requirements for:

– *basic protection* in 4.4.3; and
– *fault protection* in 4.4.4.2 and 4.4.4.3 with respect to equipotential bonding and *PE conductor.*

4.4.6.3 Protective measures for protective class II equipment

Replacement:

Protective class II equipment shall meet the requirements for enhanced protection according to 4.4.5.

Protective class II equipment shall not have means of connection for the PE conductor. This does not apply if a PE conductor is passed through the equipment to equipment series connected beyond it.

In the latter case, the PE conductor and its means for connection shall be separated from

– accessible surface of the equipment, and
– circuits which employ protective separation

with at least basic insulation designed according to the rated voltage of the series-connected equipment.

Equipment of protective class II may have provision for the connection of an earthing conductor for functional reasons or for the damping of overvoltages. In this case, the functional earthing conductor shall meet the same separation requirements like a ***DVC As*** circuit.

Equipment of protective class II shall be marked according to 6.3.7.3.3.

Compliance is checked by inspection.

4.4.6.4 Protective measures for protective class III equipment or circuits

4.4.6.4.1 General

Protective measures shall be achieved by *protective separation* by one of the following means:

– *basic insulation* and *supplementary insulation (double insulation)* according to 4.4.3.2 and 4.4.4.5;
– *reinforced insulation* according to 4.4.5.2;
– *electrically protective screening* and *simple separation* according to 4.4.4.7; or
– a combination of these provisions;

used in combination with one of the following means:

– *protective impedance* according to 4.4.5.4 comprising limitation of discharge energy and of current; or
– limitation of voltage according to 4.4.3.5.

The *protective separation* shall be fully and effectively maintained under all conditions of intended use of the *SMPS*.

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4.4.6.4.2 Connection to PELV and SELV circuits

Replacement:

External ***PELV*** or ***SELV*** circuits have to be classified to a ***DVC***, as defined in Table 5, for the investigation and treated according to their ***DVC*** classification.

NOTE **SELV**/**PELV** are usually considered ***DVC B***.

4.4.7 Insulation

4.4.7.1 General

4.4.7.1.1 Influencing factors

This subclause gives minimum requirements for *insulation*, based on the principles of IEC 60664.

Manufacturing tolerances shall be taken into account for the requirements in 4.4.7.

Insulation shall be selected after consideration of the following influences:

– pollution degree;
– overvoltage category;
– supply *system* earthing;
– impulse withstand voltage, *temporary overvoltage* and *working voltage*;
– location of *insulation*;
– type of *insulation*.

Verification of *insulation* shall be made according to 5.2.2.1, 5.2.3.2, 5.2.3.4, and 5.2.3.5.

4.4.7.1.2 Pollution degree

Insulation, especially when provided by clearances and creepage distances, is affected by pollution which occurs during the *expected lifetime* of the *SMPS*. The micro-environmental conditions for *insulation* shall be applied according to Table 8.

Table 8 – Definitions of pollution degrees

Pollution degree	Description
1	No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
2	Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation is to be expected.
3	Conductive pollution or dry non-conductive pollution occurs which becomes conductive due to condensation which is to be expected.
4	The pollution generates persistent conductivity caused, for example by conductive dust or rain or snow.

The pollution degree shall be determined according to the environmental condition for which the product is specified. See Table 18 for selection of pollution degree according to environmental classification of the *installation*.

The *insulation* may be determined according to pollution degree 2 if one of the following applies:

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a) instructions are provided with the *SMPS* indicating that it shall be installed in a pollution degree 2 environment; or
b) the specific *installation* application of the *SMPS* is known to be a pollution degree 2 environment; or
c) the *SMPS enclosure* or coatings applied within the *SMPS* according to 4.4.7.8.4.2 or 4.4.7.8.6 provide adequate protection against what is expected in pollution degree 3 and 4 (conductive pollution and condensation).

The *SMPS* manufacturer shall state in the documentation the pollution degree for which the *SMPS* has been designed.

If operation in a pollution degree 4 environment is required, protection against conductive pollution shall be provided by means of a suitable *enclosure*.

NOTE 1 See Annex B for further information about the reduction of pollution degree.

NOTE 2 The dimensions for creepage distance cannot be specified where permanently conductive pollution is present (pollution degree 4). For temporarily conductive pollution (pollution degree 3), the surface of the *insulation* may be designed to avoid a continuous path of conductive pollution, e.g. by means of ribs and grooves. Annex D provides further information about the evaluation of clearance and creepage distances.

4.4.7.1.3 Overvoltage category (OVC)

The concept of overvoltage categories (based on IEC 60364-4-44 and IEC 60664-1) is used for equipment energized from the supply mains, and addresses the level of overvoltage protection expected. The OVC for *non-mains supply* is determined by taking into account whether control of overvoltages is provided or not, and whether the *SMPS* is connected to outdoor lines or not, and if so, the length of the lines.

Four categories are considered.

– Equipment of overvoltage category IV (OVC IV) is for use at the origin of the *installation*.

NOTE 1 Examples of such equipment are electricity meters and primary overcurrent protection equipment and other equipment connected directly to outdoor open lines.

– Equipment of overvoltage category III (OVC III) is equipment in fixed *installations* and for cases where the reliability and the availability of the equipment are subject to special requirements.

NOTE 2 Examples of such equipment are switches in the fixed *installation* and equipment for industrial use with permanent connection to the fixed *installation*.

– Equipment of overvoltage category II (OVC II) is energy-consuming equipment to be supplied from the fixed *installation*.

NOTE 3 Examples of such equipment are appliances, portable tools and other household and similar loads.

If such equipment is subjected to special requirements with regard to reliability and availability, overvoltage category III applies.

– Equipment of overvoltage category I (OVC I) is equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level.

NOTE 4 Examples of such equipment are those containing electronic circuits protected to this level.

NOTE 5 Unless the circuits are designed to take the *temporary overvoltages* into account, equipment of overvoltage category 1 cannot be directly connected to the supply mains.

The measures for reduction of the impulse voltage shall ensure that the *temporary overvoltages* that could occur are sufficiently limited so that their peak value does not exceed the relevant rated impulse voltage of Table 9 and shall meet the requirement of 4.4.7.2.2, 4.4.7.2.3 and 4.4.7.3 as applicable.

Annex I shows examples of overvoltage category considerations for *insulation* requirements.

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For *SMPS* and circuits not intended to be powered from the supply mains, the appropriate overvoltage category shall be determined as required by the application based on the overvoltage control provided on the supply to the equipment or circuit.

NOTE 6 Product committees using this standard as a reference document should consider the determination of overvoltage catagories for special applications.

4.4.7.1.4 Supply system earthing

The following three basic types of *system* earthing are described in IEC 60364-1.

– TN *system*: has one point directly earthed, the accessible conductive parts of the *installation* being connected to that point by protective conductors. Three types of TN *system*, TN-C, TN-S and TN-C-S, are defined according to the arrangement of the neutral and protective conductors.

– TT *system*: has one point directly earthed, the accessible conductive parts of the *installation* being connected to earth electrodes electrically independent of the earth electrodes of the power *system*.

– IT *system*: has all *live parts* isolated from earth or one point connected to earth through an impedance, the accessible conductive parts of the *installation* being earthed independently or collectively to the *system* earthing.

4.4.7.1.5 Determination of impulse withstand voltage and temporary overvoltage

Table 9 uses the *system voltage* (see 4.4.7.1.6) and overvoltage category of the circuit under consideration to determine the impulse withstand voltage. The *system voltage* is also used to determine the *temporary overvoltage*.

A *SMPS* having more than one input or output shall be evaluated according to the input or output which gives the most severe requirements.

Table 9 – Impulse withstand voltage and *temporary overvoltage* versus system voltage

Column 1		2	3	4	5	6
***System* voltage** [a] V (see 4.4.7.1.6) Up to and including		Impulse withstand voltage V				***Temporary overvoltage*** [b] V
		Overvoltage category				
		I	II	III	IV	
a.c.	d.c.					r.m.s. / peak
50	75	330	500	800	1 500	1 250 / 1 770
100	150	500	800	1 500	2 500	1 300 / 1 840
150	225	800	1 500	2 500	4 000	1 350 / 1 910
300	450	1 500	2 500	4 000	6 000	1 500 / 2 120
600	900	2 500	4 000	6 000	8 000	1 800 / 2 550
1 000 [c]	1 500	4 000	6 000	8 000	12 000	2 200 / 3 110

[a] Interpolation of *system voltage* is not permitted when determining the impulse withstand voltage for *mains supply*.

[b] The r.m.s. values are derived using the formula (1 200 V + *system voltage*) from IEC 60664-1.

[c] The last row only applies to single-phase *systems*, or to the phase-to-phase voltage in three-phase *systems*.

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4.4.7.1.6 Determination of the system voltage

4.4.7.1.6.1 For AC mains supply

For *SMPS* supplied by an a.c. *mains supply*, the *system* voltage (in column 1 of Table 9) is:

– in TN and TT *systems*, the r.m.s. value of the rated voltage between a phase and earth;

NOTE 1 A corner-earthed *system* is a TN *system* with one phase earthed, in which the *system voltage* is the r.m.s. value of the rated voltage between a non-earthed phase and earth (i.e. the phase-phase voltage).

– in three-phase IT *systems* for determination of impulse voltage:

- the r.m.s. value of the rated voltage between a phase and an artificial neutral point (an imaginary junction of equal impedances from each phase);

  NOTE 2 For most *systems*, this is equivalent to dividing the phase-to-phase voltage by √3.

  NOTE 3 The phase to an artificial neutral point can be accepted due to the well balance *systems*. Under *single fault condition* the *system* voltage will temporary change to phase to phase voltage, but under this *single fault condition* the impulse voltage is allowed to be reduced by one step according to Table 9 and will lead to the same result for the determination of clearance.
- the r.m.s. value of the rated voltage between phases for *SMPS* with increased reliability;
- for determination of *temporary overvoltage*, the r.m.s. value of the rated voltage between phases;

– in single-phase IT *systems*, the r.m.s. value of the rated voltage between supply conductors.

NOTE 4 For *SMPS* having series-connected diode bridges (12-pulse, 18-pulse, etc.), the *system voltage* is the sum of the a.c. voltages at the diode bridges.

When the supply voltage is rectified d.c. derived from the a.c. mains, the *system voltage* is the r.m.s. value of the source a.c. before rectification, taking into account the supply *system* earthing.

NOTE 5 Voltages generated within the *SMPS* by the secondaries of transformers providing galvanic isolation from the *mains supply* are also considered to be *system voltages* for the determination of impulse voltages.

See 6.3.7.3 for marking requirements.

Addition:

4.4.7.1.6.1.100 For DC mains supply

4.4.7.1.6.1.100.1 Transients for a DC mains supply

The transients for a DC ***mains supply*** have to be determined taking into account the overall installation conditions.

Table 9 can be used to determine transients, if there is no information on the final application.

4.4.7.1.6.1.100.2 Connection to a DC mains supply

For safe and reliable connection to a DC mains supply, equipment shall be provided with one of the following:

– terminals for permanent connection to the supply;

– a non-detachable power supply cord for permanent connection to the supply, or for connection to the supply by means of a plug;

– an appliance inlet for connection of a detachable power supply cord.

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Plugs and appliance inlets shall not be of a type that is used for AC mains supplies if a hazard could be created by their use. Plugs and appliance inlets shall be so designed that reverse polarity connections are prevented if a hazard could be created by such connection.

It is permitted for one pole of the DC ***mains supply*** to be connected both to an equipment mains input terminal and to the main ***protective earthing*** terminal of the equipment, if any, provided the equipment installation instructions detail the proper earthing for the system.

Compliance is checked by inspection.

4.4.7.1.6.1.100.3 Disconnection from a DC mains supply

Additionally to the requirements for disconnection of a ***SMPS***, the disconnection device shall be rated for the DC voltage and current, and be able to interrupt the expected currents.

4.4.7.1.6.2 For non-mains supply

Replacement:

For SMPS supplied by non-mains AC or DC, the system voltage is the RMS value of the supply voltage between poles.

NOTE Non-mains supply can also relate to an external communication circuit, supplying power to the SMPS or is being supplied by the SMPS.

4.4.7.1.7 Components bridging insulation

Components bridging *insulation* shall comply with the requirements of the level of *insulation* (e.g. *basic, reinforced, double*) they are bridging.

Addition:

4.4.7.1.7.100 Selection requirements for components

As an option, already investigated components selected and used as described under

a) 7.10 for surge protection devices (SPDs), and
b) 7.13 for capacitors and RC units

are considered acceptable in the meaning of this document.

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4.4.7.2 Insulation to the surroundings

4.4.7.2.1 General

Insulation for *basic*, *supplementary*, and *reinforced insulation* between a circuit and its surroundings shall be designed according to:

– the impulse withstand voltage; or
– the *temporary overvoltage*; or
– the *working voltage* of the circuit.

For creepage distances, the r.m.s. value of the *working voltage* is used, as described in 4.4.7.5.

For clearance distances and solid *insulation*, the impulse withstand voltage, the temporary overvoltage or the recurring peak value of the *working voltage* is used, as described in 4.4.7.2.2 to 4.4.7.2.4.

NOTE 1 Examples of *working voltage* with the combination of a.c., d.c. and recurring peaks are on the d.c. link of an indirect voltage source converter, or the damped oscillation of a thyristor snubber, or internal voltages of a switch-mode power supply. For more information see A.6.

NOTE 2 The impulse withstand voltage and *temporary overvoltage* depend on the *system* voltage of the circuit, and the impulse withstand voltage also depends on the overvoltage category, as shown in Table 9.

For *PEC* with galvanic isolation between the *mains* and *non-mains* circuits, the impulse voltage withstand ratings of the *mains* and *non-mains* circuits are determined as in 4.4.7.2.2 and 4.4.7.2.3. Thereafter the effect of reduction of the overvoltage categories (OVC) across the isolation is evaluated as follows:

– The magnitude of impulses from the *mains supply* circuit on the *non-mains supply* circuit is determined by reducing the OVC of the *non-mains supply* supplies by one level, and determining the resulting impulse voltage withstand rating based on *mains supply system voltage*.
– The rating to be used on the *non-mains* circuit is the higher of the value in 4.4.7.2.3 and the value determined above.
– The magnitude of impulses from the *non-mains* circuit on the mains circuit is determined by reducing the OVC of the *non-mains* circuit by one level, and determining the resulting impulse voltage withstand rating based on *non-mains supply system voltage*.
– The rating to be used on the *mains* circuit is the higher of the value in 4.4.7.2.2 and the value determined above.

For *PEC* not providing galvanic isolation between the *mains* and *non-mains* circuits, the impulse withstand voltage ratings of the *mains* and *non-mains* circuits are determined as in 4.4.7.2.2 and 4.4.7.2.3 above. The higher of the two impulse withstand voltage ratings is used for the entire combined circuit. For circuits connected to the combined circuit without galvanic isolation, the impulse withstand voltage rating of the combined circuit applies.

NOTE 3 See I.5 for examples.

When circuits of *DVC A* or *B* are supplied from the mains through a transformer providing galvanic isolation working at a frequency higher than that of the supply, the *insulation* between the circuit and the surroundings may be determined according to the *working voltage* of the circuit.

In that case the transformers ability to reduce the impulse voltages to values less than the impulse voltage associated with the *working voltage* determined from Table 10 shall be shown by test, simulation or calculation.

NOTE 4 The ability of a high frequency transformer to reduce impulse voltages originates from the very low coupling capacitance across the galvanic *insulation* compared to a the typical grounding capacitance in the *DVC A* or *B* circuit.

4.4.7.2.2 Circuits connected to mains supply

Insulation between the surroundings and circuits which are connected directly to the *mains supply* shall be designed according to the impulse withstand voltage, *temporary overvoltage*, or *working voltage*, whichever gives the most severe requirement.

This *insulation* is normally evaluated to withstand impulses of overvoltage category III, except that overvoltage category IV shall be used when the *SMPS* is connected at the origin of the *installation*. Overvoltage category II may be used for plug-in equipment without special requirements with regard to reliability.

If measures are provided which reduce impulses of overvoltage category IV to values of category III, or values of category III to values of category II, *basic* or *supplementary insulation* may be designed for the reduced values. The requirements for *double* or *reinforced insulation* shall not be reduced to values less than those required for *basic insulation* designed to withstand impulses without these measures being present.

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If the devices used for this purpose can be damaged by overvoltages or repeated impulses, thus decreasing their ability to reduce impulses, they shall be monitored and an indication of their status provided.

NOTE 1 The determined impulse withstand voltage based on the *system* voltage may be reduced by means of inherent protection or *SPD* internal in the *SMPS* or as part of the *installation*. IEC 61643-12 provides information on the selection and use of such *SPD*.

NOTE 2 Circuits which are connected to the supply mains via *protective impedances*, according to 4.4.5.4, are not regarded as connected directly to the supply mains.

4.4.7.2.3 Circuits connected to non-mains supply

NOTE For committee considerations related to overvoltage category, refer to 4.4.7.2.3.100.

Insulation between the surroundings and circuits supplied from a *non-mains supply* shall be designed according to:

– the impulse withstand voltage determined from Table 9 using the *system voltage*;

– the *working voltage*;

– the *temporary overvoltage* if known to exist due to the nature of the supply;

whichever gives the more severe requirement.

These values are used to enter Table 10 for the design of clearance.

Temporary overvoltage on a *non-mains supply* shall be determined as follows:

– Without detailed knowledge of the *temporary overvoltage*, it shall be according to Table 9.

– If the *temporary overvoltage* is known this value shall be used.

By the determination of temporary overvoltages on non-mains supply, following situations should be considered:

– loss of the neutral in a non-mains low-voltage system;

– accidential earthing of a non-mains low voltage IT system; and

– short circuit in the non-mains low voltage installation.

For further information, see IEC 60364-4-44-2007, Clause 442.

The overvoltage category for *non-mains supply* shall be overvoltage category II. A higher overvoltage category shall be assigned when control of over-voltage is not provided, and when connected to long outdoor lines. For applications and circuits with a known low level of impulse voltages and for which it can be shown that the impulse voltages remain on a low level even under *single fault condition*, overvoltage category I may be used. This requirement is considered to be met if the expected impulse voltages do not exceed the values given in Table 9 for overvoltage category I at the appropriate *system voltage*.

NOTE 1 The overvoltage category for *non-mains supplies* does not differ between equipment *permanently connected* in fixed *installations* and equipment not *permanently connected* to the fixed *installation*.

Product committees using this standard as a reference document shall determine the appropriate overvoltage category from Table 9, based on the *system voltage* and the maximum impulse voltage likely to occur in their application. Special consideration may be applicable for product specific applications, which have not been considered in this standard.

Communication lines shall be considered as *non-mains supplies*.

If measures are provided which reduce impulses of overvoltage category III to values of category II, or values of category II to values of category I, *basic* or *supplementary insulation*

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may be designed for the reduced value. The requirements for *double* or *reinforced insulation* shall not be reduced to values less than those required for *basic insulation* designed to withstand impulses without these measures being present.

If the devices used for this purpose can be damaged by overvoltages or repeated impulses, thus decreasing their ability to reduce impulses, they shall be monitored and an indication of their status provided.

NOTE 2 The determined impulse withstand voltage based on the *system* voltage can be reduced by means of inherent protection or *SPD* internal in the *SMPS* or as part of the *installation*. IEC 61643-12 provides information on the selection and use of such *SPD*.

Addition:

4.4.7.2.3.100 Overvoltage in supply circuity

The standard overvoltage category considered in the scope of this document is overvoltage category II, and Table 9 applies, except if specified differently by the manufacturer and relevant information is provided in the accompanying documentation.

4.4.7.2.4 Insulation between circuits

Insulation between two circuits shall be designed according to the circuit having the more severe requirement.

For the design of *simple* and *protective separation* between circuits the *insulation* shall be designed according to:

– the circuit having the more severe requirement; or
– the *working voltage* between the circuits;

whichever gives the most severe requirement.

4.4.7.3 Functional insulation

If the failure of *functional insulation* does not produce a hazard (electrical, thermal, fire), no specific requirements apply for the dimensioning of *functional insulation*. In other cases the following requirements apply.

Testing is not required, except where the circuit analysis required by 4.2 shows that failure of the *insulation* could result in a hazard.

For parts or circuits that are significantly affected by external transients, *functional insulation* shall be designed according to the impulse withstand voltage of overvoltage category II, except that overvoltage category III shall be used when the *SMPS* is connected at the origin of the *installation*.

Where measures are provided that reduce transient overvoltages within the circuit from category III to values of category II, or values of category II to values of category I, *functional insulation* may be designed for the reduced values.

Where the circuit characteristics can be shown by testing (see 5.2.3.2) to reduce impulse voltages, *functional insulation* may be designed for the highest impulse voltage occurring in the circuit during the tests.

For parts or circuits that are not significantly affected by external transients, *functional insulation* shall be designed according to the *working voltage* across the *insulation*.

Addition:

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4.4.7.3.100 Additional requirements for functional insulation

Functional insulation shall satisfy one of the following requirements a) or b) or c).

a) They meet the clearance and creepage distance requirements for ***functional insulation*** according to cl. 4.4.7.4 and 4.4.7.5.

b) They withstand the electric strength tests for ***simple separation*** according to 5.2.3.4.2.

c) They are short-circuited where a short-circuit could cause
   - overheating of any material creating a risk of fire, unless the material that could be overheated is of V-1 class material, or
   - thermal damage to ***basic insulation, supplementary insulation*** or ***reinforced insulation***, thereby creating a risk of electric shock.
   - a hazardous result during fault and abnormal testing.

4.4.7.4 Clearance distances

4.4.7.4.1 Determination

Clearances for *functional*, *basic* and *supplementary insulation* shall be dimensioned according to Table 10 (see Annex D for examples of the evaluation of clearance distances). Interpolation is permitted, when clearance is determined from *temporary overvoltage* or *working voltage*.

Clearances for *reinforced insulation* shall be dimensioned to withstand an impulse voltage one step higher than the impulse withstand voltage, or 1,6 times the peak *temporary overvoltage* or peak *working voltage*, required for *basic insulation*.

Clearance distances for use in altitudes between 2 000 m and 20 000 m shall be calculated using a correction factor according to Table A.2 of IEC 60664-1:2007, which is reproduced as Table E.1.

A correction factor selected from Table F.2 is also used for determination of clearance distances for approximately homogenous fields when frequencies are greater than 30 kHz, as given in Annex F.

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Table 10 – Clearance distances for *functional*, *basic* or *supplementary insulation*

Impulse withstand voltage [d] (from Table 9) V	*Temporary overvoltage* [d f] (peak) only relevant for determining *insulation* between surroundings and circuits (from Table 9) V	*Working voltage* [d f] (recurring peak) [a] V	Minimum clearance distances in air up to 2 000 m above sea level mm			
			Pollution degree			
			1	2	3	4
330	330	260	0,01			
500	500	400	0,04	0,2 [b c]	0,8 [c]	
800	710	560	0,10			1,6 [c]
1 500	1 270	1 010	0,5	0,5		
2 500	2 220	1 770	1,5	1,5	1,5	
4 000	3 430	2 740	3,0	3,0	3,0	3,0
6 000	4 890	3 910	5,5	5,5	5,5	5,5
8 000	6 060	4 840	8,0	8,0	8,0	8,0
12 000	9 430	7 540	14	14	14	14

[a] This voltage is approximately 0,8 times the voltage required to break down the associated clearance.

[b] For printed wiring board (PWB), the values for pollution degree 1 apply except that the value shall not be less than 0,04 mm.

[c] The minimum clearance distances given for pollution degrees 2, 3 and 4 are based on the reduced withstand characteristics of the associated creepage distance under humidity conditions (see IEC 60664-5).

[d] Interpolation is permitted for *non-mains supply*.

[e] Clearances for *temporary overvoltage* and *working voltage* are derived from Table F.7a of IEC 60664-1:2007.

f Interpolation is permitted, when clearance is determined from *temporary overvoltage* and *working voltage*.

NOTE If clearances are stressed with steady-state voltages of 2,5 kV (peak) and above, dimensioning according to the breakdown values in Table 10 may not provide operation without corona (partial discharges), especially for inhomogeneous fields. In order to provide corona-free operation, it is possible either to use larger clearances, as given in Table F.7b of IEC 60664-1:2007, or to improve the field distribution.

Compliance shall be checked by visual inspection (see5.2.2.1) or by performing the impulse voltage test of 5.2.3.2 and the a.c. or d.c. voltage test of 5.2.3.4.

4.4.7.4.2 Electric field homogeneity

The dimensions in Table 10 correspond to the requirements of an inhomogeneous electric field distribution across the clearance, which are the conditions normally experienced in practice. If a homogeneous electric field distribution is known to exist, the clearance distance for *basic* or *supplementary insulation* may be reduced to not less than that required by Table F.2 (Case B) of IEC 60664-1:2007. In this case, however, the impulse voltage test of 5.2.3.2 shall be performed across the considered clearance.

If the withstand against steady state voltages, recurring peak or *temporary overvoltages* according to Table 10 is decisive for the dimensioning of clearance and if these clearances are smaller than the values of Table 10 then an a.c. or d.c. voltage test according to 5.2.3.4 is required. Clearance distances for *reinforced insulation* shall not be reduced for homogeneous fields.

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4.4.7.4.3 Clearance to conductive enclosures

The clearance between any non-insulated *live part* and the walls of a metal *enclosure* shall be in accordance with 4.4.7.4.1 during and following the deflection tests of 5.2.2.4.2.

Compliance is checked by inspection and by test of 5.2.2.4.2.

If the design clearance distance is at least 12,7 mm and the clearance distance required by 4.4.7.4.1 does not exceed 8 mm, the deflection tests may be omitted.

4.4.7.5 Creepage distances

4.4.7.5.1 Insulating material groups

Insulating materials are classified into four groups corresponding to their comparative tracking index (CTI) when tested according to 6.2 of IEC 60112:2003:

- Insulating material group I: CTI ≥ 600;
- Insulating material group II: 600 > CTI ≥ 400;
- Insulating material group IIIa: 400 > CTI ≥ 175;
- Insulating material group IIIb: 175 > CTI ≥ 100.

Creepage distance requirements for PWBs exposed to pollution degree 3 environmental conditions shall be determined based on Table 11 pollution degree 3 under “Other insulators”.

If the creepage distance is ribbed, then the creepage distance of insulating material of group I may be applied using insulating material of group II and the creepage distance of insulating material of group II may be applied using insulating material of group III. The spacing of the ribs shall equal or exceed the dimension ‘*X*’ in Table D.1. For pollution degree 2 and 3, the ribs shall be at least 2 mm high.

For inorganic insulating materials, for example glass or ceramic, which do not track, the creepage distance may equal the associated clearance distance, as determined from Table 10.

4.4.7.5.2 Determination

Creepage distances for *functional*, *basic* and *supplementary insulation* shall be dimensioned according to Table 11. Interpolation is permitted. Creepage distances for *reinforced insulation* shall be twice the distances required for *basic insulation*.

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Table 11 – Creepage distances (in millimetres)

Column 1	2	3	4	5	6	7	8	9	10	11	12
Working voltage (r.m.s.)	PWBs [a]		Other insulators								
	Pollution degree		Pollution degree								
	1	2	1	2				3			
				Insulating material group				Insulating material group			
V	All material groups	All material groups except IIIb	All material groups	I	II	IIIa	IIIb	I	II	IIIa	IIIb
≤ 2	0,025	0,04	0,056	0,35	0,35	0,35		0,87	0,87	0,87	
5	0,025	0,04	0,065	0,37	0,37	0,37		0,92	0,92	0,92	
10	0,025	0,04	0,08	0,40	0,40	0,40		1,0	1,0	1,0	
25	0,025	0,04	0,125	0,50	0,50	0,50		1,25	1,25	1,25	
32	0,025	0,04	0,14	0,53	0,53	0,53		1,3	1,3	1,3	
40	0,025	0,04	0,16	0,56	0,80	1,1		1,4	1,6	1,8	
50	0,025	0,04	0,18	0,60	0,85	1,20		1,5	1,7	1,9	
63	0,04	0,063	0,20	0,63	0,90	1,25		1,6	1,8	2,0	
80	0,063	0,10	0,22	0,67	0,95	1,3		1,7	1,9	2,1	
100	0,10	0,16	0,25	0,71	1,0	1,4		1,8	2,0	2,2	
125	0,16	0,25	0,28	0,75	1,05	1,5		1,9	2,1	2,4	
160	0,25	0,40	0,32	0,80	1,1	1,6		2,0	2,2	2,5	
200	0,40	0,63	0,42	1,0	1,4	2,0		2,5	2,8	3,2	
250	0,56	1,0	0,56	1,25	1,8	2,5		3,2	3,6	4,0	
320	0,75	1,6	0,75	1,6	2,2	3,2		4,0	4,5	5,0	
400	1,0	2,0	1,0	2,0	2,8	4,0		5,0	5,6	6,3	
500	1,3	2,5	1,3	2,5	3,6	5,0		6,3	7,1	8,0	
630	1,8	3,2	1,8	3,2	4,5	6,3		8,0	9,0	10,0	
800	2,4	4,0	2,4	4,0	5,6	8,0		10,0	11	12,5	[b]
1 000	3,2	5,0	3,2	5,0	7,1	10,0		12,5	14	16	
1 250	4,2	6,3	4,2	6,3	9	12,5		16	18	20	
1 600	[c]	[c]	5,6	8,0	11	16		20	22	25	
2 000			7,5	10,0	14	20		25	28	32	
2 500			10,0	12,5	18	25		32	36	40	
3 200			12,5	16	22	32		40	45	50	
4 000			16	20	28	40		50	56	63	
5 000			20	25	36	50		63	71	80	
6 300			25	32	45	63		80	90	100	
8 000			32	40	56	81		100	110	125	
10 000 [d]			40	50	71	100		125	140	160	

Interpolation is permitted.

[a] These columns also apply to components and parts on PWBs, and to other creepage distances with a comparable control of tolerances.

[b] Insulating materials of group IIIb are not normally recommended for pollution degree 3 above 630 V.

[c] Above 1 250 V use the values from columns 4 to 11, as appropriate.

[d] For higher voltages, creepage distances should be dimensioned according to Table F.4 of IEC 60664-1:2007

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When the creepage distance requirement determined from Table 11 is less than the clearance distance required by 4.4.7.4.1 or the clearance distance determined by impulse testing (see 5.2.3.2), then the creepage distance shall be increased to the clearance distance.

Compliance of creepage distances shall be checked by measurement or inspection (see 5.2.2.1) (see Annex D for examples of the evaluation of creepage distances).

4.4.7.6 Coating

A coating may be used to provide *insulation*, to protect a surface against pollution, and to allow a reduction in creepage and clearance distances (see 4.4.7.8.4.2 and 4.4.7.8.6).

4.4.7.7 PWB spacings for functional insulation

Spacings for *functional insulation* shall comply with the requirement of 4.4.7.4 and 4.4.7.5.

Decreased spacings on PWB are permitted when all the following are satisfied:

– the PWB has flammability rating of V-0 (see IEC 60695-11-10);
– the PWB base material has a minimum CTI of 100;
– the equipment complies with the PWB short circuit test (see 5.2.4.7).

Decreased spacings for components assembled on PWB are permitted when used in:

– pollution degree 1 or 2 environment; and
– not more than overvoltage category I.

In this case the manufacture specification may be used.

Compliance is checked by inspection and by test of 5.2.4.7 if applicable.

4.4.7.8 Solid insulation

4.4.7.8.1 General

Materials selected for solid *insulation* shall be able to withstand the stresses occurring. These include mechanical, electrical, thermal, climatic and chemical stresses which are to be expected in normal use. *Insulation* materials shall also be resistant to ageing during the *expected lifetime* of the *SMPS*.

Tests shall be performed on components and sub-assemblies using solid *insulation*, in order to ensure that the *insulation* performance has not been compromised by the design or manufacturing process.

4.4.7.8.2 Material requirements

The insulating material shall have a CTI of 100 or greater.

The insulating material shall be suitable for the maximum temperature it attains as determined by the temperature rise test of 5.2.3.10. Consideration shall be given as to whether or not the insulating material additionally provides mechanical strength and whether or not the part can be subject to impact during use.

The insulating material in contact with *live parts* higher than *DVC As* shall comply with:

– the glow-wire test described in 5.2.5.3 at a test temperature of 850 °C; or

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– the glow-wire test described in 5.2.5.3, at a lower test temperature, but not less than 550 °C, depending on the classification of the use of the *SMPS*, according to Table A.1 of IEC 60695-2-11:2011; or

– the alternative hot wire ignition test of 5.2.5.4.

Thermoplastic insulating materials used in contact with *live parts* higher than *DVC As* or used as part of the *enclosure* shall comply with the ball pressure test as abnormal heat test according to IEC 60695-10-2.

Where an insulating material is used in a *SMPS* that incorporates switching contacts, and is within 12,7 mm of the contacts, it shall comply with the high current arcing ignition test of 5.2.5.2.

In case the manufacturer of the insulating material provides data to demonstrate compliance with the above requirements no further testing is required.

No further evaluation is required when generic materials are used according to Table 12.

Table 12 – Generic materials for the direct support of uninsulated *live parts*

Generic material	Minimum thickness mm	Maximum temperature °C
Any cold-moulded composition	No limit	No limit
Ceramic, porcelain	No limit	No limit
Diallyl phthalate	0,7	105
Epoxy	0,7	105
Melamine	0,7	130
Melamine-phenolic	0,7	130
Phenolic	0,7	150
Unfilled nylon	0,7	105
Unfilled polycarbonate	0,7	105
Urea formaldehyde	0,7	100

Compliance is checked by inspection and by test of 5.2.3.10 and 5.2.5.3 or 5.2.5.2.

Addition:

4.4.7.8.2.100 Thickness through insulation

Except where another subclause of clause 4.4.7.8 applies, distances through insulation shall be dimensioned according to the application of the insulation and as follows:

– if the working voltage does not exceed DVC B limits, there is no requirement for distance through insulation;

– if the working voltage exceeds DVC B voltage limits, the following rules apply:

  - for basic insulation, no minimum distance through insulation is specified, but shall meet the electric strength requirements of 4.4.7.10.1 for basic insulation;
  - for supplementary insulation or reinforced insulation comprised of a single layer, the minimum distance through insulation shall be 0,4 mm and shall meet the electric strength requirements of 4.4.7.10.2 for supplementary insulation or reinforced insulation as applicable;
  - for supplementary insulation or reinforced insulation comprised of multiple layers, the minimum distance through insulation shall comply with 4.4.7.8.3.

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4.4.7.8.3 Thin sheet or tape material

4.4.7.8.3.1 General

4.4.7.8.3 applies to the use of thin sheet or tape materials in assemblies such as wound components and bus-bars.

Insulation consisting of thin (less than 0,75 mm) sheet or tape materials is permitted, provided that it is protected from damage and is not subject to mechanical stress under normal use.

Where more than one layer of *insulation* is used, there is no requirement for all layers to be of the same material.

NOTE 1 One layer of *insulation* tape wound with more than 50 % overlap is considered to constitute two layers.

NOTE 2 *Basic*, *supplementary* and *double insulation* can be applied as a pre-assembled *system* of thin materials.

4.4.7.8.3.2 Material thickness equal to or more than 0,2 mm

The provisions of 4.4.7.8.3.2 of IEC 62477-1:2012 **do not** apply.

4.4.7.8.3.3 Material thickness less than 0,2 mm

The provisions of 4.4.7.8.3.3 of IEC 62477-1:2012 **do not** apply.

Addition:

4.4.7.8.3.3.100 Thin sheet material

Thin sheet material shall meet one of the following requirements:

- supplementary insulation consisting of two layers of material, each layer shall meet the electric strength requirements of 4.4.7.10.1 for supplementary insulation; or
- supplementary insulation consisting of three layers of material, any combination of two layers shall meet the electric strength requirements of 4.4.7.10.1 for supplementary insulation; or
- reinforced insulation consisting of two layers of material, each layer shall meet the electric strength requirements of 4.4.7.10.2 for reinforced insulation; or
- reinforced insulation consisting of three layers of material, any combination of two layers shall meet the electric strength requirements of 4.4.7.10.2 for reinforced insulation.

If more than three layers are used, layers may be divided into two or three groups of layers.

Each group of layers shall pass the electric strength tests for the appropriate insulation.

A test on a layer or group of layers is not repeated on an identical layer or group.

4.4.7.8.3.4 Compliance

Compliance shall be checked by the tests described in 5.2.3.1 to 5.2.3.5.

When a component or sub-assembly makes use of thin sheet insulating materials, it is permitted to perform the tests on the component rather than on the material.

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Addition:

4.4.7.8.3.4.100 Separable thin sheet material

For separable layers, electric strength tests are applied in accordance with 4.4.7.10 to a single layer.

The test procedure is given in 5.2.3.102.

4.4.7.8.3.4.101 Non-separable thin sheet material

NOTE Requirements have been taken from IEC 62368-1.

4.4.7.8.3.4.101.1 General

For insulation consisting of non-separable thin sheet materials the test procedures in Table 101 are applied. There is no requirement for all layers of insulation to be of the same material and thickness.

Compliance is checked by inspection and by the tests specified in Table 101.

Table 101 – Tests for insulation in non-separable layers

Number of layers	Test procedure
Supplementary insulation	
Two or more layers:	The test procedure of 5.2.3.103 is applied.
Reinforced insulation	
Two layers:	The test procedure of 5.2.3.103 is applied.
Three or more layers:	The test procedures 5.2.3.103 and 5.2.3.104 [a] are applied.
NOTE The purpose of the tests in 5.2.3.104 is to ensure that the material has adequate strength to resist damage when hidden in inner layers of insulation. Therefore, the tests are not applied to insulation in two layers. The tests in 5.2.3.104 are not applied to ***supplementary insulation***.	
[a] Where the insulation is integral to winding wire, the test does not apply. For insulated winding wires for use without interleaved insulation, 4.4.7.8.5.100 applies.	

4.4.7.8.4 Printed wiring boards (PWBs)

4.4.7.8.4.1 General

Insulation between conductor layers in double-sided single-layer PWBs, multi-layer PWBs and metal core PWBs, shall meet the requirements of 4.4.7.8.1. *Basic*, *supplementary*, *double* and *reinforced insulation* shall meet the appropriate requirements of 4.4.7.10.1 or 4.4.7.10.2. *Functional insulation* in PWBs shall meet the requirements of 4.4.7.7.

For the inner layers of multi-layer PWBs, the *insulation* between adjacent tracks on the same layer shall be treated as either:

– a creepage distance for pollution degree 1 and a clearance as in air (see Example D.14); or

– solid *insulation*, in which case it shall meet the requirements of 4.4.7.8.1 and 4.4.7.10.

Addition:

4.4.7.8.4.1.100 Insulation of inner PWB layers acting as solid insulation

For the inner layers of multi-layer PWBs, the insulation between adjacent tracks on the same layer shall only be acceptable as solid insulation, when tested to 4.4.7.9.

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4.4.7.8.4.2 Use of coating materials

A coating material used to provide *functional*, *basic*, *supplementary* and *reinforced insulation* shall meet the requirement as specified below.

Type 1 protection (as defined in IEC 60664-3) improves the microenvironment of the parts under protection. The clearance and creepage distance of Table 10 and Table 11 for pollution degree 1 apply under the protection. Between two conductive parts, it is a requirement that one or both conductive parts, together with all the spacing between them, are covered by the protection.

Type 2 protection is considered to be similar to solid *insulation*. Under the protection, the requirements for solid *insulation* specified in 4.4.7.8 are applicable, including the coating material itself, and spacings shall not be less than those specified in Table 1 of IEC 60664-3:2003. The requirements for clearance and creepage in Table 10 and Table 11 do not apply. Between two conductive parts, it is a requirement that both conductive parts, together with the spacing between them, are covered by the protection so that no airgap exists between the protective material, the conductive parts and the printed boards.

The coating material used to provide Type 1 and Type 2 protection shall be designed to withstand the stresses anticipated to occur during the *expected lifetime* of the *SMPS*. A *type test* on representative PWBs shall be conducted according to Clause 5 of IEC 60664-3:2003. For the cold test (5.7.1 of IEC 60664-3:2003), a temperature of -25 °C shall be used, and for the rapid change of temperature test (5.7.3 of IEC 60664-3:2003): -25 °C to +125 °C. No *routine test* is required.

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4.4.7.8.5 Wound components

Varnish or enamel *insulation* of wires shall not be used for *basic*, *supplementary*, *double* or *reinforced insulation*.

Wound components shall meet the requirements of 4.4.7.8.1 and 4.4.7.10.

The component itself shall pass the requirements given in 4.4.7.8.1 and 4.4.7.10.2. If the component has *reinforced* or *double insulation*, the a.c. or d.c. voltage test of 5.2.3.4 shall be performed as a *routine test*.

Addition:

4.4.7.8.5.100 Insulated winding wires for use without interleaved insulation

The winding wire shall comply with Annex AA. The minimum number of overlapping layers of spirally wrapped tape or extruded layers of insulation shall be as follows:

– for ***basic insulation***: one layer;
– for ***supplementary insulation***: two layers;
– for ***reinforced insulation***: three layers.

For insulation between two adjacent winding wires, one layer on each conductor is considered to provide ***supplementary insulation***.

Wires investigated to IEC 60950-1:2005/AMD1:2009/AMD2:2013, Annex U, or IEC 62368-1:2014, Annex J, are equally accepted.

The winding wire shall pass a routine test for electric strength test.

4.4.7.8.6 Potting materials

A potting material may be used to provide solid *insulation* or to act as a coating to protect against pollution. If used as solid *insulation* for *basic, fault* and *enhanced protection*, it shall comply with the requirements of 4.4.7.8.1 and 4.4.7.10. If used to protect against pollution, the requirements for type 1 protection in 4.4.7.8.4.2 apply.

4.4.7.9 Connection of parts of solid insulation (cemented joints)

The creepage and clearance path in the presence of a cemented joint between two insulating parts, are determined as follows.

- Type 1 or type 2 protection as described in 4.4.7.8.4.2 apply.
- A cemented joint that is not evaluated as providing protection of type 1 or type 2, is neither considered solid *insulation* nor to reduce pollution degree. The clearance and creepage distances of Table 10 and Table 11 apply for the pollution degree of the environment around the joint. See 5.2.5.7 for test.

As an example, see Example D.9.

4.4.7.10 Requirements for electrical withstand capability

4.4.7.10.1 Basic or supplementary insulation

Basic or *supplementary insulation* shall be tested as follows:

- Test with impulse withstand voltage according to 5.2.3.2; and
- Test with a.c. or d.c. voltage according to 5.2.3.4.

4.4.7.10.2 Double or reinforced insulation

Double or *reinforced insulation* shall be tested as follows:

- Test with impulse withstand voltage according to 5.2.3.2; and
- Test with a.c. or d.c. voltage according to 5.2.3.4.

For solid *insulation*, the partial discharge test according to 5.2.3.5 shall be performed in addition to the above tests, if the recurring peak *working voltage* across the *insulation* is greater than 750 V and the voltage stress on the *insulation* is greater than 1 kV/mm.

NOTE The voltage stress is the recurring peak voltage divided by the distance between two parts of different potential.

The partial discharge test shall be performed as a *type test* on all components, sub-assemblies and PWB. In addition, a *sample test* shall be performed if the *insulation* consists of a single layer of material.

Double insulation shall be designed so that failure of the *basic insulation* or of the *supplementary insulation* will not result in reduction of the *insulation* capability of the remaining part of the *insulation*.

Addition:

4.4.7.10.2.100 Level of testing

When conducting electrical testing according to 4.4.7.10, the following shall apply.

- Testing with impulse withstand voltage and AC or DC voltage is used to test suitability of insulation. Spacings are investigated to 5.2.2.1.

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– Partial discharge testing is conducted on a final component configuration (e.g. transformer) or sub-assembly. Individual materials are not tested.
– Testing does not have to be conducted on the final product, if testing on final component configuration or sub-assembly is representative.

NOTE In some situations testing on the final product is even not possible, due to the selected insulation concept.

4.4.7.11 Insulation requirements above 30 kHz

Where voltages across *insulation* have fundamental frequencies greater than 30 kHz, further considerations apply.

Annex F contains requirements for the determination of clearance and creepage distances under these circumstances.

Compliance of creepage and clearance distances shall be checked by measurement or inspection according to Annex F.

4.4.8 Compatibility with residual current-operated protective devices (RCD)

Some domestic and industrial *installations* provide RCD as additional protection against *insulation* faults, in addition to the *basic* and *fault protection* provided by *SMPS*.

An *insulation* fault or direct contact with certain types of *SMPS* circuits can cause failure current with a d.c. component to flow in the *PE conductor* and thus reduce the ability of an RCD of type A or AC (see IEC 60755) to provide this protection for other equipment in the *installation*.

To ensure the intended work of an RCD provided by the *installation SMPS* shall satisfy one of the following conditions.

a) A Pluggable Type A single-phase *SMPS*, shall be designed so that, under normal and fault conditions any resulting d.c. component of the current in the *PE conductor* does not exceed the d.c. current withstand requirements in IEC 60755 for RCD of type A.

   NOTE At the time of writing, the requirement in IEC 60755 is for type A RCD to be able to tolerate 6 mA of d.c. current while still maintaining their protective functionality.

b) For *SMPS* that are Pluggable Type B or intended for *permanent connection*, d.c. current in the *PE conductor* is not limited if the information and marking requirements of 6.3.7.4 are complied with.

For the design and construction of electrical *installations*, care should be taken with RCD of Type B. All the RCD upstream from an RCD of Type B up to the supply transformer shall be of Type B.

Compliance with RCD provided by the *installation* shall be checked by simulation or calculation of current in the *PE conductor* under normal and *single fault conditions* according to the guideline provided in Annex H.

See 6.3.7.4 for information and marking requirements.

4.4.9 Capacitor discharge

Replacement:

For protection against shock hazard, capacitors within a ***SMPS*** shall be discharged to a voltage less than the limits outlined in 4.4.5.101, or to an energy less than the limits outlined in 4.4.5.103, after the removal of power from the ***SMPS*** or after any charge of a capacitor becomes accessible:

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– for pluggable ***SMPS*** type A and B, the discharge time shall not exceed 1 s or the hazardous ***live parts*** shall be protected against direct contact by at least IPXXB (see 4.4.3.3);
– for ***permanently connected SMPS***, the discharge time shall not exceed 5 s.

For pluggable ***SMPS*** type A and B and ***permanently connected SMPS*** which do not meet the above requirements, access shall only be possible by means of a tool or key and the information and marking requirements of 6.5.2 apply.

Compliance is checked by test of 5.2.3.8.

NOTE This requirement also applies to capacitors used for power factor correction, filtering, etc.

4.5 Protection against electrical energy hazards

4.5.1 Operator access areas

4.5.1.1 General

Equipment shall be so designed that there is no risk of electrical energy hazard in operator access areas from accessible circuits by fulfilling requirement of 4.2.

A risk of injury due to an electrical energy hazard exists if it is likely that two or more bare parts (one of which may be earthed) between which a hazardous energy level exists, will be bridged by a metallic object.

The likelihood of bridging the parts under consideration is determined by means of the test finger of Figure 1 of IEC 60529:1989, in a straight position. If it is possible to bridge the parts with this test finger, a hazardous energy level shall not exist.

Barriers, guards, and similar means preventing unintentional contact may be provided as an alternative to limiting the energy.

Compliance is checked by inspection or test of 5.2.2.2.

4.5.1.2 Determination of hazardous electrical energy level

A hazardous electrical energy level is considered to exist if:

– the voltage is 2 V or more;

and

– power available exceeds 240 VA after 60 s; or
– the energy exceeds 20 J.

Compliance shall be checked with the test in 5.2.3.9 or by calculation as follows:

in case of a capacitor the stored energy in the capacitor is at a voltage of 2 V or more, and the stored energy calculated from the following equation, exceeds 20 J:

$$E = 0{,}5\ CU^2$$

where

E *is the energy, in joules (J);*
C *is the capacitance, in farads (F);*
U *is the measured voltage on the capacitor, in volts (V).*

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4.5.2 Service access areas

Capacitors located behind panels that are removable for servicing, installation, or disconnection shall present no risk of electric energy hazard from charge stored on capacitors after disconnection of the *SMPS*.

Capacitors within a *SMPS* shall be discharged to an energy level less than 20 J, as in 4.5.1.2, within 5 s after the removal of power from the *SMPS*. If this requirement is not achievable for functional or other reasons, the information and marking requirements of 6.5.2 apply.

Compliance is checked by inspection of the equipment and relevant circuit diagrams, taking into account the possibility of disconnection with any "ON"/"OFF" switch in either position and non-operation of periodic power consuming devices or components within the *SMPS*. If the capacitor discharge time can not be accurately calculated, the discharge time shall be measured.

4.6 Protection against fire and thermal hazards

4.6.1 Circuits representing a fire hazard

The following types of circuits are considered a fire hazard:

– circuits directly connected to the mains;
– circuits that are not directly connected to the mains but exceed the limits for limited power sources in 4.6.5;
– components having unenclosed arcing parts.

4.6.2 Components representing a fire hazard

4.6.2.1 General

The risk of ignition due to high temperature shall be minimized by the appropriate selection and use of components and by suitable construction.

Electrical components shall be used in such a way that their maximum working temperature under normal or *single fault conditions* is less than that necessary to cause ignition of the surrounding materials with which they are likely to come into contact. Under normal conditions the limits in Table 14 shall not be exceeded for components or their surrounding material.

Where it is not practical to protect components against overheating under fault conditions, all materials in contact with such components shall be of flammability class V-1, according to IEC 60695-11-10, or better.

Compliance with 4.6.2 and 4.6.3 shall be confirmed by inspection of component and material data sheets and, where necessary, by test.

4.6.2.2 Components within a circuit representing a fire hazard

Inside *fire enclosures*, materials for components and other parts and all materials in contact with such parts shall comply with flammability class V-2 as classified in IEC 60695-11-10 or flammability class HF-2 as classified in ISO 9772 or better.

In case the manufacturer of components provides data to demonstrate compliance with the above requirements no further testing is required.

The above requirement does not apply to any of the following:

– electrical components which do not present a fire hazard under abnormal operating conditions when tested according to 5.2.4.6;

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– materials and components within an *enclosure* of 0,06 m^3 or less, consisting totally of metal and having no ventilation openings, or within a sealed unit containing an inert gas;
– electronic components, such as integrated circuit packages, opto-coupler packages, capacitors and other small parts that are mounted on material of flammability class V-1 or better;
– wiring, cables and connectors insulated with PVC, TFE, PTFE, FEP, neoprene or polyimide;
– the following parts, provided that they are separated from electrical parts (other than insulated wires and cables) which under fault conditions are likely to produce a temperature that could cause ignition, by at least 13 mm of air or by a solid barrier of material of flammability class V-1 or better:
  - other small parts which would contribute negligible fuel to a fire, including, labels, mounting feet, key caps, knobs and the like;
  - tubing for air or any fluid *systems*, containers for powders or liquids and foamed plastic parts, provided that they are of flammability class HB.

4.6.2.3 Components within a circuit not representing a fire hazard

For components within a circuit not representing a fire hazard 4.6.2 does not apply.

4.6.3 Fire enclosures

4.6.3.1 General

Replacement:

Fire enclosures are used to reduce the risk of fire to the environment, independent of the location where they are installed.

A fire enclosure shall be provided for all SMPS, unless it is:

a) a ***component SMPS*** and intended for final installation in equipment providing a fire enclosure; or
b) supplied by a limited power source and the circuits (according to 4.6.5) are mounted on printed wiring boards of minimum V-1 class material; or
c) for usage in areas without combustible materials (***restricted access areas***) and is marked according to 6.3.5.

4.6.3.2 Flammability of enclosure materials

Replacement:

Materials used for fire enclosures of ***SMPS*** shall meet the flammability test requirements of 5.2.5.5, except for those portions of the enclosure that enclose only circuits not representing a fire hazard.

Materials are considered to comply without test if, in the minimum thickness used, the material is of flammability class 5VA or better, according to IEC 60695-11-20:1999.

Materials for ***moveable*** and ***transportable equipment*** comply without test if, in the minimum thickness used, the material is of flammability class of V-1 or better, according to IEC 60695-11-20.

Metals, ceramic materials, and glass which is heat-resistant tempered, wired or laminated, are considered to comply without test.

Materials for components that fill an opening in a fire enclosure shall

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– be of at least V-1 class material and no larger than 100 mm in any dimension, or
– be of at least V-2 class material and there is a barrier or device(s) that forms a barrier made of a V-0 class material between the part and a source of fire hazard, or
– comply with a relevant IEC component standard that includes flammability requirements for components that are intended to form part of, or fill openings in, a fire enclosure.

NOTE Examples of these components are fuse-holders, switches, pilot lights, connectors and appliance inlets.

Polymeric materials that serve as the outer enclosure and have surface area greater than 1 m^2 or a single dimension larger than 2 m, shall have a maximum flame spread index of 100 as determined by ASTM E162 or ANSI/ASTM E84.

The manufacturer may provide data from the fire enclosure material supplier to demonstrate compliance with the above requirements. In this case, no further testing is required.

Compliance shall be checked by visual inspection and, where necessary, by test.

4.6.3.3 Openings in fire enclosures

4.6.3.3.1 General

For equipment that is intended to be used or installed in more than one orientation as specified in the product documentation, the requirements in 4.6.3.3.2 to 4.6.3.3.4 apply in each orientation.

These requirements are in addition to requirements regarding openings, in other sections of this standard.

NOTE For example the sections regarding *basic protection* with *live parts* or hazardous moving parts are additional to the requirements in this section.

4.6.3.3.2 Openings in the top and side of fire enclosures

Openings in the top surfaces of *fire enclosures* shall be designed to prevent an external object falling vertically or at up to 5° from vertically from entering the *enclosure* in an area that could lead to a fire hazard.

This requirement applies to all sides of moveable equipment with no defined top and bottom, unless top and bottom surfaces can be suitably demonstrated in the installation instructions.

Compliance shall be checked by test of 5.2.2.2.

Openings in the top surfaces of *fire enclosures* not located vertically above or within 5° from vertical of a circuit representing a fire hazard as defined in 4.6.1 are not subject to the test of 5.2.2.2 and can be of any construction if the construction prevents access to parts greater than *DVC As* with the IP3X probe as detailed in 4.4.3.3.

Where a portion of the side of a *fire enclosure* falls within the area traced out by the 5° angle in Figure 6, the limitations in 4.6.3.3.3 regarding openings in bottoms of *fire enclosures* also apply to this portion of the side.

Compliance shall be checked by visual inspection.

4.6.3.3.3 Openings in the bottom of a fire enclosure

Replacement:

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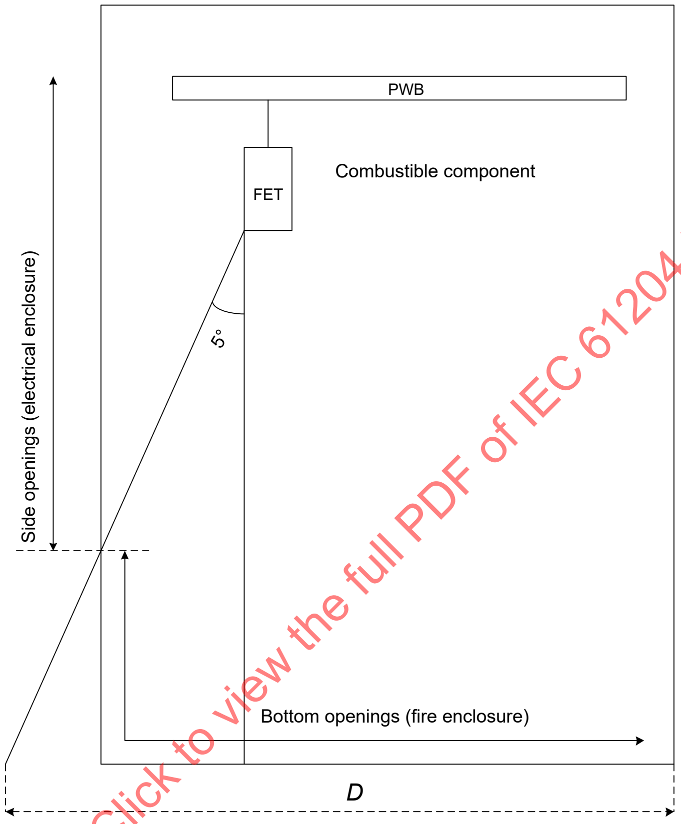
The bottom of a fire enclosure or individual barriers shall provide protection against emission of flaming or molten material under all internal parts, including partially enclosed components or assemblies, located in a circuit representing a fire hazard.

The location and size of the bottom or barrier shall cover area D in Figure 6 and shall be horizontal, lipped or otherwise shaped to provide equivalent protection. The area shall be free of openings, except for those protected by a baffle, screen or other means so that molten metal and burning material are unlikely to fall outside the fire enclosure.



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NOTE Figure 6 shows an example of a cutaway side view of a product containing a PWB with its components facing the bottom of the *enclosure*. If the PWB contains components in primary circuitry (e.g. Field Effect Transistors), it is considered a source of ignition.

The bottom *enclosure* is considered a *fire enclosure* so openings in it shall be restrictive, e.g. see Table 12.

Besides providing protection against electrical shocks, the side openings (electrical *enclosure*) located below the 5 ° projection from the source of ignition provide protection against spread of fire.

Figure 6 – *Fire enclosure* bottom openings below an unenclosed or partially enclosed fire-hazardous component

The following constructions are considered to satisfy the requirement without test:

a) no opening in the bottom of a ***fire enclosure***;

b) openings in the bottom of any size under an internal barrier, screen or the like, which itself complies with the requirements for a ***fire enclosure***;

c) baffle plate construction as illustrated in Figure 7;

d) under components and parts meeting the requirements for V-1 class material, or HF-1 class foamed material or under components that pass the needle-flame test of IEC 60695-11-5 using a 30 s flame application, bottom openings shall not exceed 6 mm in any dimension;

e) the bottom openings do not exceed a 2 mm by 2 mm mesh of at least 0,45 mm diameter metal wire;

f) the openings in the metal bottom enclosure comply with Table 34.

Compliance is checked by inspection or with the hot flaming oil test in 5.2.5.6, in case the fire enclosure is designed differently than as described above.

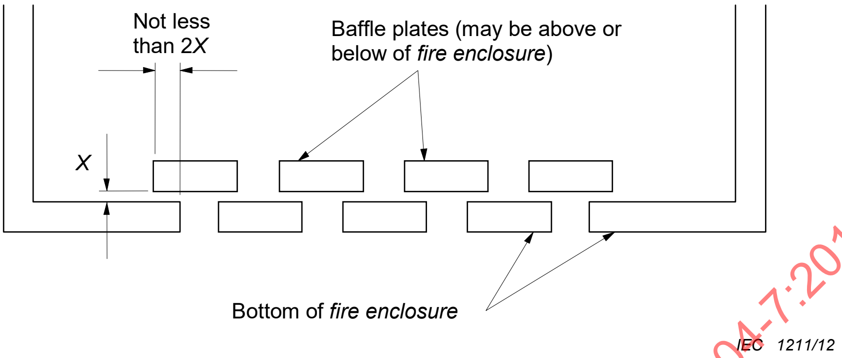

Figure 7 – *Fire enclosure* baffle construction

Table 13 – Permitted openings in *fire enclosure* bottoms

Applicable to circular holes			Applicable to other shaped openings	
Metal bottoms minimum thickness mm	Maximum diameter of holes mm	Minimum spacing of holes centre to centre mm	Maximum area mm^2	Minimum spacing of openings border to border mm
0,66	1,1	1,7	1,1	0,56
0,66	1,2	2,3	1,2	1,1
0,76	1,1	1,7	1,1	0,55
0,76	1,2	2,3	1,2	1,1
0,81	1,9	3,1	2,9	1,1
0,89	1,9	3,1	2,9	1,2
0,91	1,6	2,7	2,1	1,1
0,91	2,0	3,1	3,1	1,2
1,0	1,6	2,7	2,1	1,1
1,0	2,0	3,0	3,2	1,0

4.6.3.3.4 Doors or covers in fire enclosures

If part of a *fire enclosure* consists of a door or a cover leading to an operator access area, it shall comply with one of the following requirements:

– the door or cover shall be provided with a safety interlock; or

– a door or cover, intended to be routinely opened by the user, shall comply with both of the following conditions:

  - it shall not be removable from other parts of the *fire enclosure* by the user; and
  - it shall be provided with a means to keep it closed during normal operation.

A door or cover intended only for occasional use by an installer, such as for the installation of accessories, is permitted to be removable provided that the equipment instructions include directions for correct removal and reinstallation of the door or cover.

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Compliance is checked by inspection.

4.6.4 Temperature limits

4.6.4.1 Internal parts

Equipment and its component parts shall not attain temperatures in excess of those in Table 14 when tested in accordance with the ratings of the equipment.

Compliance is checked by test of 5.2.3.10.

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Table 14 – Maximum measured total temperatures for internal materials and components

	Materials and components	Thermocouple method °C	Rise of resistance method °C
1	Rubber- or thermoplastic-insulated conductors [a]	75	
2	Field wiring terminals and other parts that may contact the *insulation* of field wiring [b]	[b]	
3	Copper bus bars and connecting straps	[c]	
4	*Insulation systems* on magnetic components [d]	[e]	[e]
	Class A (105)	90	100
	Class E (120)	105	115
	Class B (130)	110	120
	Class F (155)	130	140
	Class H (180)	155	165
	Class N (200)	165	175
	Class R (220)	180	190
	Class S (240)	195	205
5	Phenolic composition [a]	165	
6	On bare resistor material	415	
7	Capacitor	[f]	
8	*Power electronic devices*	[g]	
9	PWBs	[h]	
10	Components bridging at least *basic protection*	[f]	
11	Liquid cooling medium	[i]	

[a] The limitation on phenolic composition and on rubber and thermoplastic *insulation* does not apply to compounds which have been investigated and found to meet the requirements for a higher temperature.

[b] The maximum terminal temperature should not exceed the temperature rating of the terminal and the *insulation* temperature rating of the conductor or cable specified by the manufacturer (see 6.3.6.4).

[c] The maximum permitted temperature is determined by the temperature limit of support materials or *insulation* of connecting wires or other components. A maximum temperature of 140 °C is recommended.

[d] The maximum temperatures on *insulation* of magnetic components assume thermocouples are applied on the surface of coils, and are therefore not located on hot-spots. Rise of resistance method results in a measurement of the average temperature of the winding.

[e] These limits are extracted from the group safety standards IEC 61558-1 and IEC 61558-2-16 (safety of power transformers, power supplies, reactors and similar products). For magnetic components, not covered by the scope of IEC 61558 series, commitees for product standards may define other limits in accordance with IEC 60085 and IEC 60216.

[f] For a component, the maximum temperature specified by the manufacturer should not be exceeded.

[g] The maximum temperature on the case should be the maximum case temperature for the applied power dissipation specified by the manufacturer of power electronic devices.

[h] The maximum operating temperature of the PWB shall not be exceeded.

[i] The maximum temperature of the cooling medium, specified by the manufacturer of the medium or determined from the known characteristics of the medium, should not be exceeded.

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The resistance method for temperature measurement as specified in Table 14 consists of the calculation of the temperature rise of a winding using the equation:

$$\Delta t = \frac{r2}{r1}(k + t1) - (k + t2)$$

where:

Δt is the temperature rise;

r_2 is the resistance at the end of the test in ohms;

r_1 is the resistance at the beginning of the test in ohms;.

t_1 is the ambient temperature at the beginning of the test (°C);

t_2 is the ambient temperature at the end of the test (°C);

k is 234,5 for copper, 225,0 for electrical conductor grade (EC) aluminium; values of the constant for other conductors shall be determined.

Addition:

4.6.4.1.100 Maximum temperature of internal parts

The maximum temperature of internal parts during normal operation shall not exceed 300°C.

NOTE Even if outlined differently in 4.6.4.1.

4.6.4.2 Accessible parts

In order to limit the touch temperatures of accessible parts of *SMPS*, and to protect against long-term degradation of building materials, the maximum temperature for accessible parts of the *SMPS* shall be in compliance with Table 15.

When surface temperatures of the *SMPS*, close to mounting surfaces, exceed the limit of Table 15, a warning according to 6.3.5 shall be provided.

It is permitted that accessible parts that are required to get hot as part of their intended function (for example heatsinks) may have temperatures up to 100 °C, if the parts are not in contact with building materials upon installation, and are marked with the warning given in 6.4.3.4. For products only for use in a *restricted access area*, the temperature may exceed 100 °C.

Product committees using this standard as a reference document shall consider the steady state temperature limits for specific products and environmental conditions.

These limits are in addition to applicable limits in 4.6.4.1.

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Table 15 – Maximum measured temperatures for accessible parts of the *SMPS*

Part	Limit °C					
	(Coated) metal[b]				Glass, porcelain and vitreous material	Plastic and rubber
	1	2	3	4		
User operated devices (knobs, handles, switches, displays, etc.). which are held continuously during normal and *single fault condition* (approx. 10 s)	55	55	55	60	65	70
User operated devices (knobs, handles, switches, displays, etc.). which are held for short periods only, during normal and *single fault condition* (approx. 1 s)[a]	60	70	65	85	75	80
Accessible *enclosure* parts likely to be touched (approx. 1 s) [a]	65	75	70	90	80	85
Enclosure parts where they contact building materials upon installation (continuously)	90					

NOTE 1 In Table 15, the values for accessible parts are taken from IEC Guide 117 (burn threshold). For short-duration contact with user operated devices the values were reduced by 5 °C to allow for some margin. IEC Guide 117 also provides values for burn thresholds for other coatings or materials.

NOTE 2 The main figures of IEC Guide117 are reproduced in Annex J for information.

[a] For products intented and expected to be operated by children and elderly persons the contact period of IEC Guide 117:2010 Clause 6, Table 2 should be considered.

[b] Coating of metal surfaces:

1: none (bare metal)

2: lac (50 μm)

3: porcelain enamel (160 μm) / powder (60 μm)

4: polyamide 11 or 12 (400 μm)

NOTE Refer to 4.6.4.2.100 for specific considerations made by the product committee.

Addition

4.6.4.2.100 Maximum limit for accessible parts

Temperatures shall not exceed 150°C for accessible parts made of wood and 100 °C for all other materials.

Temperatures exceeding the limits of Table 15 are acceptable up to a maximum of 100 °C, if one of the following conditions are met:

– an area on the external surface of the equipment that has no dimension exceeding 50 mm, and that is not likely to be touched in normal use; or

– accessible surfaces of the equipment requiring heat for the intended function (for example, equipment that contains a document laminator, thermal print head, fuser heater, etc.), and that are not likely to be touched in normal use; or

– heatsinks and metallic parts directly covering heatsinks, except those on surfaces incorporating switches or controls handled during normal use.

For these areas and parts, instructions and the caution marking for hot surfaces of IEC 60417-5041 (see Annex C) shall be provided.

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4.6.5 Limited power sources

Where a limited power source is required, the source shall comply with Table 16 or Table 17 as applicable.

A limited power source shall comply with one of the following requirements:

a) the output is inherently limited in compliance with Table 16; or

b) a linear or non-linear impedance limits the output in compliance with Table 16. If a positive temperature coefficient device (e.g. PTC) is used, it shall pass the applicable tests specified in IEC 60730-1; or

c) a regulating network limits the output in compliance with Table 16, both with and without a single fault in the regulating network; or

d) an overcurrent protective device is used and the output is limited in compliance with Table 17.

Where an overcurrent protective device is used, it shall be a fuse or a non-adjustable, non-autoreset, electromechanical device.

A limited power source operated from an a.c. *mains supply*, or a battery-operated limited power source that is recharged from an a.c. *mains supply* while supplying the load, shall incorporate an isolating transformer.

Compliance to determine the maximum available power is checked by test of 5.2.3.9.

Table 16 – Limits for sources without an overcurrent protective device

Output voltage[a] U_{oc}		Output current [b d] I_{sc}	Apparent power [c d] S
V a.c.	V d.c.	A	VA
≤ 30 V r.m.s.	≤ 30 V d.c.	≤ 8	≤ 100
-	$30 < U_{oc} \leq 60$	$\leq 150 / U_{oc}$	≤ 100

[a] U_{oc}: Output voltage measured in accordance with 5.1.5.3 with all load circuits disconnected. Voltages are for substantially sinusoidal a.c. and ripple-free d.c. For non-sinusoidal a.c. and d.c. with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

[b] I_{sc}: Maximum output current with any non-capacitive load, including a short circuit.

[c] S (VA): Maximum output apparent power in VA with any non-capacitive load.

[d] Measurement of I_{sc} and S are made 5 s after application of the load if protection is by an electronic circuit or a positive temperature coefficient device (e.g. PTC), and 60 s in other cases.

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Table 17 – Limits for power sources with an overcurrent protective device

Output voltage[a] U_{oc}		Output current [b d] I_{sc}	Apparent power [c d] S	Current rating of overcurrent protective device [e]
V a.c.	V d.c.	A	VA	A
≤ 20	≤ 20	≤ 1 000/U_{oc}	≤ 250	≤ 5,0
20 < U_{oc} ≤ 30	20 < U_{oc} ≤ 30			≤ 100/U_{oc}
–	30 < U_{oc} ≤ 60			≤ 100/U_{oc}

[a] U_{oc}: Output voltage measured in accordance with 5.1.5.3 with all load circuits disconnected. Voltages are for substantially sinusoidal a.c. and ripple free d.c. For non-sinusoidal a.c. and for d.c. with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

[b] I_{sc}: Maximum output current with any non-capacitive load, including a short circuit, measured 60 s after application of the load.

[c] S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of the load.

[d] Current limiting impedances remain in the circuit during measurement, but overcurrent protective devices are bypassed.

NOTE The reason for making measurements with overcurrent protective devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the overcurrent protective devices.

[e] The current ratings of overcurrent protective devices that break the circuit within 120 s with a current equal to 210 % of the current rating specified in the table.

4.7 Protection against mechanical hazards

4.7.1 General

Failure of any component within the *SMPS* shall not release sufficient energy to lead to a hazard, for example, expulsion of material into an area occupied by personnel.

4.7.2 Specific requirements for liquid cooled SMPS

4.7.2.1 General

NOTE Sealed heat-pipe cooling *systems*, used to transfer heat from a hot component to a heat sink, are not considered to be liquid cooling *systems* in this standard. However, the possible failure of such components should be considered during the circuit analysis of 4.2.

4.7.2.2 Coolant

The specified coolant (see 6.2) shall be suitable for the anticipated ambient temperatures during storage and operation. Coolant temperature in operation shall not exceed the limit specified in Table 14.

The coolant used in a cooling *system* shall be a refrigerant investigated for the purpose, water, glycol, a mixture of water and glycol or non flammable synthetic oils.

Compliance is checked by inspection and test of 5.2.3.10.

NOTE Flammable coolants used in cooling *systems* are not covered by this standard.

4.7.2.3 Design requirements

4.7.2.3.1 General

The liquid containment *system* components shall be compatible with the liquid to be used.

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Equipment using liquids shall be so constructed that it is unlikely that either a dangerous concentration of these materials or a hazard in the meaning of this standard will be created by condensation, vaporization, leakage, spillage or corrosion during normal operation, storage, filling or emptying.

Compliance is checked by inspection.

The flexible hoses should be made of material free of conductive contaminents such as carbon.

4.7.2.3.2 Corrosion resistance

All cooling *system* components shall be suitable for use with the specified coolant. They shall be corrosion resistant and shall not corrode as a result of prolonged exposure to the coolant and/or air.

Compliance is checked by inspection.

4.7.2.3.3 Tubing, joints and seals

Cooling *system* tubing, joints and seals shall be designed to prevent leakage during excursions of pressure over the life of the equipment. The entire cooling *system* including tubing shall satisfy the requirements of the hydrostatic pressure test of 5.2.7.

4.7.2.3.4 Provision for condensation

Where internal condensation occurs during normal operation or maintenance, measures shall be taken to prevent degradation of *insulation*. In those areas where such condensation is expected, clearance and creepage distances of Table 10 and Table 11 shall be evaluated at least for a pollution degree 3 environment (see Table 8), and provision shall be made to prevent accumulation of water (for example by providing a drain).

Compliance is checked by inspection.

4.7.2.3.5 Leakage of coolant

Measures shall be taken to prevent leakage of coolant onto *live parts* as a result of normal operation, servicing, or loosening or detachment of hoses or other cooling *system* parts during the *expected lifetime*. If a pressure relief mechanism is provided, this shall be located so that there shall be no leakage of coolant onto *live parts* when it is activated.

During a leakage measures has to ensure that coolant will not result in wetting of *live parts* or electrical *insulation*.

Compliance is checked by inspection.

4.7.2.3.6 Loss of coolant

Loss of coolant from the cooling *system* shall not result in thermal hazards, explosion, or shock hazard. The requirements of the loss of coolant test of 5.2.4.9.4 shall be satisfied.

4.7.2.3.7 Conductivity of coolant

When the coolant is intentionally in contact with *live parts* (for example non-earthed heatsinks), the conductivity of the coolant shall be continuously monitored and controlled, in order to avoid hazardous current flow through the coolant.

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4.7.2.3.8 *Insulation* requirements for coolant hoses

When the coolant is intentionally in contact with *live parts* (for example non-earthed heatsinks), the coolant hoses form a part of the *insulation system*. Depending on the location of the hoses, the requirements of 4.4.7 for *functional* or *simple* or *protective separation* shall be applied where relevant.

4.8 Equipment with multiple sources of supply

If equipment is provided with more than one supply connection (for example, with different voltages or frequencies or as backup power), the design shall be such that all of the following conditions are met:

- separate means of connection are provided for different circuits; and
- supply plug connections, if any, are not interchangeable if a hazard could be created by incorrect plugging; and
- hazards, within the meaning of this standard, shall not be present under normal or *single fault conditions* due to the presence of multiple sources of supply. Actions such as disconnection or de-energizing of a supply are considered a normal condition.

Compliance is checked by the evaluation of 4.2.

Information is to be provided with the equipment indicating the presence of multiple sources of supply and disconnection procedures (see 6.5.5).

Examples of the types of hazards that should be considered are:

a) Backfeed prevention – preventing voltage or energy available within the SMPS or one of its sources from being fed back to any of the input terminals for another source, either directly or by a leakage path.
b) Protection against unintentional islanding.
c) Touch current levels may be higher with multiple sources connected simultaneously (if that is a normal condition for the equipment).
d) Hazard resulting from damage to one or more connected sources (for example, a generator) due to energy from another source, for example the mains.
e) Damage to wiring due to currents higher than the wiring is designed for flowing from another source.

4.9 Protection against environmental stresses

The manufacturer has to specify the following service conditions for operation, storage and transportation:

- coolant temperature (min/max);
- ambient temperature (min/max);
- humidity (min/max);
- pollution degree;
- vibration;
- UV resistance;
- OVC (overvoltage category);
- altitude for thermal consideration, if rated for operation above 1 000 m;
- altitude for *insulation* coordination considerations, if rated for operation above 2 000 m.

NOTE Environmental categories as specified in the IEC 60721 series can be used where appropriate.

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The manufacturer shall state the environmental service condition for the *SMPS* according to Table 18.

Where the *SMPS* complies with the requirements of this standard only at conditions higher than the minimum values or lower than the maximum values given in Table 18, then this shall be by agreement between the supplier and the customer. The specific conditions shall be identified in the operating manual and on the product as specified in 6.3.3.

Table 18 – Environmental service conditions

Condition	**Indoor conditioned** **IEC 60721-3-3**	**Indoor unconditioned** **IEC 60721-3-3**	**Outdoor unconditioned** **IEC 60721-3-4**
Climatic	**class 3K2** (Temperature: +15 °C to 30 °C) (Humidity: 10 to 75 % R.H. non-condensing)	**class 3K3** (Temperature: +5 °C to 40 °C) (Humidity: 5 to 85 % R.H. / non-condensing)	**class 4K6** (Temperature: -20 °C to 55 °C) (Humidity: 4 to100 % R.H. / condensing)
Pollution degree	**2**	**3**[b]	**4**[c]
Humidity condition of the skin	**dry**	**waterwet**[a]	**salt water wet**[a]
Chemically active substances	**class 3C1** (No salt mist)	**class 3C1** (No salt mist)	**class 4C2** (Salt mist)[a]
Mechanically active substances	**class 3S1** (No requirement)	**class 3S1** (No requirement)	**class 4S2** (Dust and sand)
Mechanical	**class 3M1** (Vibration: 1 m/s^2)	**class 3M1** (Vibration: 1 m/s^2)	**class 4M1** (Vibration: 1 m/s^2)
Biological	**class 3B1** (No requirement)	**class 3B1** (No requirement)	**class 4B2** (Mould/fungus/rodents/termites)

[a] Where it is ensured that the equipment will not be used in water wet or salt water wet condition, the manufacturer may choose to rate the equipment for a less severe condition. In this case the rating shall be indicated in the documentation, according to 6.3.3.

[b] Pollution degree 2 may be provided if the conditions in 4.4.7.1.2 are satisfied

[c] Pollution degree 2 or 3 may be provided if the *enclosure* provides sufficient protection against conductive pollution and the conditions in 4.4.7.1.2 are satisfied

Compliance is checked by test of 5.2.6.

4.10 Protection against sonic pressure hazards

4.10.1 General

The equipment shall provide protection against the effects of sonic pressure. Compliance tests are carried out if the equipment is likely to cause such hazards.

4.10.2 Sonic pressure and sound level

If equipment produces noise at a level which could cause a hazard, the noise shall be measured to determine the maximum sound pressure level which the equipment can produce (except that sounds from alarms are not included). If the measured sound pressure exceeds 70 dBA the documentation shall provide information regarding the sound level of the equipment.

Compliance is checked by inspection, measurement, and calculation of the maximum sound pressure level in accordance with ISO 3746 or ISO 9614-1.

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4.11 Wiring and connections

4.11.1 General

The wiring and connections between parts of the equipment and within each part shall be protected from mechanical damage during installation. The *insulation*, conductors and routing of all wires of the equipment shall be suitable for the electrical, mechanical, thermal and environmental conditions of use. Conductors which are able to contact each other shall be provided with *insulation* rated for the *DVC* requirements of the relevant circuits.

The compliance with 4.11.2 to 4.11.8 shall be checked by inspection (see 5.2.1) of the overall construction and datasheets if applicable.

4.11.2 Routing

A hole through which insulated wires pass in a sheet metal wall within the *enclosure* of the equipment shall be provided with a smooth, well-rounded bushing or grommet or shall have smooth, well-rounded surfaces upon which the wires bear to reduce the risk of abrasion of the *insulation*.

Wires shall be routed away from sharp edges, screw threads, burrs, fins, moving parts, drawers, and similar parts, which abrade the wire *insulation*. The minimum bend radius specified by the wire manufacturer shall not be violated.

Clamps and guides, either metallic or non-metallic, used for routing stationary internal wiring shall be provided with smooth, well-rounded edges. The clamping action and bearing surface shall be such that abrasion, or deformation of the *insulation* does not occur. If a metal clamp is used for conductors having thermoplastic *insulation* less than 0,8 mm thick, non-conducting mechanical protection shall be provided.

4.11.3 Colour coding

Insulated conductors, other than those which are integral to ribbon cable or multi-cord signal cable, identified by the colour green with or without one or more yellow stripes shall only be used for *protective equipotential bonding*.

NOTE The choice of green or green/yellow for the *protective equipotential bonding* is covered by national regulations.

4.11.4 Splices and connections

All splices and connections shall be mechanically secured and shall provide electrical continuity.

Electrical connections shall be soldered, welded, crimped, or otherwise securely connected. A soldered joint, other than a component on a PWB, shall additionally be mechanically secured.

NOTE Stranded wire should not be consolidated with solder where secured in a terminal that relies on pressure for contact or equivalent

When stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire do not contact:

– other uninsulated *live parts* not always of the same potential as the wire;

– de-energized metal parts.

When screw terminal connections are used, the resulting connections may require routine maintenance (tightening). Appropriate reference shall be made in the maintenance manual (see 6.5.1).

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4.11.5 Accessible connections

In addition to measures given in 4.4.6.4 it shall be ensured that neither insertion error nor polarity reversal of connectors can lead to a voltage on an accessible connection higher than the maximum of *DVC As*. This applies for example to plug-in sub-assemblies or other plug-in devices which can be plugged in without the use of a tool or key or which are accessible without the use of a tool or key. This does not apply to equipment intended to be installed in *restricted access areas*.

If relevant, non-interchangeability and protection against polarity reversal of connectors, plugs and socket outlets shall be confirmed by inspection and trial insertion.

4.11.6 Interconnections between parts of the SMPS

In addition to complying with the requirements given in 4.11.1 to 4.11.5, the means provided for the interconnection between parts of the *SMPS* shall comply with the following requirements or those of 4.11.7.

Cable assemblies and flexible cords provided for interconnection between sections of equipment or between units of a *system* shall be suitable for the service or use involved. Cables shall be protected from physical damage as they leave the *enclosure* and shall be provided with mechanical strain relief.

Misalignment of male and female connectors, insertion of a multipin male connector in a female connector other than the one intended to receive it, and other manipulations of parts which are accessible to the operator shall not result in mechanical damage or a risk of thermal hazards, electric shock, or injury to persons.

When external interconnecting cables terminate in a plug which mates with a receptacle on the external surface of an *enclosure*, no risk of electric shock shall exist at accessible contacts of either the plug or receptacle when disconnected.

NOTE An interlock circuit in the cable to de-energize the accessible contacts whenever an end of the cable is disconnected meets the intent of these requirements.

4.11.7 Supply connections

The connection points provided shall be of appropriate construction to preclude the possibility of loose strands reducing the spacing between conductors when careful attention is paid to installation.

See 6.3.6.4 for marking requirement and documentation.

Addition:

4.11.7.100 Connection by mains supply cord

Mains supply cords shall comply with 7.9.

Pluggable equipment type A configurations shall be used only, if ***touch currents*** are within the limits outlined in 4.4.5.102.

4.11.8 Terminals

4.11.8.1 Construction requirements

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

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Terminal connections shall be such that the conductors can be connected by means of screws, springs or other equivalent means so as to ensure that the necessary contact pressure is maintained.

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

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

The requirements of this subclause are met by using terminals complying with IEC 60947-7-1 or IEC 60947-7-2, as appropriate.

4.11.8.2 Connecting capacity

Terminals shall be provided which accommodate the conductors specified in the installation and maintenance manuals (see 6.3.6.4) and cables in accordance with the wiring rules applicable at the *installation*. The terminals shall meet the temperature rise test of 5.2.3.10.

Information regarding the permitted wire sizes shall be given in the installation manual.

Standard values of cross-section of round copper conductors are shown in Annex G, which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

Addition:

4.11.8.2.100 Terminals for external conductors

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.

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 AB), except the manufacturer allows different configurations (e.g. material, type, sizes and connection methods) in the accompanying documents.

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4.11.8.3 Connection

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

Sets of terminals for connection to the same input or output shall be grouped together and shall be located in proximity to each other and to the main *protective earthing* terminal, if any. If the installation instructions provide detail on the proper earthing of the *system*, the *protective earthing* terminal need not be placed in proximity to the terminals.

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

4.11.8.4 Wire bending space for wires 10 mm^2 and greater

The distance between a terminal for connection to the main supply, or between major parts of the *SMPS* (for example a transformer), and an obstruction toward which the wire is directed upon leaving the terminal shall be at least that specified in Table 19.

Table 19 – Wire bending space from terminals to *enclosure*

Size of wire mm^2	Minimum bending space, terminal to *enclosure* mm		
	Wires per terminal		
	1	2	3
10 to 16	40	-	-
25	50	-	-
35	65	-	-
50	125	125	180
70	150	150	190
95	180	180	205
120	205	205	230
150	255	255	280
185	305	305	330
240	305	305	380
300	355	405	455
350	355	405	510
400	455	485	560
450	455	485	610

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4.12 Enclosures

4.12.1 General

The following requirements are in addition to *enclosure* requirements given in other sections relating to specific hazards, for example electric shock hazard in 4.4 and fire hazard in 4.6.

Enclosures shall be suitable for use in their intended environments. The manufacturer shall specify the intended environment (see 6.3.3) and the IP rating of the *enclosure* (see 5.2.2.3 for test).

Equipment shall have adequate mechanical strength and shall be so constructed that no hazard occurs when subjected to handling as may be expected.

Mechanical strength tests are not required on an internal barrier, screen or the like, provided to meet the requirements of 4.6.3, if the *enclosure* provides mechanical protection.

An *enclosure* shall be sufficiently complete to contain or deflect parts which, because of failure or for other reasons, might become loose, separated or thrown from a moving part.

Compliance shall be checked by the relevant tests of 5.2.2.4 to 5.2.2.7 as specified. If the *enclosure* complies with the applicable thickness requirement of 4.12.3 or 4.12.4 the test in 5.2.2.4.2 and 5.2.2.4.3 can be waived.

For *open type* equipment the tests of 5.2.2.4 to 5.2.2.7 are not required.

4.12.2 Handles and manual controls

Handles, knobs, grips, levers and the like shall be reliably fixed so that they will not work loose in normal use, if this could result in a hazard. Sealing compounds and the like, other than self-hardening resins, shall not be used to prevent loosening. If handles, knobs and the like are used to indicate the position of switches or similar components, it shall not be possible to fix them in a wrong position if this could result in a hazard.

Compliance shall be checked by inspection, and as applicable by the tests of 5.2.2.7.

4.12.3 Cast metal

Die-cast metal, except at threaded holes for conduit, where a minimum of 6,4 mm thickness is required, shall be:

– not less than 2,0 mm thick for an area larger than 155 cm^2 or having any dimension larger than 150 mm;

– not less than 1,2 mm thick for an area of 155 cm^2 or less and having no dimension larger than 150 mm.

The area under evaluation may be bounded by reinforcing ribs subdividing a larger area.

Malleable iron or permanent-mould cast aluminium, brass, bronze, or zinc, except at threaded holes for conduit, where a minimum of 6,4 mm thickness is required, shall be:

– at least 2,4 mm thick for an area greater than 155 cm^2 or having any dimension more than 150 mm;

– at least 1,5 mm thick for an area of 155 cm^2 or less having no dimension more than 150 mm.

A sand-cast metal *enclosure* shall be a minimum of 3,0 mm thick except at locations for threaded holes for conduit, where a minimum of 6,4 mm is required.

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4.12.4 Sheet metal

The thickness of a sheet-metal *enclosure* at points to which a wiring *system* is to be connected shall be not less than 0,8 mm thick for uncoated steel, 0,9 mm thick for zinc-coated steel, and 1,2 mm thick for non-ferrous metal.

Enclosure thickness at points other than where a wiring *system* is to be connected shall be not less than that specified in Table 20 or Table 21.

With reference to Table 20 or Table 21, a supporting frame is a structure of angle or channel or folded section of sheet metal, which is attached to and has the same outside dimensions as the *enclosure* surface, and which has torsional rigidity to resist the bending moments that are applied by the *enclosure* surface when it is deflected. A structure which is as rigid as one built with a frame of angles or channels has equivalent reinforcing.

Constructions without supporting frame include:

– a single sheet with single formed flanges – formed edges;

– a single sheet which is corrugated or ribbed;

– an *enclosure* surface loosely attached to a frame, for example, with spring clips; and

– an *enclosure* surface having an unsupported edge.

See Figure 8 for supported and unsupported *enclosure* surfaces.

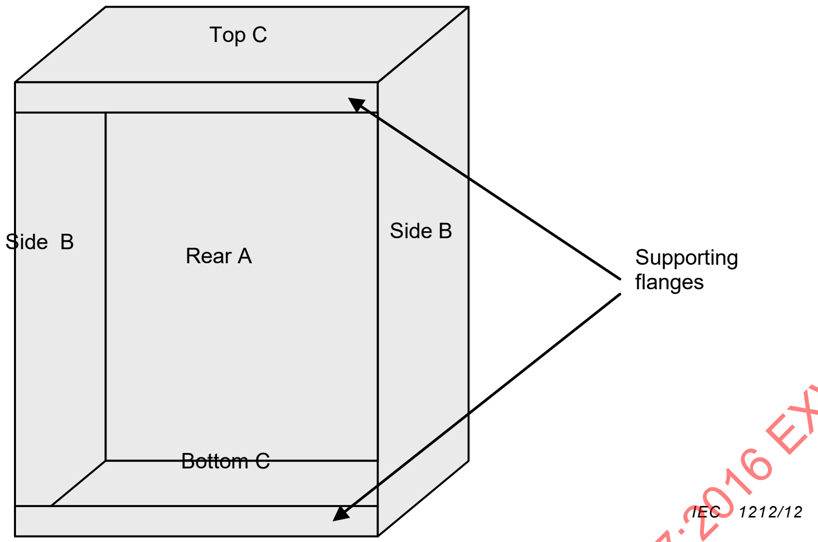

Figure 8 – Supported and unsupported *enclosure* parts

Each *enclosure* surface is evaluated individually based on the length and width dimensions. For each set of surface dimensions, A, B or C, the width is the smaller dimension regardless of its orientation to other surfaces. In Table 20 and Table 21, there are two sets of dimensions that correspond to a single metal thickness requirement and the following describes the applicable procedure for determining the minimum metal thickness for each surface.

For a supported surface, all of the table dimensions, including the “not limited” lengths, are able to be applied. The rear surface “A”, top and bottom surfaces “C”, are supported either by adjacent surfaces of the *enclosure* or by a 12,7 mm (1/2 inch) wide flange. To determine required metal thickness for supported surfaces, the width is to be measured and compared with the table value in the maximum width column that is equal to or greater than the measured width. When the corresponding length in the maximum length column is “not limited”, the minimum thickness in the far right column is to be used. When the corresponding length in the maximum length column is a numerical value, and the measured length of the side does not exceed this value, the minimum thickness from the far right column is to be used. When the measured length of the side exceeds the numerical value, the next line in the Table 20 and Table 21 is to be used.

For an unsupported surface, only the table dimensions that include a specific length requirement are applied. The dimensions with a “not limited” length do not apply. The front edge of the left and right surfaces “B”, are not supported by an adjacent surface or by a flange. To determine the required metal thickness for unsupported surfaces, the length is to be measured and compared with the table value in the maximum length column that is not less than the measured length, ignoring the “not limited” entries. When the corresponding width in the maximum width column is not less than the measured width, the minimum thickness from the far right column is to be used. When the measured width of the surface exceeds the value in the maximum width column, the next line in the Table 20 and Table 21 is to be used.

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Table 20 – Thickness of sheet metal for *enclosures*: carbon steel or stainless steel

Without supporting frame [a]		With supporting frame [a]		Minimum thickness
Maximum width mm [b]	Maximum length mm [c]	Maximum width mm [c]	Maximum length mm [c]	mm
100	Not limited	160	Not limited	0,6 [d]
120	150	170	210	
150	Not limited	240	Not limited	0,75 [d]
180	220	250	320	
200	Not limited	310	Not limited	0,9
230	290	330	410	
320	Not limited	500	Not limited	1,2
350	460	530	640	
460	Not limited	690	Not limited	1,4
510	640	740	910	
560	Not limited	840	Not limited	1,5
640	790	890	1 090	
640	Not limited	990	Not limited	1,8
740	910	1 040	1 300	
840	Not limited	1 300	Not limited	2,0
970	1 200	1 370	1 680	
1 070	Not limited	1 630	Not limited	2,5
1 200	1 500	1 730	2 130	
1 320	Not limited	2 030	Not limited	2,8
1 520	1 880	2 130	2 620	
1 600	Not limited	2 460	Not limited	3,0
1 850	2 290	2 620	3 230	

[a] See 4.12.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal which is part of an *enclosure*. Adjacent surfaces of an *enclosure* are able to have supports in common and be made of a single sheet.

[c] Not limited applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet steel for an *enclosure* intended for outdoor use should be not less than 0,86 mm thick.

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Table 21 – Thickness of sheet metal for *enclosures*: aluminium, copper or brass

Without supporting frame [a]		With supporting frame [a]		Minimum thickness
Maximum width, mm [b]	Maximum length, mm [c]	Maximum width, mm [b]	Maximum length, mm [c]	mm
75 90	Not limited 100	180 220	Not limited 240	0,6 [d]
100 125	Not limited 150	250 270	Not limited 340	0,75
150 165	Not limited 200	360 380	Not limited 460	0,9
200 240	Not limited 300	480 530	Not limited 640	1,2
300 350	Not limited 400	710 760	Not limited 950	1,5
450 510	Not limited 640	1 100 1 150	Not limited 1 400	2,0
640 740	Not limited 1 000	1 500 1 600	Not limited 2 000	2,4
940 1 100	Not limited 1 350	2 200 2 400	Not limited 2 900	3,0
1 300 1 500	Not limited 1 900	3 100 3 300	Not limited 4 100	3,9

[a] See 4.12.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal which is part of an *enclosure*. Adjacent surfaces of an *enclosure* are able to have supports in common and be made of a single sheet.

[c] Not limited applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet aluminium, copper or brass for an *enclosure* intended for outdoor use should be not less than 0,74 mm thick.

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4.12.5 Stability test for enclosure

Under conditions of normal use, units and equipment shall not become physically unstable to the degree that they could become a hazard to an operator or to a service person.

If units are designed to be fixed together on site and not used individually, the stability of each individual unit is exempt from the requirements of 4.12.5.

The requirements of 4.12.5 are not applicable if the installation instructions for a unit specify that the equipment is to be secured to the building structure before operation.

Under conditions of operator use, a stabilizing means, if needed, shall be automatic in operation when drawers, doors, etc., are opened.

During operations performed by a service person, the stabilizing means, if needed, shall either be automatic in operation, or a marking shall be provided to instruct the service person to deploy the stabilizing means.

Compliance is checked by test of 5.2.2.5.

5 Test requirements

The provisions of Clause 5 of IEC 62477-1:2012 apply, except as follows.

5.1 General

5.1.1 Test objectives and classification

Testing, as defined in this Clause 5, is required to demonstrate that *SMPS* is fully in accordance with the requirements of this standard. Testing may be waived if permitted by the relevant requirements subclause of Clause 4.

The subclauses in this Clause 5 describe the procedures to be adopted for the testing of *SMPS*. The tests are classified as:

– type tests;

– routine tests;

– sample tests.

The manufacturer and/or test house shall ensure that the specified maximum and/or minimum environment (or test) values are imposed, taking tolerances and measurement uncertainties fully into account.

WARNING! These tests can result in hazardous situations. Suitable precautions shall be taken to avoid injury.

5.1.2 Selection of test samples

When testing a range or series of similar products, it may not be necessary to test all models in the range. Each test should be performed on a model or models having mechanical and electrical characteristics that adequately represent the entire range for that particular test.

NOTE For example, tests on *enclosures* of the same material but different sizes can be represented by a single *enclosure* but tests on power components that are different ratings often cannot be represented by testing on one particular model.

5.1.3 Sequence of tests

In general, there is no requirement for tests to be performed in a set sequence, nor is it required that they are all performed on the same sample of equipment. However, the pass criteria for some of the tests require that they are followed by one or more further tests.

5.1.4 Earthing conditions

Test requirements shall be determined using the worst-case (most stressful) *system* earthing allowed by the manufacturer. *Systems* earthing may include:

– neutral to earth;

– line to earth;

– neutral to earth through high impedance;

– isolated (not earthed).

5.1.5 General conditions for tests

5.1.5.1 Application of tests

Unless otherwise stated, upon conclusion of the tests, the equipment need not be operational.

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5.1.5.2 Test samples

Unless otherwise specified, the sample or samples under test shall be representative of the equipment the user would receive, or shall be the actual equipment ready for shipment to the user.

As an alternative to carrying out tests on the complete equipment, tests may be conducted separately on circuits, components or sub-assemblies outside the equipment, provided that inspection of the equipment and circuit arrangements indicates that the results of such testing will be representative of the results of testing the assembled equipment. If any such test indicates a likelihood of non-conformance in the complete equipment, the test shall be repeated in the equipment.

Where in this standard compliance of materials, components or sub-assemblies is checked by inspection or by testing of properties, it is permitted to confirm compliance by reviewing any relevant data or previous test results that are available instead of carrying out the specified *type tests*. See also 4.1.

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5.1.5.3 Operating parameters for tests

Except where specific test conditions are stated elsewhere in the standard and where it is clear that there is a significant impact on the results of the test, the tests shall be conducted under the most unfavourable combination within the manufacturer's operating specifications of the following parameters:

– supply voltage;
– supply frequency;
– operating temperature taking derating and cooling control characteristic into account;
– physical location of equipment and position of movable parts;
– operating mode;
– load conditions;
– adjustment of thermostats, regulating devices or similar controls in *restricted access area*, which are:
  - adjustable without the use of a tool or key; or
  - adjustable using a means, such as a key or a tool, deliberately provided for the operator.

NOTE In determining the most unfavourable frequency for the power to energize the equipment under test, different rated frequencies within the rated frequency range should be taken into account (for example, 50 Hz and 60 Hz) but consideration of the tolerance on a rated frequency (for example, 50 Hz ± 0,5 Hz) is not normally necessary.

Addition:

5.1.5.3.100 Standard test conditions

SMPS shall be tested at least for the following conditions:

a) indoor use;
b) altitude up to 2 000 m;
c) ambient temperature from 5 °C to 30 °C;
d) maximum relative humidity: 10 % to 75 % R.H. non-condensing;
e) ***mains supply*** voltage fluctuations as stated under 5.1.5.3.101;
f) transient overvoltages of category II on the ***mains supply***;
g) pollution degree 2.

Increased specifications can be used, based on manufacturers declaration.

5.1.5.3.101 Supply voltage

Unless specifically stated for a test, in determining the most unfavourable supply voltage for a test, the following variables shall be taken into account:

- multiple rated voltages;
- extremes of rated voltage ranges; and
- tolerance on rated voltage as declared by the manufacturer.

Unless the manufacturer declares a wider tolerance, the minimum tolerance shall be taken as +10 % and −10 % for ***AC mains supply*** and +20 % and −15 % for ***DC mains supply***. Equipment intended by the manufacturer to be restricted to connection to a conditioned power supply system (for example, a UPS) may be provided with a narrower tolerance if the equipment is also provided with instructions specifying such restriction.

5.1.5.3.102 Electrical measuring instruments

Electrical measuring instruments shall have adequate bandwidth to provide accurate readings, taking into account all components (DC, mains frequency, high frequency and harmonic content) of the parameter being measured.

If an RMS value is measured, care shall be taken that the measuring instrument gives a true RMS reading of non-sinusoidal waveforms as well as sinusoidal waveforms.

Measurements are made with a meter whose input impedance has a negligible influence on the measurement.

5.1.6 Compliance

Compliance with this standard shall be verified by carrying out the appropriate tests specified in this Clause 5.

Compliance may only be claimed if all relevant tests have been passed.

Compliance with construction requirements and information to be provided by the manufacturer shall be verified by suitable examination, visual inspection, and/or measurement.

Whenever design or component changes have potential impact upon compliance, new *type testing* shall be performed to confirm compliance. It is desirable that the modified product should be identified, for example by using a suitable date code or serial number as described in 6.2.

5.1.7 Test overview

Replacement:

Table 22 provides an overview of the *type*, *routine* and *sample testing* of electronic components, equipment and ***SMPS***.

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Table 22 – Test overview

Test	Type	Routine	Sample	Requirement(s)	Specification
Visual inspection	X	X	X		5.2.1
Mechanical tests					5.2.2
Clearance and creepage distances test	X			4.4.7.1, 4.4.7.5	5.2.2.1
Non-accessibility test	X			4.4.3.3, 4.5.1.1, 4.6.3.3.2	5.2.2.2
Ingress protection test (IP rating)	X			4.12.1	5.2.2.3
Enclosure integrity test	X			4.12.1	5.2.2.4
Deflection test	X			4.12.1	5.2.2.4.2
Steady force test, 30 N	X			4.12.1	5.2.2.4.2.2
Steady force test, 250 N	X			4.12.1	5.2.2.4.2.3
Impact test	X			4.12.1	5.2.2.4.3
Drop test	X			4.12.1	5.2.2.4.4
Stress relief test	X			4.12.1	5.2.2.4.5
Stability test	X			4.12.1	5.2.2.5
Wall or ceiling mounted equipment test	X			4.12.1	5.2.2.6
Handles and manual control securement test	X			4.12.1	5.2.2.7
Electrical tests				4.4.7.10	5.2.3
Impulse voltage test	X		X	4.4.3.2, 4.4.5.4, 4.4.7.1,4.4.7.8.3, 4.4.7.10.1, 4.4.7.10.2	5.2.3.2
AC or DC voltage test	X	X		4.4.3.2, 4.4.5.4, 4.4.7.1, 4.4.7.8.4.2, 4.4.7.10.1, 4.4.7.10.2,	5.2.3.4
Partial discharge test	X		X	4.4.7.1, 4.4.7.8.3, 4.4.7.10.2	5.2.3.5
Protective impedance test	X	X		4.4.5.4	5.2.3.6
Touch current measurement test	X			4.4.5.102	5.2.3.7
Circuits with current limitation	X			4.4.5.102, 4.4.5.103	5.2.3.7.100
Capacitor discharge test	X			4.4.9, 4.4.5.103	5.2.3.8, 5.2.3.8.100
Limited power source test	X			4.5.1.2, 4.6.5	5.2.3.9
Temperature rise test	X			4.6.4	5.2.3.10
Protective equipotential bonding test	X	X		4.4.4.2.2	5.2.3.11
Protective equipotential bonding short circuit withstand test	X		X	5.2.3.11.3	5.2.4.3
Input test	X			6.2.100	5.2.3.100
Determination of working voltage	X			4.4.2.2.3	5.2.3.101
Standard test procedure for separable thin sheet material	X			4.4.7.8.3.100	5.2.3.102
Standard test procedure for non-separable thin sheet material	X		X	4.4.7.8.3.101	5.2.3.103
Mandrel test	X		X	4.4.7.8.3.101	5.2.3.104

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Test	Type	Routine	Sample	Requirement(s)	Specification
Insulated winding wires for use without interleaved insulation	X	X	X	4.4.7.8.5.100	5.2.3.105
Abnormal operation tests				4.2	5.2.4
Setting of voltage selector	X			4.2	5.2.4.1.100.2
Polarity test	X			4.2	5.2.4.1.100.3
Output short circuit test	X			4.3	5.2.4.4
Output overload test	X			4.3	5.2.4.5
Breakdown of components test	X			4.2	5.2.4.6
PWB short circuit test	X			4.4.7.7	5.2.4.7
Loss of phase test	X			4.2	5.2.4.8
Cooling failure tests	X			4.2, 4.7.2.3.6	5.2.4.9
Inoperative blower test	X			4.2	5.2.4.9.2
Clogged filter test	X			4.2	5.2.4.9.3
Loss of coolant test	X			4.7.2.3.6	5.2.4.9.4
Transformer overload	X			7.6	5.2.4.100
Covering of ventilation openings	X			4.2	5.2.4.101
Fuse test (AC fuse in DC application)	X			5.2.4.2 i)	5.2.4.2 i)
Material tests					5.2.5
High current arcing ignition test	X			4.4.7.8.2	5.2.5.2
Glow-wire test	X			4.4.7.8.2	5.2.5.3
Hot wire ignition test	X			4.4.7.8.2	5.2.5.4
Flammability test	X			4.6.3	5.2.5.5
Flaming oil test	X			4.6.3.3.3	5.2.5.6
Cemented joints test	X			4.4.7.9	5.2.5.7
Environmental tests	X			4.9	5.2.6
Dry heat test	X			4.9	5.2.6.3.1
Damp heat test	X			4.9	5.2.6.3.2
Vibration test	X			4.9	5.2.6.4
Salt mist test	X			4.9	5.2.6.5
Dust and sand test	X			4.9	5.2.6.6
Hydrostatic pressure test	X	X		4.7.2.3.3	5.2.7

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5.2 Test specifications

5.2.1 Visual inspections (type test, sample test and routine test)

Visual inspections shall be made:

– as *routine tests*, to check features such as adequacy of labelling, warnings and other safety aspects;

– as acceptance criteria of individual *type tests*, *sample tests* or *routine tests*, to verify that the requirements of this standard have been met.

Routine inspections may be part of the production or assembly process.

Before *type testing*, a check shall be made that the *SMPS* delivered for the test is as expected with respect to supply voltage, input and output ranges, etc.

5.2.2 Mechanical tests

5.2.2.1 Clearances and creepage distances test (type test)

Replacement:

It shall be verified by measurement or visual inspection that the clearance and creepage distances comply with 4.4.7.4 and 4.4.7.5. See Annex D for measurement examples.

5.2.2.2 Non-accessibility test (type test)

This test is intended to show that *live parts*, protected by means of *enclosures* or barriers in compliance with 4.4.3.3, are not accessible.

This test shall be performed as a *type test* of the *enclosure* of a *SMPS* as specified in IEC 60529 for the *enclosure* classification for protection against access to hazardous parts. Except as noted below:

– the test probe for IP3X (2,5 mm Ø) shall not penetrate the top surface of the *enclosure* when probed from the vertical direction ±5 ° only.

The test probes are reproduced in Annex M for convenience.

5.2.2.3 Ingress protection test (IP rating) (type test)

The claimed IP rating of the *enclosure* shall be verified. This test shall be performed as a *type test* of the *enclosure* of a *SMPS* as specified in IEC 60529 for the *enclosure* classification.

5.2.2.4 Enclosure integrity test (type test)

5.2.2.4.1 General

The integrity tests apply to *SMPS*, and also where *SMPS* are intended for operation without a further *enclosure* in *restricted access areas*. After completion of the integrity test, the *SMPS* shall pass the tests of 5.2.3.2 and 5.2.3.4 and shall be inspected to confirm that:

– no degradation of any safety-relevant component of the *SMPS* has occured*;*

– *hazardous live parts* have not become accessible (see 4.4.3.3);

– *enclosures* show no cracks or openings which could cause a hazard;

– clearances are not less than their minimum permitted values and other *insulation* is undamaged;

– barriers have not been damaged or loosened;

– no moving parts which could cause a hazard are exposed.

The integrity tests shall be performed at the worst case point on representative accessible face(s) of the *enclosure*.

The *SMPS* is not required to be operational after testing and the *enclosure* may be deformed to such an extent that its original IP rating is not maintained.

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5.2.2.4.2 Deflection test (type test)

5.2.2.4.2.1 General

If requested by 4.12.1 the test in 5.2.2.4.2.2 and 5.2.2.4.2.3 applies, for metallic *enclosure*, as applicable.

The *enclosure* shall be held firmly against a rigid support.

The tests are not applied to handles, levers, knobs or to transparent or translucent covers of indicating or measuring devices, unless parts at hazardous voltage are accessible by means of the test finger (Figure 2, test probe B of IEC 61032:1997) if the handle, lever, knob or cover is removed.

During the tests of 5.2.2.4.2.2 and 5.2.2.4.2.3, earthed or unearthed conductive *enclosures* shall not reduce clearance and creepage distances required for *basic insulation* or withstand the impulse voltage test in 5.2.3.2.

5.2.2.4.2.2 Steady force test, 30 N

Parts of an *enclosure* located in an *restricted access area*, which are protected by a cover or door meeting the requirements of 5.2.2.4.2.3, are subjected to a steady force of 30 N ± 3 N for a period of 5 s, applied by means of a straight unjointed version of the test finger (Figure 2, test probe B of IEC 61032:1997), to the part on or within the equipment.

5.2.2.4.2.3 Steady force test, 250 N

External *enclosures* are subjected to a steady force of 250 N ± 10 N for a period of 5 s, applied in turn to the top, bottom and sides of the *enclosure* fitted to the equipment, by means of a suitable test tool providing contact over a circular plane surface 30 mm in diameter. However, this test is not applied to the bottom of an *enclosure* of equipment having a mass of more than 18 kg or to surfaces that are mounted to a wall.

For surfaces neither horizontal nor vertical, test shall be performed by tilting the equipment in a suitable way so that the surface is either horizontal or vertical.

5.2.2.4.3 Impact test (type test)

External polymeric surfaces of *enclosures*, the failure of which would give access to hazardous parts, are tested as follows.

A sample consisting of the complete *enclosure*, or a portion thereof representing the largest unreinforced area, is supported in its normal position. A solid smooth steel ball, approximately 50 mm in diameter and with a mass of 500 g ± 25 g, is permitted to fall freely from rest through a vertical distance (H) of 1,3 m (see Figure 9) onto the sample. Vertical surfaces are exempt from this test.

In addition, the steel ball is suspended by a cord and swung as a pendulum in order to apply a horizontal impact, dropping through a vertical distance (H) of 1,3 m (see Figure 9) onto the sample. Horizontal surfaces are exempt from this test. Alternatively, the sample is rotated 90° about each of its horizontal axes and the ball dropped as in the vertical impact test.

The test is not applied to flat panel displays or to the platen glass of equipment.

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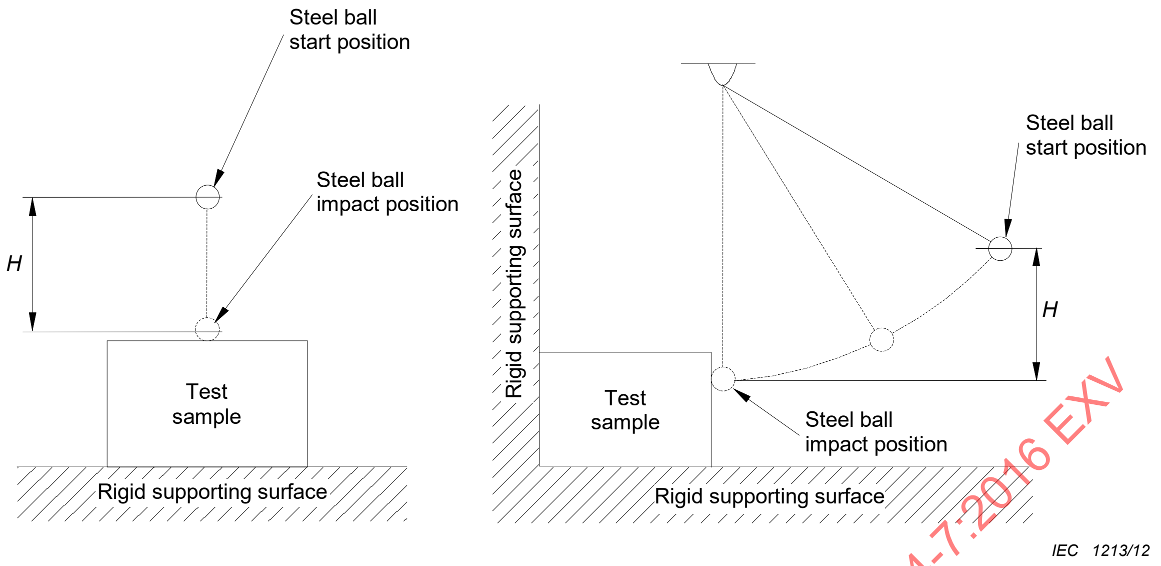

Figure 9 – Impact test using a steel ball

5.2.2.4.4 Drop test

Plugable hand-held, direct plug-in and transportable equipment with mass of 18 kg or less is subjected to the following test.

A sample of the complete equipment is subjected to three impacts that result from being dropped onto a sufficiently rigid horizontal surface in positions likely to produce the most adverse results.

The height of the drop shall be 1 000 mm.

Addition:

5.2.2.4.4.100 Drop test surface

A 50 mm thick hardwood board having a density of more than 700 kg/m3 lying flat on a rigid base such as concrete, is considered to be sufficiently rigid for the drop test.

5.2.2.4.5 Stress relief test

Enclosures of moulded or formed thermoplastic materials shall be so constructed that any shrinkage or distortion of the material due to release of internal stresses caused by the moulding or forming operation does not result in the exposure of hazardous parts or in the reduction of creepage distances or clearances below the minimum required.

Compliance shall be checked by the test procedure described below or by the inspection of the construction and the available data where appropriate.

One sample consisting of the complete equipment, or of the complete *enclosure* together with any supporting framework, is placed in a circulating air oven (according to IEC 60216-4-1) at a temperature 10 K higher than the maximum temperature of the *enclosure* during the test of 5.2.3.10, but not less than 70 °C, for a period of 7 h, then permitted to cool at room temperature.

With the concurrence of the manufacturer, it is permitted to increase the above time duration. For large equipment where it is impractical to condition a complete *enclosure*, it is permitted to use a portion of the *enclosure* representative of the complete assembly with regard to thickness and shape, including any mechanical support members.

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5.2.2.5 Stability test

To prove the stability of the equipment the following tests shall be carried out, where relevant. Each test is carried out separately. During the tests, reservoirs are to contain the amount of liquid within their rated capacity producing the most disadvantageous condition. All castors and jacks, if used in normal operation, are placed in their most unfavourable position, with wheels and the like locked or blocked. However, if the castors are intended only to transport the unit, and if the installation instructions require jacks to be lowered after installation, then the jacks (and not the castors) are used in this test; the jacks are placed in their most unfavourable position, consistent with reasonable leveling of the unit.

A unit having a mass of 7 kg or more shall not fall over when tilted to an angle of 10° from its normal upright position. Doors, drawers, etc., are closed during this test. A unit provided with multi-positional features shall be tested in the least favourable position permitted by the construction.

A floor-standing unit having a mass of 25 kg or more shall not fall over when a force equal to 20 % of the weight of the unit, but not more than 250 N, is applied in any direction except upwards, at a height not exceeding 2 m from the floor. Doors, drawers, etc., which may be moved for servicing by the operator or by a service person, are placed in their most unfavourable position, consistent with the installation instructions.

A floor-standing unit shall not fall over when a constant downward force of 800 N is applied at the point of maximum moment to any horizontal surface of at least 12,5 cm by at least 20 cm, at a height up to 1 m from the floor. Doors, drawers, etc., are closed during this test. The 800 N force is applied by means of a suitable test tool having a flat surface of approximately 12,5 cm by 20 cm. The downward force is applied with the complete flat surface of the test tool in contact with the equipment under test; the test tool need not be in full contact with uneven surfaces (for example, corrugated or curved surfaces).

5.2.2.6 Wall or ceiling mounted equipment test

The equipment is mounted in accordance with the manufacturer's instructions. A force in addition to the weight of the equipment is applied downwards through the geometric centre of the equipment, for 1 min. The additional force shall be equal to three times the weight of the equipment but not less than 50 N. The equipment and its associated mounting means shall remain secure during the test.

5.2.2.7 Handles and manual controls securement test

Handles and manual controls shall be tested by manual test and by trying to remove the handle, knob, grip or lever by applying for 1 min an axial force as shown in Table 23.

Table 23 – Pull values for handles and manual control securement

	Axial pull unlikely N			Axial pull likely N		
Intented for operation by	Fingers	1 hand	2 hands	Fingers	1 hand	2 hands
Operating means of components[a]	15	100	200	30	150	300
Other	20	150	300	50	200	450

[a] Handles, knobs, grips levers and the like intented to operate components, such as valve controls, electrical switch handles etc.

Under the tests above the handles, knobs, grips levers and the like shall remain fixed to the equipment as intended.

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5.2.3 Electrical tests

5.2.3.1 General

The electrical tests described in 5.2.3.2 to 5.2.3.5 are applicable to *basic*, *supplementary* and *reinforced insulation*. Before performing these tests, preconditioning according to 5.2.6.3.1 and 5.2.6.3.2 is required.

When performing electrical and preconditioning tests, the preferred procedure is to test the entire equipment; however it is acceptable to test the components or sub-assemblies providing the *basic* and *reinforced insulation*. When components or sub-assemblies are tested, test conditions shall simulate the least favourable conditions occurring inside the equipment at the place of *installation*.

5.2.3.2 Impulse voltage test (type test and sample test)

The impulse voltage test is performed with a voltage having a 1,2/50 µs waveform (see 6.1 and 6.2 of IEC 61180-1:1992) and is intended to simulate overvoltages of atmospheric origin. It also covers overvoltages due to switching of equipment. See Table 24 for conditions of the impulse voltage test.

Tests on clearances smaller than required by 4.4.7.4 and test on solid *insulation* required by 4.4.7.8 are performed as *type tests* using appropriate voltages from Table 25.

Tests on components and devices for *protective separation* are performed as a *type test* and a *sample test* before they are assembled into the *SMPS*, using the impulse withstand voltages listed in column 3 or column 5 of Table 25.

To ensure that *surge protective devices* (see 4.4.7.2.2, 4.4.7.2.3, 4.4.7.3) are able to reduce the overvoltage, the values of column 2 or column 4 in Table 25, are applied to the *SMPS* as a *type test*. The measured peak voltage shall not exceed the next lower voltage value of the same column of that table.

If it is necessary to test a clearance that has been designed according to 4.4.7.4.1 for altitudes between 2 000 m and 20 000 m (using Table A.2 of IEC 60664-1:2007, which is reproduced as Table E.1) or test a clearance designed according to 4.4.7.11 for frequencies above 30 kHz, the appropriate test voltage may be determined from the clearance distance, using Table 10 in reverse.

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Table 24 – Impulse voltage test

Subject	Test conditions	
Test reference	IEC 61180-1:1992, 6.1. and 6.2; IEC 60664-1:2007: 6.1.3.3 1	
Requirement reference	According to 4.4.3.2, 4.4.5.4 and 4.4.7	
Preconditioning	*Precondition according to 5.2.3.1* *Live parts* belonging to the same circuit shall be connected together. *Protective impedances* may be disconnected unless required to be tested. Impulse voltage to be applied: 1) between circuit under test and the surroundings; and 2) between circuits to be tested. Power is not applied to circuits under test.	
Initial measurement	According to specification of *SMPS*, component, or device.	
Test equipment	Impulse generator 1,2/50 µs with an output impedance not higher than: – 2 Ω for surge protective devices; – 2 Ω for testing clearances, *solid insulation* and components. A higher impedance, but not more than 500 Ω, may be chosen, if the impulse voltage is verified at the object under test.	
Measurement and verification	a) Clearances smaller than required by Table 10 Clearances reduced by *surge protective device* or by circuit characteristics Solid *basic* or *supplementary insulation*	b) Components and devices for *protective separation* Solid *reinforced insulation*
	Three pulses 1,2/50 µs of each polarity in ≥ 1 s interval, peak voltage (±5 %) according to:	
Test voltage	Column 2 or column 4 of Table 25	Column 3 or column 5 of Table 25
Altitude correction	When the test is carried out on a clearance at an altitude less than 2 000 m, the test voltage shall be increased according to Table F.5, 6.1.2.2.1.1, of IEC 60664-1:2007, which is reproduced as Table E.2 in this standard. The altitude correction factor does not apply to impulse voltage testing on solid *insulation* according to 6.1.3.3.1 of IEC 60664-1:2007.	

The impulse voltage test is successfully passed if no puncture of *insulation*, flashover, or sparkover occurs. In the case of components and devices which use solid *insulation* for *protective separation*, a subsequent partial discharge test (see 5.2.3.5) shall also be passed.

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Table 25 – Impulse test voltage

Column 1	2	3	4	5
System voltage **(see 4.4.7.1.6)**	**Impulse withstand voltage for *insulation* between circuits connected to *non-mains supply* and their surroundings according to overvoltage category II**		**Impulse withstand voltage for *insulation* between circuits connected to *mains supply* and their surroundings according to overvoltage category III**	
	Basic or supplementary	**Reinforced**	**Basic or supplementary**	**Reinforced**
V	V	V	V	V
≤ 50	500	800	800	1 500
100	800	1 500	1 500	2 500
150	1 500	2 500	2 500	4 000
300	2 500	4 000	4 000	6 000
600	4 000	6 000	6 000	8 000
1 000	6 000	8 000	8 000	12 000
-	Interpolation is permitted		Interpolation is not permitted	

NOTE 1 Test voltages for overvoltage categories I and III can be derived in a similar way from Table 9.

NOTE 2 Test voltages for overvoltage categories II and IV can be derived in a similar way from Table 9.

5.2.3.3 Alternative to impulse voltage test (type test and sample test)

An a.c. or d.c. voltage test according to 5.2.3.4 may be used as an alternative method to the impulse voltage test of 5.2.3.2.

For an a.c. voltage test the peak value of the a.c. test voltage shall be equal to the impulse test voltage of Table 25 and applied for three cycles of the a.c. test voltage.

For a d.c. voltage test the average value of the d.c. test voltage shall be equal to the impulse test voltage of Table 25 and applied three times for 10 ms in each polarity.

See IEC 60664-1:2007, 6.1.2.2.2, for further information.

5.2.3.4 AC or DC voltage test (type test and routine test)

5.2.3.4.1 Purpose of test

Replacement:

The test is used to verify that solid insulation of components and assembled ***SMPS*** have adequate dielectric strength to resist temporary overvoltage conditions.

5.2.3.4.2 Value and type of test voltage

The values of the test voltage for circuits connected to *mains supply* are determined from column 2 or 3 of Table 26.

The test voltage from column 2 is used for testing circuits with *basic insulation*.

Between circuits with *protective separation* (*double* or *reinforced insulation*), the test voltage of column 3 shall be applied for *type tests*. For *routine tests* between circuits with *protective separation* the values from column 2 shall be applied to prevent damage to the *solid insulation* by partial discharge.

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The values of column 3 shall apply to *SMPS* with *enhanced protection* according to 4.4.3.

For circuits connected to *non-mains supply* the test voltage shall be:

- For *type testing* circuits with *simple separation*, and for all *routine testing*: the *temporary overvoltage* (a.c. r.m.s. or d.c.) as determined in 4.4.7.2.3.
- For *type testing* circuits with *protective separation*, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3): twice the *temporary overvoltage* (a.c. r.m.s. or d.c.) as determined in 4.4.7.2.3.

For *non-mains* circuits, where *temporary overvoltages* are not present, the test voltages are determined from Table 27, based on the *working voltage*.

The test is performed between circuits and accessible surfaces of *SMPS*, which are non-conductive or which are conductive but not connected to the *PE conductor*.

The voltage test shall be performed with a sinusoidal voltage at 50 Hz or 60 Hz. If the circuit contains capacitors the test may be performed with a d.c. voltage of a value equal to the peak value of the specified a.c. voltage.

Table 26 – AC or d.c. test voltage for circuits connected directly to *mains supply*

Column 1 *System voltage* (see 4.4.7.1.6)	2 Voltage for *type testing* circuits with *simple separation*, and for all *routine testing*		3 [b] Voltage for *type testing* circuits with *protective separation*, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3)	
	a.c. r.m.s. [a]	d.c.	a.c. r.m.s.	d.c.
V	V	V	V	V
≤ 50	1 250	1 770	2 500	3 540
100	1 300	1 840	2 600	3 680
150	1 350	1 910	2 700	3 820
300	1 500	2 120	3 000	4 240
600	1 800	2 550	3 600	5 090
1 000	2 200	3 110	4 400	6 220

Interpolation is permitted.

[a] Corresponding to 1 200 V + *system voltage*.

[b] A voltage source with a short circuit current of at least 0,1 A according to 5.2.2.2 of IEC 61180-1:1992 is used for this test.

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Table 27 – A.c. or d.c. test voltage for circuits connected to *non-mains supply* without *temporary overvoltages*

Column 1 *Working voltage* (recurring peak) (see 4.4.7.1.6.2)	2 [a] Voltage for *type testing* circuits with *simple separation*, and for all *routine testing*		3 [a] Voltage for *type testing* circuits with *protective separation,* and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3)	
V	a.c. r.m.s. V	d.c. V	a.c. r.m.s. V	d.c. V
≤71	80	110	160	220
141	160	225	320	450
212	240	340	480	680
330	380	530	760	1 100
440	500	700	1 000	1 400
600	680	960	1 400	1 900
1 000	1 100	1 600	2 200	3 200
1 600	1 800	2 600	2 900	4 200
2 300	2 600	3 700	4 200	5 900
3 000	3 400	4 800	5 400	7 700
4 600	5 200	7 400	8 300	11 800
7 600	8 500	12 000	14 000	19 000
16 000	18 000	26 000	29 000	42 000
23 000	26 000	37 000	42 000	59 000
30 000	34 000	48 000	54 000	77 000
38 000	43 000	61 000	69 000	98 000
50 000	57 000	80 000	91 000	130 000
60 000	70 000	99 000	109 000	154 000

Interpolation is permitted.

NOTE Test voltages in this table are based upon 80 % of the withstand voltage for the corresponding clearance of Table 10 as provided by Table A.1 of IEC 60664-1:2007.

[a] A voltage source with a short circuit current of at least 0,1 A according to 5.2.2.2 of IEC 61180-1:1992 is used for this test.

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Routine tests are performed to verify that clearances have not been reduced during the manufacturing operations. Protective devices designed to reduce impulse voltages on the circuits under test (see 4.4.7.2.2 and 4.4.7.2.3), and circuits belonging to monitoring or protection circuits, not designed to sustain the test overvoltage for the duration of the test, shall be disconnected in order to avoid damage and to ensure that the test voltage can be applied without a false indication of failure.

5.2.3.4.3 Performing the voltage test

Replacement:

The test shall be applied as follows, according to Figure 10:

a) Test (1) between accessible conductive part (connected to earth) and each circuit sequentially (except ***DVC As*** circuits). Test voltage according to Table 26, or Table 27, column 2, corresponding to voltage of considered circuit under test.

Test (2) between accessible surface (non-conductive or conductive but not connected to earth) and each circuit sequentially (except ***DVC As*** circuits). Test voltage according to

Table 26 or Table 27, column 3 (for type test) or column 2 (for routine test), corresponding to voltage of considered circuit under test.

b) Test between each considered circuit sequentially and the other adjacent circuits connected together. Test voltage according to Table 26 or Table 27, column 2, corresponding to voltage of considered circuit under test.

c) Test between ***DVC As*** circuit and each ***adjacent circuit*** sequentially. Test voltage according to Table 26 or Table 27, column 3 (for ***type test***) or column 2 (for ***routine test***), corresponding to the circuit with the higher voltage. Either the adjacent circuit or the ***DVC As*** circuit may be earthed for this test.

   Because circuits of ***DVC As*** and circuits of ***DVC C*** are typically separated from chassis (earth) by ***basic insulation***, it is typically impossible to test ***double*** or ***reinforced insulation*** separating low-voltage circuits from high-voltage circuits in a fully-assembled ***SMPS*** without overstressing the ***basic insulation***. Because of this, it may be necessary to disassemble the ***SMPS***, or it may not be possible to perform type tests of protective insulation at voltages according to column 3 of Table 26 to Table 27. In these cases the type test of insulation used for protective separation shall be performed at voltages according to column 2 of the appropriate table.

For Figure 10, refer to Figure 10 of IEC 62477-1:2012.

The tests shall be performed with the doors of the enclosure closed.

When the circuit is electrically connected to accessible conductive parts, the voltage test is not relevant, and may be omitted.

To create a continuous circuit for the voltage test on the ***SMPS***, terminals, open contacts on switches and semiconductor devices, etc. shall be bridged where necessary. Before testing, semiconductor devices and other vulnerable components within a circuit may be disconnected and/or their terminals bridged to avoid damage occurring to them during the test.

Wherever practicable, individual components forming part of the ***insulation*** under test, for example interference suppression capacitors, should not be disconnected or bridged before the test. In this case, it is recommended to use the DC test voltage according to 5.2.3.4.2.

Where the ***SMPS*** is covered totally or partly by a non-conductive accessible surface, a conductive foil, to which the test voltage is applied, shall be wrapped around this surface for testing. In this case, the ***insulation*** test between a circuit and non-conductive accessible surface may be performed as a sample test instead of a routine test.

Routine testing of the assembled ***SMPS*** is not required if

– routine testing of all sub-assemblies related to the insulation system of the SMPS is performed, and
– it can be demonstrated that final assembly will not compromise the insulation system, and
– type testing of the fully-assembled ***SMPS*** was performed successfully.

Protective impedances according to 4.4.5.4 shall either be included in the testing or the connection to the protectively separated part of the circuit shall be opened before testing. In the latter case, the connection shall be carefully restored after the voltage test in order to avoid any damage to the ***insulation***. Protective screens according to 4.4.4.7 shall remain connected to accessible conductive parts during the voltage test.

5.2.3.4.4 Duration of the AC or DC voltage test

The duration of the test shall be at least 60 s for the *type test* and 1 s for the *routine test*. The test voltage may be applied with increasing and/or decreasing ramp voltage but the full voltage shall be maintained for 60 s and 1 s respectively for *type* and *routine tests*.

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5.2.3.4.5 Verification of the AC or DC voltage test

The test is successfully passed if no *electrical breakdown* occurs during the test.

5.2.3.5 Partial discharge test (type test, sample test)

The partial discharge test shall confirm that the solid *insulation* (see 4.4.7.8) used in components and sub-assemblies for *protective separation* of electrical circuits remains partial-discharge-free within the specified voltage range (see Table 28).

This test shall be performed as a *type test* and a *sample test*. It may be omitted for insulating materials which are not degraded by partial discharge, for example ceramics.

The partial discharge inception and extinction voltage are influenced by climatic factors (e.g. temperature and moisture), equipment self heating, and manufacturing tolerance. These influencing variables can be significant under certain conditions and shall therefore be taken into account during *type testing*.

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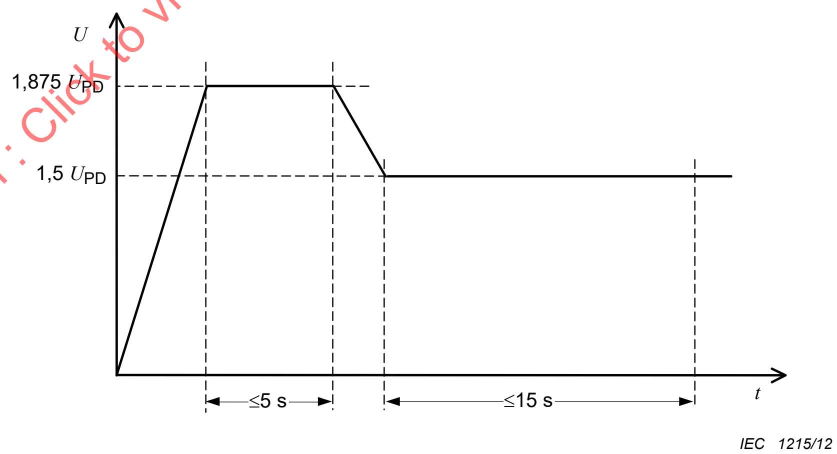
Table 28 – Partial discharge test

Subject	Test conditions
Test reference	6.1.3.5 of IEC 60664-1:2007
Requirement reference	4.4.7.8
Preconditioning	*Precondition according to 5.2.3.1* *Live parts* belonging to the same circuit shall be connected together. It is recommended that the partial discharge test is performed after the impulse voltage test (see 5.2.3.1) in order that any damage caused by the impulse voltage test is apparent. It is advisable that the partial discharge test is performed before inserting the components or devices into the equipment because partial discharge testing is not normally possible when the equipment is assembled.
Initial measurement	According to specification of component or device.
Test equipment Test circuit Test voltage Test method Calibration of test equipment	Calibrated charge measuring device or radio interference meter without weighting filters. C.1 of IEC 60664-1:2007. The peak value of a.c. 50 Hz or 60 Hz. 6.1.3.5 of IEC 60664-1:2007: F_1 = 1,2; F_2, F_3 = 1,25. Test procedure 6.1.3.5.3 of IEC 60664-1:2007. C.4 of IEC 60664-1:2007.
Measurement Verification	Starting from a voltage below the rated partial discharge test voltage U_{PD} [a], the voltage shall be linearly increased to 1,875 times U_{PD} and held for a maximum time of 5 s. The voltage shall then be linearly decreased to 1,5 times U_{PD} (± 5 %) and held for a maximum time of 15 s, during which the partial discharge is measured. The test shall be considered to have been successfully passed if the partial discharge is less than 10 pC during the measurement period 
NOTE Partial discharge testing of *solid insulation* with a d.c. *working voltage* according to A.6.3 can be omitted	
[a] The rated partial discharge test voltage U_{PD} is the recurring peak voltage measured across the *insulation*.	

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5.2.3.6 Protective impedance test (type test and routine test)

A *type test* shall be performed to verify that the current through a *protective impedance* under normal operating or single-fault conditions does not exceed the values given in 4.4.3.4. The test shall be performed using the circuit of IEC 60990:1999, Figure 4.

The test circuit of IEC 60990:1999, Figure 4, is reproduced in Annex L.

NOTE IEC 60990 states that the use of a single network for the measurement of a.c. combined with d.c. has not been investigated, but no suggestion is made for measurement in such cases.

The value of the *protective impedance* shall be verified as a *routine test*.

5.2.3.7 Touch current measurement test (type test)

Replacement:

The ***touch current*** shall be measured to determine if the measures of protection need not be taken (see 4.4.4.3.3). The testing shall be conducted at the most unfavourable supply voltage (refer to 5.1.5.3.101). The ***SMPS*** shall be set up in an insulated state without any connection to the earth. Under these conditions, the ***touch current*** shall be measured between the means of connection for the ***PE conductor*** and the ***PE conductor.***

– For a ***SMPS*** to be connected to an earthed neutral system, the neutral of the mains of the test site shall be directly connected to the ***PE conductor***.
– For a ***SMPS*** to be connected to an isolated system or impedance system, the neutral shall be connected through a resistance of 1 kΩ to the ***PE conductor*** which shall be connected to each input phase in turn. The highest value will be taken as the definitive result.
– For a ***SMPS*** to be connected to a corner earthed system, the ***PE conductor*** shall be connected to each input phase in turn. The highest value will be taken as the definitive result.
– For a ***SMPS*** with a particular system earthing, this system shall operate as intended during the test.
– If a ***SMPS*** is intended to be connected to more than one system network, each of these different system networks (or the worst-case, if that can be determined) shall be used to make the ***touch current*** measurement.

For non-sinusoidal waveforms the peak values apply and the current is measured using the measuring network specified in Figure 4 of IEC 60990:1999, for currents up to 2 mA, or Figure 5, of IEC 60990:1999, for currents above.

For sinusoidal waveforms and DC the RMS values apply, and the current may be measured using a 2 000 Ω ± 10 % resistor.

This is performed as a ***type test***.

Addition:

5.2.3.7.100 Circuits with current limitation

To qualify circuits with current limitation, the following conditions have to be considered and fulfilled:

a) the circuit has to meet the requirements of 4.4.5.101 or 4.4.5.103 in no load or open circuit condition, and
b) the circuit has to meet the requirements of 4.4.5.102 during load condition, when measured with the measuring network;
c) the requirements of a) and b) shall be fulfilled under normal, fault and abnormal operation.

5.2.3.8 Capacitor discharge test (type test)

The capacitor discharge time as required by 4.4.3.4 may be verified by a *type test* and/or by calculation taking into account the relevant tolerances.

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Addition:

5.2.3.8.100 Capacitor discharge test conditions

The discharge test shall be carried out at maximum input voltage including the tolerance and at the most unfavourable loading condition, which is usually no load. If a resistor is provided to comply with the requirements of 4.4.5.103, an overcurrent protective device, if provided, shall not be wired between the capacitor and resistor.

5.2.3.9 Limited power source test (type test)

When required by 4.6.5 a limited power circuit shall be tested as below, with the equipment operating under normal operating conditions.

In case the limited power source requirement depends on overcurrent protective device(s), the device(s) shall be short-circuited.

With the equipment operating under normal operating conditions, a variable resistive load is connected to the parts under consideration and adjusted to obtain a level of required limited VA power. Further adjustment is made, if necessary, to maintain the limited VA power for a period specified by 4.6.5.

A variable resistive load is connected to the circuit under consideration and adjusted to obtain the limit of apparent power as indicated in Table 16 or Table 17, as applicable. Further adjustment is made, if necessary, to maintain the limit of apparent power for the time period indicated in Table 16 or Table 17, as applicable.

The test is passed, if after the test period the available apparent power does not exceed the limits indicated in Table 16 or Table 17, as applicable.

In case the limited power source requirement depends on overcurrent protective device(s), the current rating of at least one of the protective device(s) in the current path shall not exceed the limit in Table 17.

5.2.3.10 Temperature rise test (type test)

The test is intended to ensure that parts and accessible surfaces of the *SMPS* do not exceed the temperature limits specified in 4.6.4 and the manufacturer’s temperature limits of safety-relevant parts.

Where possible, the *SMPS* shall be tested at worst-case conditions of rated power and *SMPS* output current, taking derating and cooling control characteristic into account.

For equipment where the amount of heating or cooling is designed to be dependent on temperature (for example, the equipment contains a fan that has a higher speed at a higher temperature), the temperature measurement shall be performed at the worst case ambient temperature condition within the manufacturer's specified operating range.

If this is not possible, it is permitted to simulate the temperature rise, if the validity of the simulation can be demonstrated by tests at lower power levels.

The *SMPS* shall be tested with at least 1,2 m of wire attached to each *field wiring terminal*. The wire shall be of the smallest size intended to be connected to the *SMPS* as specified by the manufacturer for installation. When there is only provision for the connection of bus-bars to the *SMPS*, they shall be of the minimum size intended to be connected to the *SMPS* as specified by the manufacturer, and they shall be at least 1,2 m in length.

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The test shall be maintained until thermal stabilization has been reached. That is, when three successive readings, taken at intervals of 10 % of the previously elapsed duration of the test and not less than 10 min intervals, indicate no change in temperature, defined as ±1 °C between any of the three successive readings, with respect to the ambient temperature.

The temperature of an electrical *insulation* (other than that of windings) is measured on the surface of the *insulation* at a point close to the heat source, if a failure of this *insulation* could cause a hazard. If temperatures of windings are measured by the thermocouple method, the thermocouple shall be located on the surface of the winding assuming the hottest part due to surrounding heat emitting components. See also notes in Table 14.

The maximum temperature attained shall be corrected to the rated ambient temperature of the *SMPS* by adding the difference between the ambient temperature during the test and the equipment's maximum rated ambient temperature.

No corrected temperature shall exceed the rated temperature of the material or component measured.

During the test, thermal cutout, overload detection functions and devices shall not operate.

5.2.3.11 Protective equipotential bonding tests (type tests and routine test)

5.2.3.11.1 General

Each conductive accessible part under consideration shall be tested separately, to determine if the *protective equipotential bonding* path for that part is adequate to withstand the test current that the bonding path may be subjected to under fault conditions.

The circuit under consideration shall be selected from amongst those circuits adjacent to the accessible part under consideration and separated from it by only *basic* or *functional insulation*.

All of these selected circuits have to be analyzed regarding *prospective short circuit current* and the associated protective element(s):

– If the circuit under consideration exceeds the 5 s disconnection time requirement of IEC 60364-4-41, the *protective equipotential bonding* impedance test of 5.2.3.11.2 and the *protective equipotential bonding* short circuit test of 5.2.3.11.3 have to be performed.

  NOTE 1 Examples for circuits with disconnection times of more than 5 s: non mains circuits where the short circuit current is limited by internal impedances or current limiters or by the load characteristics like solar panels.

– If the circuit under consideration meets the 5 s disconnection time requirement of IEC 60364-4-41, the *protective equipotential bonding* short circuit test of 5.2.3.11.3 has to be performed.

  NOTE 2 Examples for circuits with disconnection times of not exceeding 5 s: mains circuits where the *prospective short circuit current* is limited by the impedance of the main.

– If the circuit under consideration meets the disconnection time requirement of IEC 60364-4-41:2005, Table 41.1, as applicable, depending on the earthing system of the *installation*, no *type test* is required.

For *pluggable equipment type A only the* the *protective equipotential bonding* impedance test of 5.2.3.11.2 have to be performed.

The testing shall include an individual test of the *protective equipotential bonding* path for each conductive accessible part unless analysis shows that the short circuit withstand capability of the path is adequate, or that the results of one combination are representative of the anticipated results of another combination.

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5.2.3.11.2 Protective equipotential bonding impedance test

5.2.3.11.2.1 Test conditions

Where required by 4.4.4.2.2 and 5.2.3.11.2.1, the impedance of *protective equipotential bonding* means shall be checked by passing a test current through the bond for a period of time. The test current is based on the rating of the overcurrent protection for the equipment or part of the equipment under consideration, as follows:

- for *pluggable equipment type A*, the overcurrent protective device is that provided external to the equipment (for example, in the building wiring, in the mains plug or in an equipment rack);
- for *pluggable equipment type B* and *permanently connected* equipment, the maximum rating of the overcurrent protective device specified in the equipment installation instructions to be provided external to the equipment;
- the rating of the provided overcurrent device for a circuit or part of the equipment for which an overcurrent protective device is provided as part of the equipment.

Voltages are measured from the *protective earthing* terminal to all the parts whose *protective equipotential bonding* means are being considered. The impedance of the *PE conductor* is not included in the measurement. However, if the *PE conductor* is supplied with the equipment, it is permitted to include the conductor in the test circuit, but the measurement of the voltage drop is made only from the main *protective earthing* terminal to the accessible part required to be earthed.

On equipment where the protective earth connection to a sub-assembly or to a separate unit is part of a cable that also supplies power to that sub-assembly or unit, the resistance of the *protective equipotential bonding* conductor in that cable is not included in the *protective equipotential bonding* impedance measurements for the sub-assembly or separate unit as in Figure 11. However, this option is only permitted if the cable is protected by a suitably rated protective device that takes into account the size of the conductor. Otherwise the impedance of the *protective equipotential bonding* conductor between the separate units is to be included, by measuring to the *protective earthing* terminal where the power source enters the first unit in the *system*, as in Figure 12.

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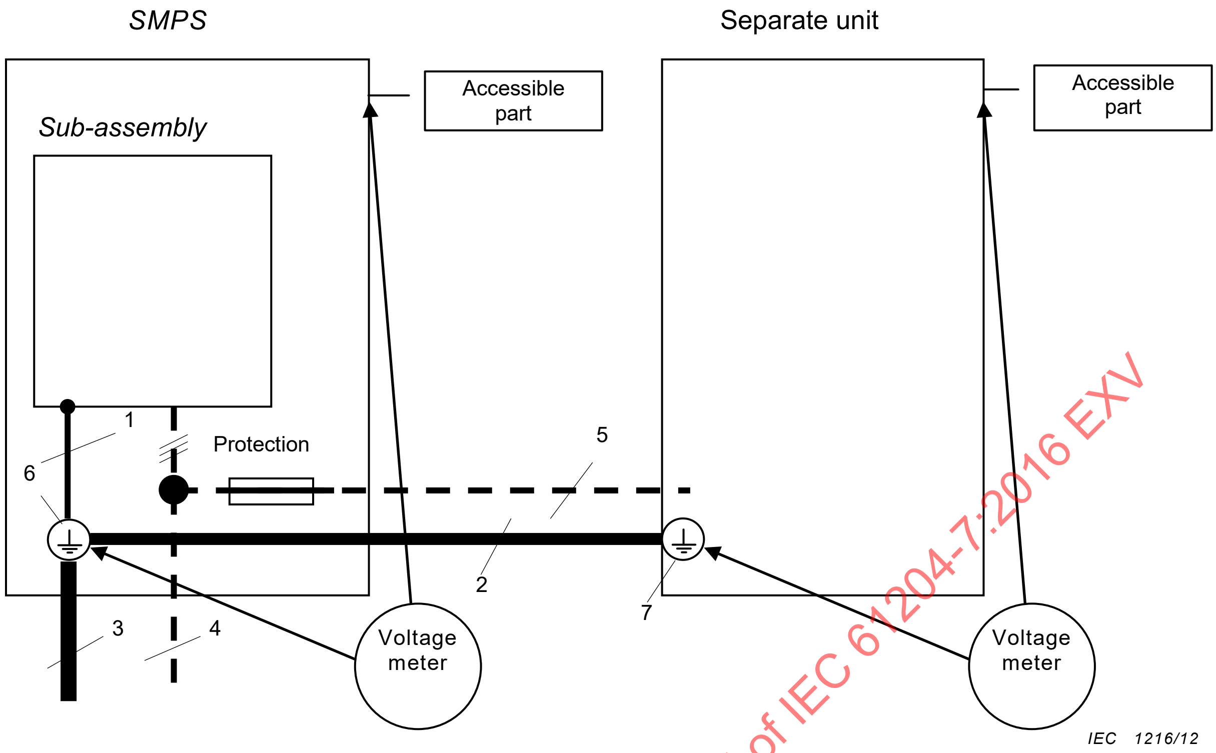

Key

1 = *protective equipotential bonding*

2 = *PE conductor* for the separate unit

3 = *PE conductor* for the *SMPS*

4 = energy supply from the mains

5 = energy supply from the *SMPS* to the separate unit

6 = terminal point of the external *PE conductor*

7 = terminal point of the *PE conductor* for the separate unit

Figure 11 – Protective equipotential bonding impedance test for separate unit with power fed from the *SMPS* with protection for the power cable

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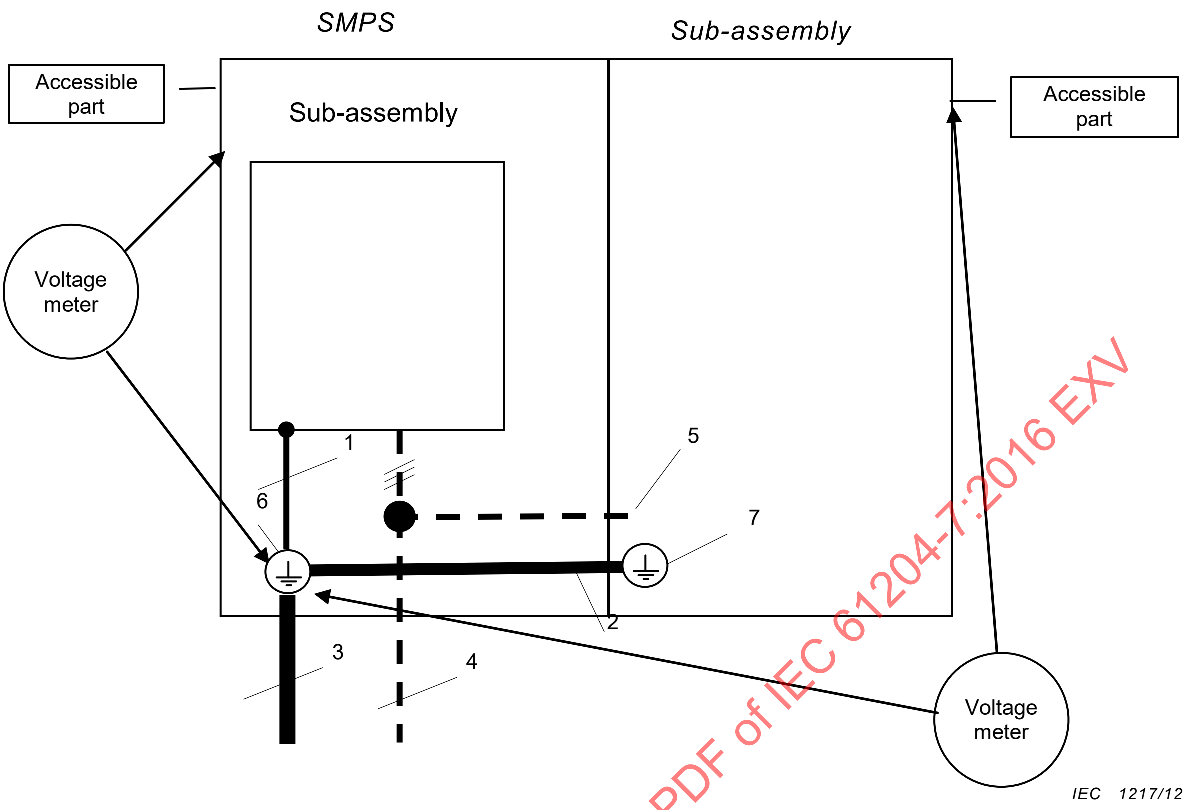

Key

1 = protective *equipotential* bonding

2 = protective *equipotential* bonding for the sub-assembly

3 = *PE conductor* for the *SMPS*

4 = energy supply from the mains

5 = energy supply from the *SMPS* to the sub-assembly

6 = terminal point of the external *PE conductor*

7 = connection point of the bonding to the sub-assembly (may be more than1)

Figure 12 – Protective equipotential bonding impedance test for sub-assembly with accessible parts and with power fed from the *SMPS*

The test current is derived from an a.c or d.c supply source, the output of which is not earthed.

NOTE For protection of the person performing the test, the source should have a maximum no-load voltage below the limits for *DVC A*.

5.2.3.11.2.2 Test current, duration and acceptance criteria

The test current, duration of the test and acceptance criteria are as follows.

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Table 29 – Test duration for *protective equipotential bonding* test

Overcurrent protective device rating A	Duration of the test min
up to 32	2
33 to 63	4
64 to 100	6
101 to 200	8
201 to 460	10

a) For *SMPS* with an overcurrent protective device rating of 16 A or less, this test may be omitted, if an impedance not exceeding 0,1 Ω can be demonstrated.

b) As an alternative to Table 29, where the time-current characteristic of the overcurrent protective device that limits the fault current in the *protective equipotential bonding* means is known because the device is either provided in the equipment or fully specified in the installation instructions, the test duration may be based on that specific device's time-current characteristic. The tests are conducted for a duration corresponding to the 200 % current value on the time-current characteristic.

c) For *SMPS* with an overcurrent protective device rating of more than 460 A, calculations or simulations according to IEC 60949 shall be used to show the ability of the prospective short circuit current to fulfill the requirements. The *protective equipotential bonding* continuity *routine test* of 5.2.3.11.4 shall be performed to show that the impedance of the *protective equipotential bonding* means during and at the end of the test shall not exceed the expected value.

Acceptance criteria:

The test current is 200 % of the overcurrent protective device rating and the duration of the test is as shown in Table 29. The voltage drop in the *protective equipotential bonding* means, during and at the end of the test, shall not exceed *DVC As*, as determined from Table 2 and Table 5 with respect to the accessible surface of the *enclosure*.

After the tests, visual inspection shall show no damage to the *protective equipotential bonding* means.

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5.2.3.11.3 Protective equipotential bonding short circuit withstand test (type test)

As required by 5.2.3.11.2.1 the short circuit test in 5.2.4.3 shall be performed to ensure that *protective equipotential bonding* has the ability to withstand the *prospective short circuit current* that it may be subjected to under fault conditions.

The testing shall include an individual test of the *protective equipotential bonding* path for each conductive accessible part unless analysis shows that the short circuit withstand capability of the path is adequate, or that the results of one combination are representative of the anticipated results of another combination.

5.2.3.11.4 Protective equipotential bonding continuity test (routine test)

The *protective equipotential bonding* continuity *routine test* shall be conducted when:

- the continuity of the *protective equipotential bonding* is achieved by a single means only (for example a single conductor or a single fastener); or
- the *SMPS* is assembled at the *installation* location; or
- if required by 5.2.3.11.2.2 c).

The test current may be any convenient value sufficient to allow measurement or calculation of the resistance of the *protective equipotential bonding* means.

NOTE Larger currents used for the continuity test increases the accuracy of the test result, especially with low impedance values, i.e. larger cross sectional areas and/or lower conductor length. In general 25 A is considered sufficient for most products.

The expected value of the resistance is the result of calculation or simulation according to 5.2.3.11.2.2 considering the length, the cross sectional area and the material of the related protective bonding conductor(s).

Acceptance criteria: the resistance measured shall be within 90 % upto 110 % of the expected value.

Addition:

5.2.3.100 Input test (type test)

In determination of the input current or input power, the following variables shall be considered:

– loads due to optional features, offered or provided for by the manufacturer for inclusion in or with the EUT;

– loads due to other units of equipment intended by the manufacturer to draw power from the EUT;

– loads that could be connected to any standard supply outlet on the equipment that is ***accessible*** to an ***operator,*** up to the value specified by the manufacturer.

Artificial loads may be used to simulate such loads during testing.

In each case, the readings are taken when the input current or input power has stabilized. If the current or power varies during the normal operating cycle, the steady-state current or power is taken as the mean indication of the value, measured on a recording RMS ammeter or power meter, during a representative period.

The measured input current or input power under ***normal operating conditions***, but at the ***rated voltage*** or at each end of each ***rated voltage range***, shall not exceed the ***rated current*** or ***rated power*** by more than 10 %.

Compliance is checked by measuring the input current or input power of the equipment under the following conditions:

– where equipment has more than one ***rated voltage***, the input current or input power is measured at each ***rated voltage***;

– where equipment has one or more ***rated voltage ranges***, the input current or input power is measured at each end of each ***rated voltage range***

  • where a single value of ***rated current*** or ***rated power*** is marked, it is compared with the higher value of input current or input power measured in the associated ***rated voltage range***,

  • where two values of ***rated current*** or ***rated power*** are marked, separated by a hyphen, they are compared with the two values measured in the associated ***rated voltage range***.

5.2.3.101 Determination of working voltage (type test)

5.2.3.101.1 General

In determining ***working voltages***, all of the following requirements apply:

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a) unearthed accessible conductive parts are assumed to be earthed;

b) if a transformer winding or other part is not connected to a circuit that establishes its potential relative to earth, the winding or other part are assumed to be earthed at a point by which the highest ***working voltage*** is obtained;

c) for insulation between two transformer windings, the highest voltage between any two points in the two windings is the ***working voltage***, taking into account the voltages to which the input windings will be connected;

d) for insulation between a transformer winding and another part, the highest voltage between any point on the winding and the other part is the ***working voltage***;

e) where ***double insulation*** is used, the ***working voltage*** across the ***basic insulation*** is determined by imagining a short-circuit across the ***supplementary insulation***, and vice versa. For ***double insulation*** between transformer windings, the short-circuit is assumed to take place at the point by which the highest ***working voltage*** is produced accross the other insulation;

f) when the ***working voltage*** is determined by measurement, the input power supplied to the equipment shall be the rated voltage or the voltage within the rated voltage range that results in the highest measured value;

g) the ***working voltage*** between
   - any point in the circuit supplied by the mains and any part connected to earth; and
   - any point in the circuit supplied by the mains and any point in a circuit isolated from the mains,

   shall be assumed to be the greater of the following:
   - the rated voltage or the upper voltage of the rated voltage range; and
   - the measured ***working voltage.***

5.2.3.101.2 RMS working voltage

In determining the RMS ***working voltage***, short-term conditions and non-repetitive transients (for example, due to atmospheric disturbances) are not taken into account.

NOTE The creepage distances are determined from the RMS working voltages.

5.2.3.101.3 Peak working voltage

For the peak ***working voltage*** used to determine the required impulse withstand voltage for minimum clearances and test voltages for electric strength:

- when determining the peak ***working voltage*** between circuits connected to the mains and circuits isolated from the mains, the voltage of any ***DVC As*** or ***DVC B*** circuit or external circuits shall be regarded as 0;
- when determining the peak ***working voltage*** for an external circuit that does not have transients, the peak ***working voltage*** of repetitive signals shall be taken into account;
- non-repetitive transients (for example, due to atmospheric disturbances) shall not be taken into account.

5.2.3.102 Standard test procedure for separable thin sheet material (type test)

One layer of the material is placed in the electric strength test instrument, as shown in Figure 100, and the test voltage is applied. It has to be made sure, that the foil does sufficiently extend the borders of the vertical test rods in order to avoid an electric breakdown around the foil.

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Dimensions in millimetres

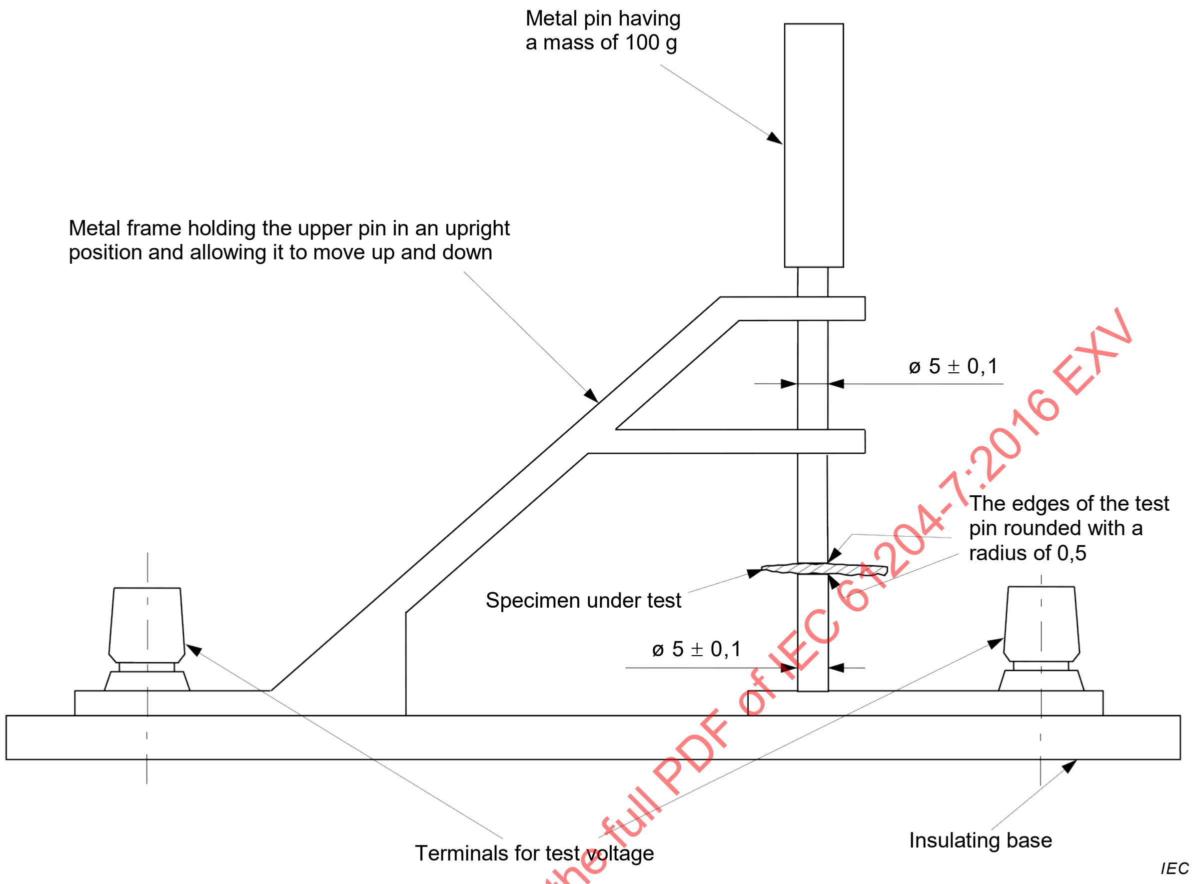

Figure 100 – Electric strength test instrument

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5.2.3.103 Standard test procedure for non-separable thin sheet material (type test, sample test)

For non-separable layers, electric strength tests are applied in accordance with 4.4.7.10 to all layers together. The test voltage is:

– 200 % of U_{test} if two layers are used; or

– 150 % of U_{test} if three or more layers are used,

where U_{test} is the test voltage specified in 4.4.7.10 for supplementary insulation or ***reinforced insulation*** as appropriate.

NOTE Unless all the layers are of the same material and have the same thickness, there is a possibility that the test voltage will be divided unequally between layers, causing breakdown of a layer that would have passed if tested separately.

5.2.3.104 Mandrel test (type test, sample test)

The test requirements for ***reinforced insulation*** made of three or more thin insulating sheets of material that are inseparable are specified below.

NOTE This test is based on IEC 61558-1 and will give the same results.

Three test samples, each individual sample consisting of three or more layers of non-separable thin sheet material forming ***reinforced insulation***, are used. One sample is fixed to the mandrel of the test fixture given in Figure 101. The fixing shall be performed as shown in Figure 102.

Dimensions in millimetres

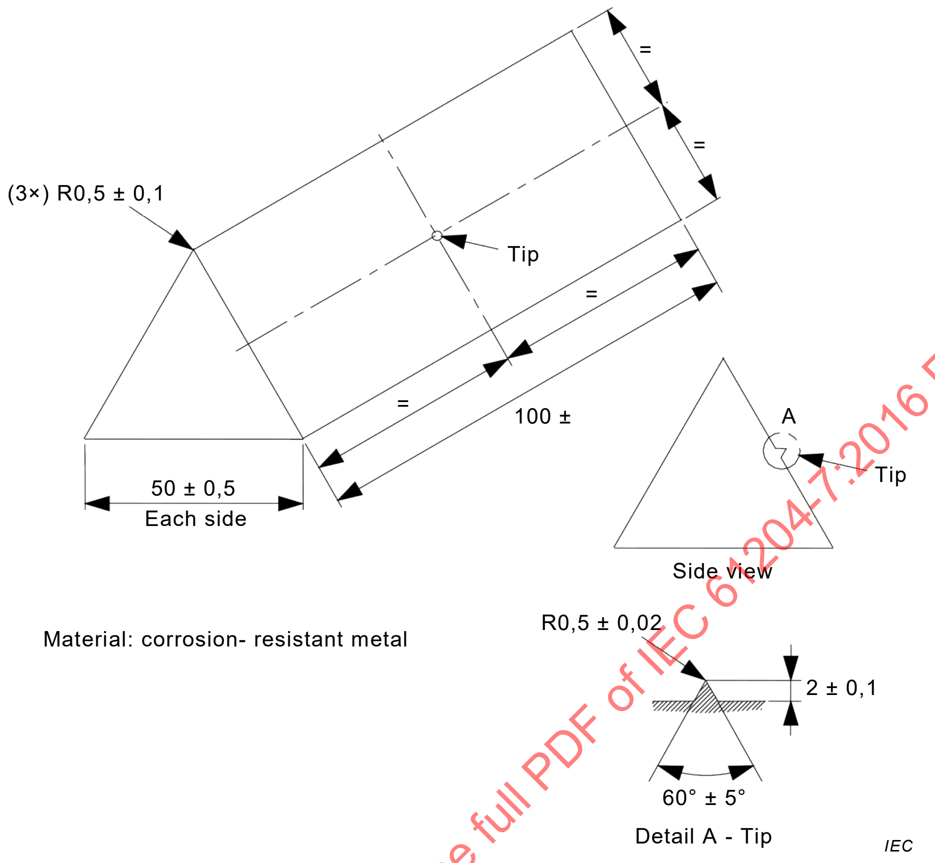
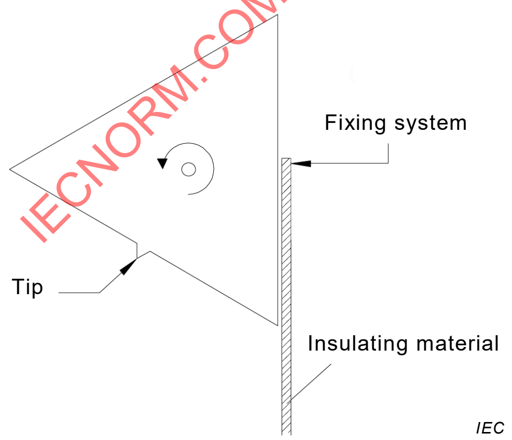
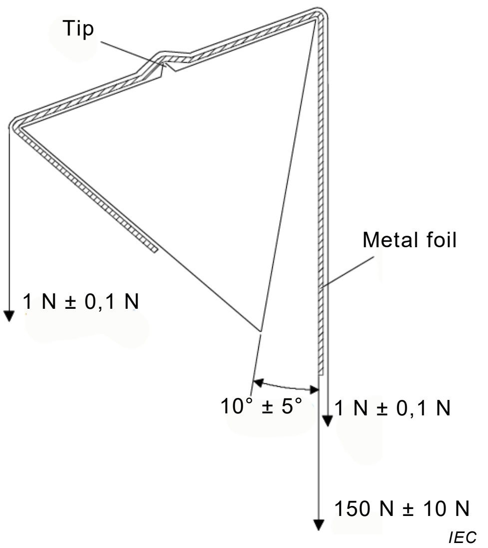


Figure 101 – Mandrel

Dimensions in millimetres





The final position of the mandrel is rotated 230° ± 5° from the initial position.

Figure 102 – Initial position of mandrel

Figure 103 – Final position of mandrel

A pull is applied to the free end of the sample, using an appropriate clamping device. The mandrel is rotated:

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– from the initial position (Figure 102) to the final position (Figure 103) and back;
– a second time from the initial position to the final position.

If a sample breaks during rotation where it is fixed to the mandrel or to the clamping device, this does not constitute a failure. If a sample breaks at any other place, the test has failed.

After the above test, a sheet of metal foil, 0,035 mm ± 0,005 mm thick, at least 200 mm long, is placed along the surface of the sample, hanging down on each side of the mandrel (see Figure 103). The surface of the foil in contact with the sample shall be conductive, not oxidized or otherwise insulated. The foil is positioned so that its edges are not less than 20 mm from the edges of the sample (see Figure 104). The foil is then tightened by two equal weights, one at each end, using appropriate clamping devices.

Dimensions in millimetres

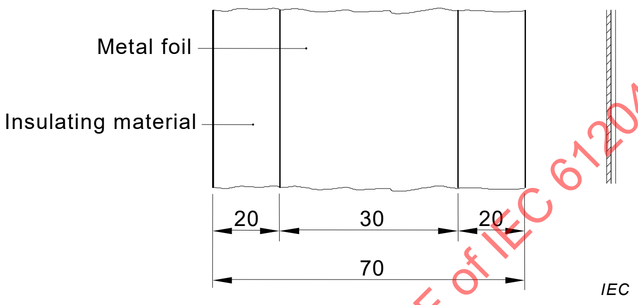

Figure 104 – Position of metal foil on insulating material

While the mandrel is in its final position, and within the 60 s following the final positioning, electric strength tests are applied between the mandrel and the metal foil in accordance with 4.4.7.10. The test voltage is 150 % of U_{test}.

U_{test} is the test voltage specified in 4.4.7.10 for ***reinforced insulation***.

Where the peak voltage of 150 % of U_{test} is less than 7,1 kV, the impulse and AC or DC voltage test shall be replaced by an AC voltage test of 5 kV RMS.

The test is repeated on the other two samples.

5.2.3.105 Insulated winding wires for use without interleaved insulation (type test, sample test)

Refer to Annex AA for further information on the test procedure.

5.2.4 Abnormal operation and simulated faults tests

5.2.4.1 General

Protection against risk of thermal, electric shock and energy hazards in case of abnormal operating condition of a *SMPS* in combination with its *installation* shall be evaluated by:

a) tests defined in this section; or
b) calculation or simulation based on tests as defined in 5.2.4.4 and 5.2.4.6 on a representative model of *SMPS*, where no damage other than opening of overcurrent protective devices has occurred to the test sample.

NOTE A representative model means a *SMPS* with similar power elements (for example, *power semiconductor devices*, fuses, circuit breakers, capacitors, overcurrent detection and output inductances) and circuit topologies as the *SMPS* under consideration.

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Before all abnormal tests, the test sample shall be mounted, connected, and operated as described in the temperature rise test.

Simulated faults or abnormal operating conditions shall be applied one at a time. Faults that are the direct consequence of a simulated fault or abnormal operating conditions are considered to be part of that simulated fault or abnormal operating condition.

In the case of a *SMPS* supplied without an *enclosure*, a wire mesh cage which is 1,5 times the individual linear dimensions of the *SMPS* part under study shall be used to simulate the intended *enclosure*.

The *SMPS*, and the wire mesh cage (if used), shall be earthed according to the requirements of 4.4.4.2.2.

Cheese cloth or surgical cotton shall be placed at all openings, handles, flanges, joints and similar locations on the outside of the *enclosure* and the wire mesh cage (if used), in a manner which will not significantly affect the cooling.

Where the *SMPS* under test is specified in its installation manual to require external means of protection against faults, these specific means shall be provided for the test.

The voltages of accessible *SELV*, *PELV* and *DVC As* circuits as well as accessible earthed and unearthed conductive parts shall be monitored.

The supply shall be capable of delivering the specified *prospective short circuit current* (see 4.3.1) at the connection to the *SMPS*, unless the circuit analysis of 4.2 demonstrates that a lesser value may be used.

The individual tests shall be performed until terminated by activation of a protective device or mechanism (internal or external), a component failure occurs that interrupts the fault condition, or the temperatures stabilize.

Addition:

5.2.4.1.100 Additional considerations

5.2.4.1.100.1 Power source used for testing

Individual tests within this document define a specific power source.

In case there is no definition for a specific power source, the sample is to be tested at a source representative for the available power in the final application.

NOTE A limited voltage drop of 10 % and an available current of min. 10 times the rating of the overcurrent protection during load can constitute a suitable power source, if no further information of the final application is available.

5.2.4.1.100.2 Setting of voltage selector (type test)

Equipment to be supplied from the ***mains*** and provided with a voltage setting device to be set by the ***operator***, is tested with the ***mains*** voltage setting device at the most unfavourable position.

5.2.4.1.100.3 Polarity test (type test)

If a connection is not polarized and the connection is accessible to an ***operator***, then the possible influence of polarity shall be taken into account for testing.

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5.2.4.2 Pass criteria

Replacement:

As a result of the abnormal operation tests, the ***SMPS*** shall comply with the following:

a) there shall be no emission of flame, burning particles or molten metal;
b) the cheese cloth or surgical cotton indicator shall not have ignited;
c) the earth connection and ***protective equipotential bonding*** of the ***SMPS*** shall not have opened;
d) doors and covers shall remain in place;
e) during and after the test ***DVC As*** circuits and accessible conductive parts shall not exhibit voltages greater than the time dependent voltages of Table 5, as appropriate and shall be separated from ***live parts*** at voltages greater than ***DVC As*** with at least ***basic insulation***. Compliance shall be checked by the AC or DC voltage test of 5.2.3.4 for ***basic insulation***;
f) during and after the test, ***live parts*** at voltages greater than ***DVC As*** shall not become accessible;
g) overcurrent protective device currents are measured, if there is certain doubt that such a component is operated outside its maximum current interrupt capability;
h) if a fault is terminated by the opening of a fuse and if the fuse does not operate within approximately 1 s, the current through the fuse under the relevant fault condition shall be measured. Evaluation with the pre-arcing time/current characteristics shall be made to find out whether the minimum operating current of the fuse is reached or exceeded and what the maximum time before the fuse operates is. The current through the fuse may vary as a function of time;
i) fuses are not permitted to shatter or rupture their casing. Small holes in fuse end caps are acceptable, but end caps shall not become loose during the abnormal tests. Where fuses rated for AC are used in DC circuits, then the test shall be repeated 10 times using the DC supply, and shall pass the AC or DC voltage test of 5.2.3.4 for ***basic insulation***;
j) an electrolytic capacitor is permitted to vent if venting does not cause a safety hazard within the meaning of this document;
k) wire conductors and traces of printed circuit boards are not permitted to act as fuses. If a wire or trace opens, then it is to be linked out across the break and the test repeated. This process shall be repeated until the test reaches an ultimate conclusion.

The ***SMPS*** is not required to be operational after testing and it is possible that the ***enclosure*** can become deformed. Overcurrent protection integral to the ***SMPS***, or required to be used with the ***SMPS***, is allowed to open.

5.2.4.3 Protective equipotential bonding short circuit withstand test (type test)

5.2.4.3.1 General

When required by 5.2.3.11.2.1, a *protective equipotential bonding* path shall be subjected to the following short circuit withstand test.

5.2.4.3.2 Test conditions

The equipment under test shall be supplied with power and the output *port* shall be operating as intended in 5.2.4.1 prior to closing the switching means that applies the short circuit, unless energizing the equipment with the short circuit already applied will be more severe.

The *protective equipotential bonding* short circuit test shall be performed with the *SMPS* working with light load, unless analysis shows that higher short circuit currents are available under higher loading conditions.

A new sample may be used for each short circuit test.

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5.2.4.3.3 Protective equipotential bonding short circuit test method

The test current is applied by connecting the accessible part under consideration to one of the conductors of the the test source circuit through a switching means that will not limit the short circuit current. The switch shall be located such that the source is short circuited through the accessible part and its *protective equipotential bonding* path back to the *protective earthing* terminal for the source circuit under consideration. The connections to the shorting switch shall be through cables having the same cross-section as specified for the *PE conductor* in the *installation* and the length of the cables shall be limited to 2 m. If the size of the *SMPS* requires a greater length, the length shall be as short as practical to perform the test and the short circuit current shall be calibrated at the entrance of the product.

5.2.4.3.4 Pass criteria

Replacement:

The pass criteria of 5.2.4.2 e) apply, and at the conclusion of the test, there shall be no damage to the ***protective equipotential bonding*** means under test. Compliance shall be checked by inspection, and if necessary, by the ***protective equipotential bonding*** continuity test (***routine test***) of 5.2.3.11.4.

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5.2.4.4 Output short-circuit test (type test)

5.2.4.4.1 Load conditions

The short-circuit test shall be performed with the *SMPS* at full load or light load whichever creates the more severe condition.

5.2.4.4.2 Short-circuit test method

Power output *port* terminals shall be provided with cable of a cross-section as specified for the *installation* connected to an appropriate switching means that will not limit the short circuit current. The complete length of the cable (forth and back) shall be approximately 2 m, unless the size of the *SMPS* requires a greater length, in which case the length shall be as short as practical to perform the test.

The equipment under test shall be supplied with power and the output *port* shall be operating as intended prior to closing the switching means that applies to the short circuit, unless energizing the equipment with the short circuit already applied will be more severe.

The testing shall include individual tests of each output *port* where combinations of two or more terminals, including earth, on each individual *port* are subjected to short circuit tests on those terminals. Analysis may be used to reduce the number of tests if it is shown that the results of one combination are representative of the anticipated results of another combination.

A new sample may be used for each short circuit test.

In addition to determining compliance with the criteria of 5.2.4.2, this test is used to determine the *output short circuit current* rating of the *port* under consideration, in accordance with 4.3.2.3. An oscilloscope or other suitable instrument shall be used to measure the peak current during the test, and to measure or calculate the r.m.s. value of the current.

The value(s) to be recorded and to be provided with the *SMPS* instructions, in accordance with 6.2, are the peak current, and the highest of the r.m.s. current values measured or calculated over a time period as follows:

a) for a.c. signals, three cycles of the nominal a.c. frequency for the *port* under consideration, in which case the value is to be stated as the 3-cycle r.m.s. value;

b) for all signals, the duration of the short circuit from the time the short circuit is applied, until the time the short circuit current is interrupted by a protective device or other mechanism, in which case the value stated is to include the r.m.s. value and the time period in seconds;
c) for short circuit tests that result in a continuous non-zero value, the steady-state r.m.s. value, in which case the value is to be stated as a continuous r.m.s value.

For *SMPS* with internal short circuit protection according to 4.3.2.3, which protects the output *port* within some few µs, the requirements in a), b) and c) are not applicable.

5.2.4.5 Output overload test (type test)

The overload test shall be performed after operating the *SMPS* at full load until normal operating temperatures are attained. Each output of the *SMPS*, and each section of a tapped output, shall be overloaded in turn, one at a time. The other outputs and windings are loaded or not loaded whichever load condition of normal use is less favorable.

Overloading is carried out by connecting a variable load across the output or winding. The load is adjusted as quickly as possible and readjusted, if necessary, after 1 min to maintain the applicable overload. No further readjustments are then permitted.

If overcurrent protection is provided by a current-sensitive device or circuit, the overload test current is the maximum current which the overcurrent protection device is just capable of passing for 1 h. Before the test, the overcurrent protection device is made inoperative or replaced by a link with negligible impedance.

For equipment in which the output voltage is designed to collapse when a specified overload current is reached, the overload is slowly increased to the point of maximum output power before the point which causes the output voltage to collapse.

In all other cases, the loading is the maximum power output obtainable from the output.

5.2.4.6 Breakdown of components test (type test)

5.2.4.6.1 Load conditions

The breakdown of a component, identified as a result of the circuit analysis of 4.2, shall be tested with the *SMPS* at full load or light load whichever creates the more severe condition.

5.2.4.6.2 Application of short circuit or open-circuit

The short circuit shall be applied with cable of a cross-section appropriate for the current that normally flows through the component, but not less than 2,5 mm^2. The length of the loop shall be as short as practical to perform the test. Short circuits and open circuits are applied using an appropriate switching device.

Each identified component shall be subjected to only one breakdown of components test unless both open- and short circuit failure modes are likely in that component.

5.2.4.6.3 Test sequence

For the breakdown of components test, identified components shall be short circuited or open-circuited, whichever creates the worst hazard, one at a time.

5.2.4.7 PWB short circuit test (type test)

On PWBs, *functional insulation* provided by spacings which are less than those specified in Table 10 and Table 11 (see 4.4.7.7) shall be *type tested* as described below.

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The decreased spacings shall be short circuited one at a time, on representative samples, and the short circuit shall be maintained until no further damage occurs.

5.2.4.8 Loss of phase test (type test)

A multi-phase *SMPS* shall be operated with each line (including neutral, if used) disconnected in turn at the input. The test shall be performed by disconnecting one line with the *power conversion* equipment operating at its maximum normal load and shall be repeated by initially energizing the *SMPS* with one lead disconnected.

The test shall continue until terminated by a protective mechanism, a component failure occurs, or the temperature stabilizes.

For *SMPS* with rated input current greater than 500 A, compliance can be shown through simulation.

5.2.4.9 Cooling failure tests (type tests)

5.2.4.9.1 General and pass criteria

For *SMPS* having a combination of cooling mechanisms, all relevant tests shall be performed. It is not necessary to perform the tests simultaneously.

The test shall continue:

– until the temperature stabilizes, in which case the temperature limits of 4.4.6.4.2 apply; or

– until terminated by a protective mechanism or a component failure occurs, in which case the temperature limits of accessible parts in 4.4.6.4.2 may be exceeded by not more than 5 °C. If this is not possible a warning statement shall be provided in the user documentation.

NOTE The temperature increase of 5 °C with regard to the steady state limits reflect the spread of the burn threshold given in IEC Guide 117.

5.2.4.9.2 Inoperative blower motor test

A *SMPS* having forced ventilation shall be operated at rated load with fan or blower motor or motors made inoperative, single or in combination from a single fault, by physically preventing their rotation.

5.2.4.9.3 Clogged filter test

Enclosed *SMPS* having filtered ventilation openings shall be operated at rated load with the openings blocked to represent clogged filters. The test shall be performed initially with 50 % of the ventilation openings surface blocked. The test shall be repeated under a full blocked condition.

5.2.4.9.4 Loss of coolant test

A liquid cooled *SMPS* shall be operated at rated load. Loss of coolant shall be simulated by draining the coolant, blocking the flow or disabling the *system* coolant pump.

If the *SMPS* is shut down due to the operation of a thermal device located inside the coolant, then the test shall be repeated with the coolant drained out of the *system*.

NOTE It is presumed that the thermal device will be inoperative if not surrounded by coolant liquid.

Addition:

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5.2.4.100 Transformer overload tests (type tests)

NOTE Requirements have been taken from IEC 62368-1.

5.2.4.100.1 Test conditions

If the tests are carried out under simulated conditions on the bench, these conditions shall include any protection device that would protect the transformer in the complete equipment.

Transformers for ***SMPS*** are tested in the complete unit. Test loads are applied to the output of the ***SMPS***.

A linear transformer or a ferro-resonant transformer has each winding isolated from the mains loaded in turn, with any other winding isolated from the mains loaded between zero and its specified maximum load to result in the maximum heating effect.

The transformer output (after the first rectification component) is loaded to result in the maximum heating effect in the transformer.

Where an overload condition cannot occur or is unlikely to cause an insulation relied on for safety to fail, the tests are not made.

5.2.4.100.2 Compliance criteria

Maximum temperatures of windings shall not exceed the values in Table 102 when measured as specified in 5.2.3.10, and determined as specified below:

– with external overcurrent protection: at the moment of operation, for determination of the time until the overcurrent protection operates, reference may be made to a data sheet of the overcurrent protective device showing the trip time versus the current characteristics;
– with an automatic reset overtemperature protection device: as shown in Table 102 and after 400 h;
– with a manual reset overtemperature protection device: at the moment of operation;
– for current limiting transformers: after the temperature has stabilized.

Windings isolated from the mains, that exceed the temperature limits but that become open circuit or otherwise require replacement of the transformer, do not constitute a failure of this test provided that the transformer continues to comply with 5.2.4.2.

During the test the transformer shall not emit flames or molten-metal.

Table 102 – Temperature limits for transformer windings

Method of protection	Maximum temperature °C							
	Class 105 (A)	Class 120 (E)	Class 130 (B)	Class 155 (F)	Class 180 (H)	Class 200 (N)	Class 220 (R)	Class 250 -
Protection by inherent or external impedance	150	165	175	200	225	245	265	295
Protection by protective device that operates during the first hour	200	215	225	250	275	295	315	345
Protection by any protective device:								
– maximum after first hour	175	190	200	225	250	270	290	320

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– arithmetic average during the 2nd hour and during the 72th hour [a]	150	165	175	200	225	245	265	295
The classes are related to the classification of electrical insulating materials and EIS in accordance with IEC 60085. The assigned letter designations are given in parentheses.								

[a] The arithmetic average temperature is determined as follows:

The graph of temperature against time (see Figure 105), while the power to the transformer is cycling on and off, is plotted for the period of test under consideration. The arithmetic average temperature (t_A) is determined by the formula:

$$t_A = \frac{t_{max} + t_{min}}{2}$$

where

t_{max} is the average of the maxima;

t_{min} is the average of the minima.

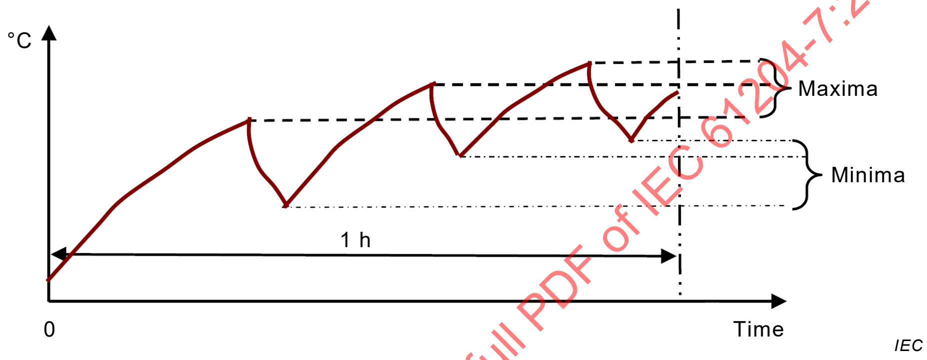

Figure 105 – Determination of arithmetic average temperature

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5.2.4.100.3 Alternative test method

The transformer is covered with a single layer of cheesecloth and is placed on a wooden board that is covered with a single layer of wrapping tissue. The transformer is then gradually loaded until one of the following situations occurs:

- the overload protective device operates;
- the winding becomes an open circuit;
- the load cannot be increased any further without reaching a short-circuit or foldback condition.

The transformer is then loaded to a point just before the above applicable situation occurs and is operated for 7 h.

During the test, the transformer shall not emit flames or molten metal. The cheesecloth shall not char or catch fire.

If the transformer voltage exceeds ***DVC As***, the ***basic insulation*** or ***reinforced insulation*** provided in the transformer shall withstand the AC or DC voltage test to clause 5.2.3.4 as applicable after it has cooled to room temperature.

5.2.4.101 Covering of ventilation openings (type tests)

The top, sides and the back of stationary and moveable equipment, if such surfaces have ventilation openings, shall be covered one at a time.

All openings of transportable equipment are covered simultaneously.

5.2.5 Material tests

5.2.5.1 General

When requested by 4.4.7.8.2, the manufacturer shall test the flammability properties of the materials used for insulating purposes, as defined in 5.2.5.2, 5.2.5.3 and 5.2.5.4.

When requested by 4.6.3.2 the manufacturer shall test the flammability properties of the materials used for *fire enclosure*, as defined in 5.2.5.5.

5.2.5.2 High current arcing ignition test (type test)

Five samples of each insulating material (Figure 13) to be tested are used. The samples shall have minimum 130 mm length and 13 mm width and of uniform thickness representing the thinnest section of the part. Edges shall be free from burrs, fins, etc.

Each test is made with a pair of test electrodes and a variable inductive impedance load connected in series to a source of 220 V to 240 V a.c, 50 Hz or 60 Hz (see Figure 13).

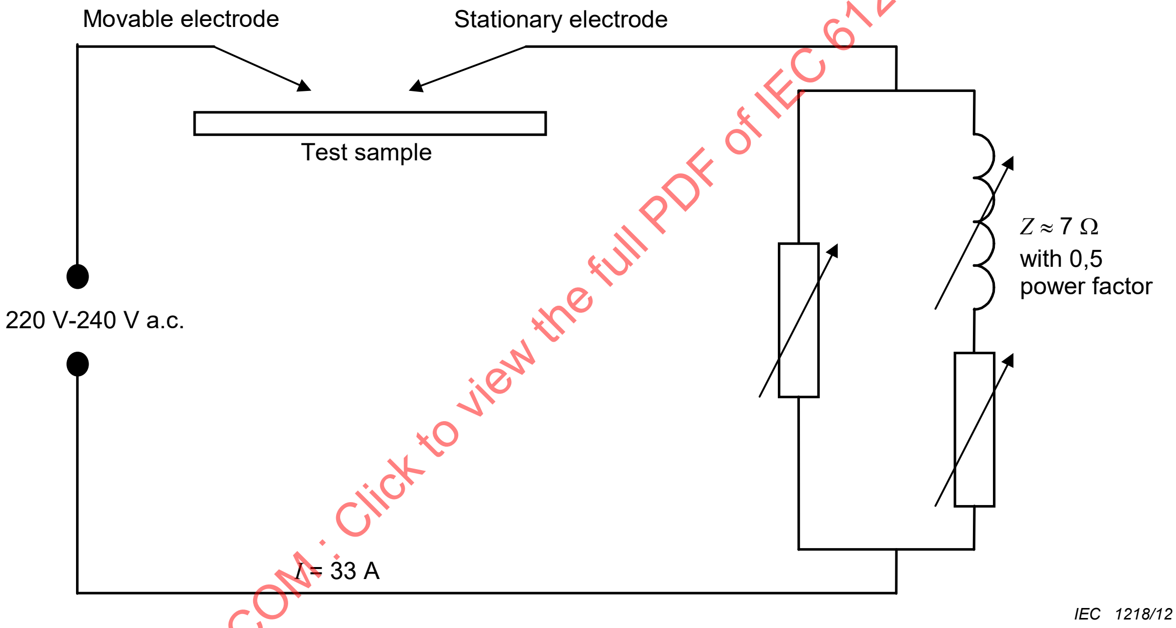

Figure 13 – Circuit for high-current arcing test

It is permitted to use an equivalent circuit.

One electrode is stationary and the second movable. The stationary electrode consists of a 3,5 mm diameter solid copper conductor having a 30° chisel point. The movable electrode is a 3 mm diameter stainless steel rod with a symmetrical conical point having a total angle of 60° and is capable of being moved along its own axis. The radius of curvature for the electrode tips does not exceed 0,1 mm at the start of a given test. The electrodes are located opposing each other, in the same plane, at an angle of 45° to the horizontal. With the electrodes short circuited, the variable inductive impedance load is adjusted until the current is 33 A at a power factor of 0,5.

The sample under test is supported horizontally in air or on a non-conductive surface so that the electrodes, when touching each other, are in contact with the surface of the sample. The movable electrode is manually or otherwise controlled so that it can be withdrawn from contact with the stationary electrode to break the circuit and lowered to remake the circuit, so as to produce a series of arcs at a rate of approximately 40 arcs/min, with a separation speed of 250 mm/s ± 25 mm/s.

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The test is continued until ignition of the sample occurs, a hole is burned through the sample or a total of 200 arcs have elapsed.

The average number of arcs to ignition of the specimens tested shall be not less than 15 for V-0 class materials and not less than 30 for other materials.

5.2.5.3 Glow-wire test (type test)

The glow-wire test shall be made under the conditions specified in 4.4.7.8.2 according to IEC 60695-2-10 and IEC 60695-2-13.

5.2.5.4 Hot wire ignition test (type test – alternative to glow-wire test)

Five samples of each insulating material (see Figure 14) are tested. The samples shall have minimum 130 mm length and 13 mm width and of a uniform thickness representing the thinnest section of the part. Edges shall be free from burrs, fins, etc.

A 250 mm ± 5 mm length of nichrome wire (nominal composition 80 % nickel, 20 % chromium, iron-free) approximately 0,5 mm diameter and having a cold resistance of approximately 5 Ω/m is used. The wire is connected in a straight length to a variable source of power which is adjusted to generate 0,25 W/mm ± 0,01 W/mm in the wire for a period of 8 s to 12 s. After cooling, the wire is wrapped around a sample to form five complete turns spaced 6 mm apart.

The wrapped sample is supported in a horizontal position (see Figure 14) and the ends of the wire connected to the variable power source, which is again adjusted to generate 0,25 W/mm ± 0,01 W/mm in the wire.

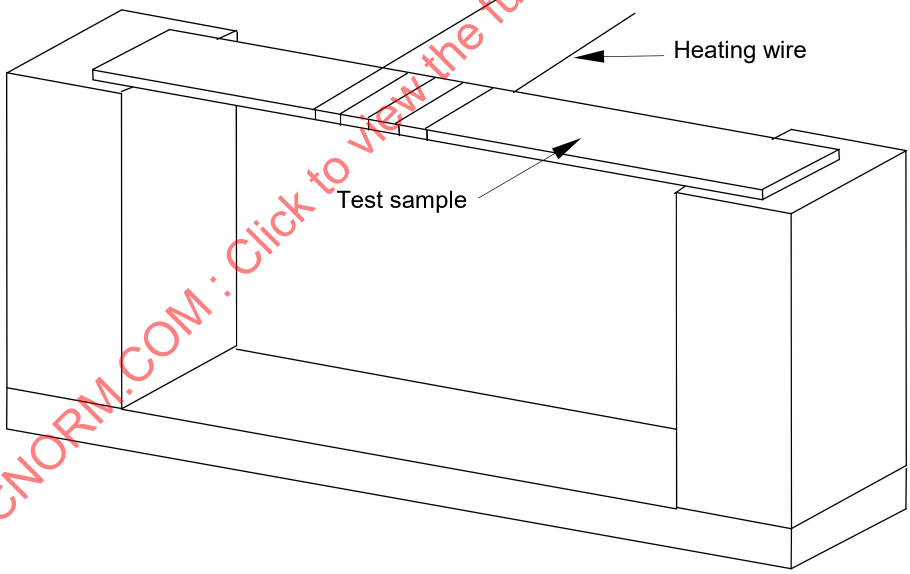

Figure 14 – Test fixture for hot-wire ignition test

The test is continued until the test specimen ignites or until 120 s have passed. When ignition occurs or 120 s have passed, the test is discontinued and the test time recorded. For specimens which melt through the wire without ignition, the test is discontinued when the specimen is no longer in intimate contact with all five turns of the heater wire.

The test is repeated on the remaining samples.

The average ignition time of the specimens tested shall not be less than 15 s.

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5.2.5.5 Flammability test (type test)

Three samples of the complete equipment or three test specimens of the *enclosure* thereof (see 4.6.3) shall be subjected to this test. Consideration shall be given to leaving in place components and other parts that might influence the performance. The test samples shall be conditioned in a full draft circulating air oven for seven days at 10 °C greater than the maximum use temperature, as determined by the temperature rise test 5.2.3.10, but not less than 70 °C in any case. Prior to testing, the samples shall be conditioned for a minimum of 4 h at 23 °C ± 2 °C and 50 % ± 5 % relative humidity. The flame shall be applied to an inside surface of the sample at a location judged to be likely to become ignited because of its proximity to a source of ignition including surfaces provided with ventilation holes. If more than one part is near a source of ignition, each sample shall be tested with the flame applied to a different location.

The three test samples shall result in the acceptable performance described below. If one sample does not comply, the test shall be repeated on a set of three new samples with the flame applied under the same conditions as for the unsuccessful sample. If all the new specimens comply with the requirements described below the material is acceptable.

The laboratory burner, adjustment and calibration shall be identical to that described in IEC 60695-11-20.

When a complete *enclosure* is used to conduct the flame test, the sample shall be mounted as intended in service, if it does not impair the flame testing, in a draft-free test chamber, *enclosure*, or laboratory hood. A layer of absorbent 100 % cotton shall be located 305 mm below the point of application of the test flame. The 127 mm flame shall be applied to any portion of the interior of the part judged as likely to be ignited (by its proximity to live or arcing parts, coils, wiring, and the like) at an angle of approximately 20 ° insofar as possible from the vertical so that the tip of the blue cone touches the specimen. The test flame shall be applied to three different locations on each of the three samples tested. A supply of technical-grade methane gas shall be used with a regulator and meter for uniform gas flow. Natural gas having a heat content of approximately 37 MJ/m^3 at 23 °C has been found to provide similar results and may be used.

The flame shall be applied for 5 s and removed for 5 s. The operation shall be repeated until the specimen has been subjected to five applications of the test flame.

The following conditions shall be met as a result of this test:

– the material shall not continue to burn for more than 1 min after the fifth 5 s application of the test flame, with an interval of 5 s between applications of the flame;

  and

– flaming drops or flaming or glowing particles that ignite surgical cotton 305 mm below the test specimen shall not be emitted by the test sample at any time during the test.

After the test, equipment shall meet the requirements for *basic protection* by means of *enclosures* or barriers in 4.4.3.3.

5.2.5.6 Flaming oil test (type test)

When required by 4.6.3.3.3 compliance is shown by the flame oil test as follows.

A sample of the complete finished bottom of the *fire enclosure* is securely supported in a horizontal position. Bleached cheesecloth of approximately 40 g/m2 is placed in one layer over a shallow, flat-bottomed pan approximately 50 mm below the sample, and is of sufficient size to cover completely the pattern of openings in the sample, but not large enough to catch any of the oil that runs over the edge of the sample or otherwise does not pass through the openings.

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NOTE Use of a metal screen or a wired-glass partition surrounding the test area is recommended.

A small metal ladle (preferably no more than 65 mm in diameter), with a pouring lip and a long handle whose longitudinal axis remains horizontal during pouring, is partially filled with 10 ml of a distillate fuel oil that is a medium volatile distillate having a mass per unit volume between 0,845 g/ml and 0,865 g/ml, a flash point between 43,5 °C and 93,5 °C and an average calorific value of 38 MJ/l. The ladle containing the oil is heated and the oil ignited and permitted to burn for 1 min, at which time all of the hot flaming oil is poured at the rate of approximately 1 ml/s in a steady stream onto the centre of the pattern of openings, from a position approximately 100 mm above the openings.

The test is repeated twice at 5 min intervals, using clean cheesecloth.

During the test the cheesecloth shall not ignite.

5.2.5.7 Cemented joints test (type test)

When required by 4.4.7.9 representative samples of cemented joints providing protection of type 1 or type 2 as defined in IEC 60664-3:2003 shall be tested as a *type test* as follows.

The samples shall be subjected to the conditioning procedure specified in 5.7 of IEC 60664-3:2003, using the following parameters: for the cold test (5.7.1), a temperature of -25 °C shall be used, and for the rapid change of temperature test (5.7.3): –25 °C to +125 °C.

After the conditioning the samples shall pass the following tests in the prescribed order:

a) The mechanical strength of the joint shall be evaluated by loading the joint using the forces anticipated to be present under normal conditions. There shall be no separation of the parts.
b) The *insulation* resistance between the conductive parts separated by the joint shall be measured according to 5.8.3 of IEC 60664-3:2003.
c) Cemented joints shall be treated as to be thin sheet material and shall be tested according 4.4.7.8.3.
d) The sectioning of the joint shall not show any cracks, voids or separation.

5.2.6 Environmental tests (type tests)

5.2.6.1 General

Environmental testing is required to establish the safety of the *SMPS* at the extremes of the environmental classification to which it will be subjected.

If size or power considerations prevent the performance of these tests on the complete *SMPS*, it is permitted to test individual parts that are considered to be relevant to the safety of the *SMPS*.

When testing components or sub-assemblies separately, the temperature during the dry-heat test shall be chosen as to simulate actual use in the end-product. The component or sub-assembly shall be energized simulating the same conditions as in the end-product.

Table 30 shows the standard tests to be performed for the different environmental conditions.

Compliance is shown by conducting test of 5.2.3.6, 5.2.6.4, 5.2.6.5 and 5.2.6.6 according to Table 30 as applicable for the environmental conditions specified by the manufacture.

Where the *SMPS* is required to operate in conditions outside the range of values given in this standard, then the test conditions shall be agreed on between the supplier and the customer,

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as defined in the particular individual enquiry or purchasing specification. In any case the test requirements shall not be less demanding than the operating conditions specified.

Table 1 – Environmental tests

Test condition	Indoor conditioned IEC 60721-3-3	Indoor unconditioned IEC 60721-3-3	Outdoor unconditioned IEC 60721-3-4
Climatic	Dry heat (see 5.2.6.3.1) Damp heat (see 5.2.6.3.2)	Dry heat (see 5.2.6.3.1) Damp heat (see 5.2.6.3.2)	Dry heat (see 5.2.6.3.1) Damp heat (see 5.2.6.3.2)
Chemically active substances	**No test requirement**	**No test requirement**	**Test Kb of IEC 60068-2-52** Salt mist [a] (see 5.2.6.5)
Mechanically active substances	**No test requirement**	**No test requirement**	**Test Lc of IEC 60068-2-68** Dust and sand (see 5.2.6.6)
Mechanical	**Test Fc of IEC 60068-2-6** Vibration (see 5.2.6.4)	**Test Fc of IEC 60068-2-6** Vibration (see 5.2.6.4)	**Test Fc of IEC 60068-2-6** Vibration (see 5.2.6.4)
Biological	**No test requirement**	**No test requirement**	**No test requirement**

[a] Refer to Footnote a in Table 18.

When special environmental conditions are specified, additional tests (e.g. for chemically active substances) shall be considered.

5.2.6.2 Acceptance criteria

The following acceptance criteria shall be satisfied:

– no degradation of any safety-relevant component of the *SMPS;*
– no potentially hazardous behaviour of the *SMPS* during the test;
– no sign of component overheating;
– no *hazardous live part* greater than *As* shall become accessible;
– no cracks in the *enclosure* and no damaged or loose insulators;
– pass routine a.c. or d.c. voltage test 5.2.3.4;
– pass *protective equipotential bonding* impedance test 5.2.3.11.2;
– no potentially hazardous behaviour when the *SMPS* is operated following the test.

5.2.6.3 Climatic tests

5.2.6.3.1 Dry heat test (steady state)

To prove the ability of components and equipment to be operated, transported or stored at high temperatures the dry heat (steady state) test shall be performed according to the conditions specified in Table 31.

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Table 31 – Dry heat test (steady state)

Subject	Test conditions
Test reference	Test Bd of IEC 60068-2-2
Requirement reference	4.9
Preconditioning	According to 5.1.2 and 5.2.1
Operating conditions Temperature Accuracy Humidity Duration of exposure	Operating at rated conditions Temperature classification according to Table 18 or, for separate testing of components and sub-assemblies, according to 5.2.3.1 or manufacturer's specified maximum temperature, whichever is higher ± 2 °C (see IEC 60068-2-2) According to IEC 60068-2-2, Test Bd (16 ± 1) h
Recovery procedure – Time – Climatic conditions – Temperature – Relative humidity – Barometric pressure – Power supply	 1 h minimum 15 °C to 35 °C 25 % to 75 % 86 kPa to 106 kPa Power supply unconnected

5.2.6.3.2 Damp heat test (steady state)

To prove the resistance to humidity, the *SMPS* shall be subjected to a damp heat test (steady state) according to the conditions specified in Table 32.

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Table 32 – Damp heat test (steady state)

Subject	Test conditions
Test reference	Test Cab of IEC 60068-2-78:2001
Requirement reference	4.9
Preconditioning	According to 5.1.2 and 5.2.1
Operating conditions	Power supply disconnected
Special precautions	Internal voltage sources may remain connected if the heat produced by them in the specimen is negligible
Temperature	Manufacturer's specified maximum temperature or, for separate testing of components and sub-assemblies, according to 5.2.3.1 , whichever is higher
Accuracy	± 2 °C (see Clause 5 of IEC 60068-2-78:2001)
Humidity	Manufacturer's specified maximum humidity
Accuracy	± 3 % (see Clause 5 of IEC 60068-2-78:2001)
Duration of exposure	4 days
Recovery procedure	
– Time	1 h minimum
– Climatic conditions	
– Temperature	15 °C to 35 °C
– Relative humidity	25 % to 75 %
– Barometric pressure	86 kPa to 106 kPa
– Power supply	Power supply disconnected
– Condensation	All external and internal condensation shall be removed by air flow prior to performing the a.c. or d.c. voltage test or re-connecting the *PEC* to a power supply

5.2.6.4 Vibration test (type test)

NOTE No special considerations made by the product committee, beyond the conditions outlined in 5.1.5.3.100.

To verify the mechanical vibration strength the *SMPS* in combination with its *installation* shall be evaluated by:

a) tests defined in this section according to the conditions specified in Table 33; or

b) calculation or simulation based on tests, as defined in this section, on a representative model of *SMPS*.

For *SMPS* with a mass more than 100 kg, this test may be performed on sub-assemblies.

NOTE For large equipment, the possibility of using a shock test as an alternative to a vibration test is under consideration.

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Table 33 – Vibration test

Subject	Test conditions
Test reference	Test Fc of IEC 60068-2-6
Requirement reference	4.9
Preconditioning	According to 5.1.2 and 5.2.1
Conditions	Power supply unconnected
Motion	Sinusoidal
Vibration amplitude/acceleration	
10 Hz ≤ f ≤ 57 Hz	0,075 mm amplitude
57 Hz < f ≤ 150 Hz	10 m/s^2 (1 g)
Vibration duration	10 sweep cycles per axis on each of three mutually perpendicular axes
Detail of mounting	According to manufacturer's specification
Where the manufacturer specifies vibration levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed. Where the environmental conditions are known to be lower product committees using this standard as a reference document might specify lower level or no vibration test according to this table. The acceptance criteria shall not be changed. NOTE Ths test is an accelerated test which means that the level is higher than indicated in Table 18.	

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5.2.6.5 Salt mist test (type test)

NOTE No special considerations made by the product committee, beyond the conditions outlined in 5.1.5.3.100.

To verify the resistance against salt mist, the *SMPS* in combination with its *installation* shall be evaluated by tests defined in this section according to the conditions specified in Table 34.

For *SMPS* with a mass more than 100 kg, this test may be performed on sub-assemblies.

Table 34 – Salt mist test

Subject	Test conditions
Test reference	Test Kb of IEC 60068-2-52
Requirement reference	Table 18
Preconditioning	According to 5.1.2 and 5.2.1
Conditions	Power supply unconnected
Severity level	Severity level 2
Where the manufacturer specifies salt mist levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed. Where the environmental conditions are known to be lower product committees using this standard as a reference document might specify lower level or no salt mist test according to this table. The acceptance criteria shall not be changed.	

5.2.6.6 Dust and sand test (type test)

NOTE No special considerations made by the product committee, beyond the conditions outlined in 5.1.5.3.100.

To verify the mechanical strength against dust and sand the *SMPS* in combination with its *installation* shall be evaluated by tests defined in this section under the conditions specified in Table 35.

For *SMPS* with a mass more than 100 kg, this test may be performed on sub-assemblies.

Table 35 – Dust and sand test

Subject	Test conditions
Test reference	Test Lc1 of IEC 60068-2-68
Requirement reference	Table 18
Preconditioning	According to 5.1.2 and 5.2.1
Conditions Particle size Dust concentration Air velocity Air pressure in the specimen Test duration	Power supply unconnected Fine dust 2 g/m^3 5 m/s Air pressure in the specimen is that of the ambient air pressure 24 h
Where the manufacturer specifies dust and sand levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed. Where the environmental conditions are known to be lower product committees using this standard as a reference document might specify lower level or no dust and sand test according to this table. The acceptance criteria shall not be changed.	

5.2.7 Hydrostatic pressure test (type test and routine test)

For *type tests*, the pressure inside the cooling *system* of a liquid cooled *SMPS* (see 4.7.2.3.3) shall be increased at a gradual rate until a pressure relief mechanism (if provided) operates, or until a pressure of twice the operating value or 1,5 times the maximum pressure rating of the *system* is achieved, whichever is the greater.

NOTE For the purpose of this test the coolant pump may be disabled.

For *routine tests*, the pressure shall be increased to the maximum pressure rating of the *system*.

The pressure shall be maintained for at least one minute.

There shall be no thermal, shock, or other hazard resulting from the test. There shall be no leakage of coolant or loss of pressure during the test, other than from a pressure relief mechanism during a *type test*.

After the hydrostatic pressure *type test* the *SMPS* shall pass the a.c. or d.c. voltage test in 5.2.3.4.

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6 Information and marking requirements

The provisions of Clause 6 of IEC 62477-1:2012 apply, except as follows.

6.1 General

Replacement

The provisions of clause 6.1 of IEC 62477-1:2012 apply, except the Table 36 is replaced by:

Table 36 – Information requirements

Information	Subclause reference	Location [a, b]					Technical subclause reference
		1	2	3	4	5	
For selection	**6.2**						
Manufacturer's name or trademark	6.2	X	X	X	X	X	
Catalogue number	6.2	X	X	X	X	X	
Voltage rating	6.2	X		X	X	X	
Current / power rating	6.2	X		X		X	
Power rating	6.2	X		X		X	
Frequency and numbers of phases	6.2	X		X		X	
Protective class	6.2, 6.3.7.3	X		X		X	4.4.6, 4.4.4.3.2, 4.4.6.3
Type of electrical supply system	6.2; 6.3.7.2			X			6.3.7.2
Short circuit ratings	6.2			X			4.3
IP rating of enclosure	6.2	X		X		X	4.4.3.3, 4.12.1
Reference to standards	6.2			X			
Supply requirements for the load	6.2			X			
Coolant type and design pressure	6.2			X		X	4.7.2
Reference to instructions	6.2			X	X	X	
Additional marking requirements for SMPS	6.2.100	X		X	X	X	
Additional information for component SMPS	6.2.101			X		X	
For installation and commissioning	**6.3**						
Dimensions (SI units)	6.3.2			X		X	
Mass (SI units)	6.3.2		X	X		X	
Mounting details (SI units)	6.3.2			X		X	
Operating and storage environments	6.3.3			X		X	4.9
Handling requirements	6.3.4		X	X		X	
Enclosures temperature	6.3.5			X		X	4.6.4.2, 4.6.3.1
Interconnection and wiring diagrams	6.3.6.2			X		X	
Cable requirements	6.3.6.3			X		X	4.11
Terminal details	6.3.6.4			X		X	4.11.8
Polarity identification	6.3.6.4.100	X		X		X	
Mains socket-outlets	6.3.6.4.101	X		X	X	X	
Field wiring terminal temperature marking	6.3.6.4.102	X		X		X	
Protection requirements	6.3.7			X		X	4.3
Accessible parts and circuits	6.3.7.1			X		X	4.4.3.3; 4.4.6.4.2
Touch current	6.3.7.4	X		X		X	4.4.4.3.3
Manual reference for high touch current	6.3.7.4.100	X		X		X	.4.4.3.3
Compatibility with RCD	6.3.7.5	X		X		X	4.4.8
Special requirements	6.3.7.6			X		X	
External protective devices	6.3.7.7			X		X	4.3.2, 4.3.3, 5.2.4
Replacement fuse identification and rating markings	6.3.7.7.100	X		X		X	
Commissioning information	6.3.8			X			
For use	**6.4**						

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Information	Subclause reference	Location [a, b] 1	2	3	4	5	Technical subclause reference
General	6.4.1				X		
Adjustment	6.4.2	X		X	X	X	
Labels, signs and signals	6.4.3	X		X	X	X	
For maintenance	**6.5**						
Date code or serial number	6.5.1	X					
Maintenance procedures	6.5.1					X	4.4.3.3
Maintenance schedules	6.5.1				X	X	
Sub-assembly and component locations	6.5.1					X	
Repair and replacement procedures	6.5.1					X	
Adjustment procedures	6.5.1			X	X	X	
Special tools list	6.5.1			X		X	
Capacitor discharge	6.5.2	X		X		X	4.4.3.4
Auto restart/bypass	6.5.3			X	X	X	
Other hazards	6.5.4	X		X		X	
Multiple power sources	6.5.5			X	X	X	
Electrical ratings (for multiple power sources)	6.5.5.100			X		X	
External disconnect device	6.5.100			X	X	X	
Power cord as disconnecting device	6.5.101			X	X	X	

[a] Location: 1. On product (see 6.4.3); 2. On packaging; 3. In installation manual; 4. In user's manual; 5. In maintenance manual.

[b] The installation, user's and maintenance manuals may be combined as appropriate and, if acceptable to the customer, may be supplied in electronic format. When more than one of any product is supplied to a single customer, it is not necessary to supply a manual with each unit, if acceptable to the customer.

6.2 Information for selection

Each part of a *SMPS* that is supplied as a separate product shall be provided with information relating to its function, electrical characteristics, and intended environment, so that its fitness for purpose and compatibility with other parts of the *SMPS* can be determined. This information includes, but is not limited to:

– the name or trademark of the manufacturer, supplier or importer;

– catalogue number or equivalent;

– electrical ratings for each power *port*:

  - maximum nominal input voltage;
  - maximum nominal output voltage;
  - maximum nominal output current or nominal output power rating;
  - maximum nominal input current rms for dimensioning overload protective elements and wiring;
  - number of phases (e.g. 3 a.c.);
  - nominal frequency range; (e.g. 50-60Hz) protective class (I, II, III);

– the type of electrical supply *system* (e.g. TN, IT, etc.) to which the *SMPS* may be connected;

– *prospective short circuit current* rating(s) in accordance with 4.3.2.2 and 5.2.4.4;

– *output short circuit current* accordance with 4.3.2.3;

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– protective device characteristics, in accordance with 4.3.2 and 5.2.4.4;
– supply requirements of the load (if applicable);
– liquid coolant type and design pressure for liquid cooled *SMPS*;
– IP rating for *enclosure*;
– operating and storage environment;
– reference(s) to relevant standard(s) for manufacture, test, or use;
– reference to instructions for installation, use and maintenance.

The information shall be limited to that which is essential for correct selection to be made, and should relate to specific equipment. If information covers a number of product variants, it shall be readily possible to distinguish between them.

Addition:

6.2.100 Additional marking requirements for SMPS

NOTE Requirements have been taken from IEC 62368-1.

The ***SMPS*** shall be marked with the following information:

a) nature of supply:

The nature of the supply voltage, DC, AC, or three-phase AC, shall be marked on the equipment and shall immediately follow the equipment voltage rating. If a symbol is used to identify AC or DC, the symbol IEC 60417-5032 (2002-10) shall be used for AC and the symbol IEC 60417-5031 (2002-10) shall be used for d.c, as shown in Table C.100.

Three-phase equipment may be identified with “3-phase” or “3Ø” or any other arrangement that clearly indicates the phase of the supply voltage of the equipment.

NOTE 1 Use IEC 61293:1994 as guidance for marking of rated voltages. The rating should help to distinguish between 3-phase supplies with and without neutral.

b) rated voltage:

The rated voltage of the equipment shall be marked on the equipment. The voltage rating marking shall be immediately followed by the nature of the supply marking.

The rated voltage may be

– a single, nominal value, or
– a single nominal value and a tolerance percentage of the nominal value, or
– two or more nominal values separated by a solidus (/), or
– a range indicated by minimum and maximum values separated by a hyphen, or
– any other arrangement that clearly indicates the voltage of the equipment.

If the equipment has more than one nominal voltage, all such voltages may be marked on the equipment. However, the voltage for which the equipment is set shall be clearly indicated.

For transportable ***SMPS*** the indication shall be visible from the exterior. If the ***SMPS*** is so constructed that the supply voltage setting can be altered without the use of a tool, the action of changing the setting shall also change the indication.

Three-phase equipment shall be marked with the phase-to-phase voltage, a symbol indicating power supply system in accordance with IEC 61293:1994, a solidus (/), the phase-to-neutral voltage, the symbol for voltage (V) and the number of phases, in that order. Any other arrangement that clearly indicates the three-phase rated voltage of the equipment is also acceptable.

NOTE 2 The solidus (/) represents the word “or” and the hyphen (-) represents the word “to”.

c) rated frequency:

The rated frequency of the equipment shall be marked on the equipment.

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The rated frequency may be

– a single, nominal value, or
– a single nominal value and a tolerance percentage of the nominal value, or
– two or more nominal values separated by a solidus (/), or
– a range indicated by minimum and maximum values separated by a hyphen, or
– any other arrangement that clearly indicates the rated frequency of the equipment.

d) rated current or rated power:

The rated current or rated power of the equipment shall be marked on the equipment.

For three-phase equipment, the rated current or rated power is the current or power of one phase.

Subclause 5.2.3.100 establishes criteria for the way in which rated current or rated power are measured.

NOTE 3 The rated current or rated power need not be stated to more than one significant digit.

NOTE 4 In some countries, for markings on equipment, a period is required as the decimal designator.

If the equipment has a ***mains socket-outlet*** for providing mains power to other equipment, the rated current or rated power of the equipment shall include the assigned current or power of the ***mains socket-outlet*** (see also clause 6.3.6.4.101).

If the equipment has more than one rated voltage, the rated current or rated power for each rated voltage shall be marked on the equipment. The arrangement of the markings shall clearly indicate the rated current or rated power associated with each rated voltage of the equipment.

e) DC outputs and AC auxiliary outputs of ***stand-alone SMPS*** shall be marked with polarity, voltage and current ratings. In addition AC auxiliary outputs shall be marked with the frequency if different from the input frequency. This information may be provided in the instructions if the output appears on a polarized connector.

f) Ventilation and orientation requirements, if this information is necessary for safe operation.

6.2.101 Additional information for component SMPS

Component SMPS shall be provided additionally with the following information for input and output as applicable, either on the unit or in the ***installation*** instructions or data sheets or specifications

– output ***DVC*** classification;
– output ratings (voltage, current and/or power);
– specification of limits for intermittent operation;
– output limited power source (LPS) classification;
– ventilation and orientation requirements.

6.3 Information for installation and commissioning

6.3.1 General

Safe and reliable installation is the responsibility of the installer, machine builder, and/or user. The manufacturer of any part of the *SMPS* shall provide information to support this task. This information shall be unambiguous, and may be in diagrammatic form.

6.3.2 Mechanical considerations

The following drawings shall be prepared by the manufacturer:

– dimensional drawing, including mass information;
– mounting drawing.

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Dimensions, mass, etc., shall be in SI units.

6.3.3 Environment

In accordance with 4.9 the following environmental conditions shall be specified, for operation, transportation and storage:

– climatic (temperature, humidity, altitude, pollution, ultra-violet light, etc.);
– mechanical (vibration, shock, drop, topple, etc.);
– electrical (overvoltage category).

NOTE Environmental categories as specified in IEC 60721 may be used where appropriate.

6.3.4 Handling and mounting

In order to prevent injury or damage, the installation documents shall include warnings of any hazards which can be experienced during installation. Where necessary, instructions shall be provided for:

– packing and unpacking;
– moving;
– lifting;
– strength and rigidity of mounting surface;
– fastening;
– provision of adequate access for operation, adjustment and maintenance.

6.3.5 Enclosure temperature

When surface temperatures of the *SMPS*, close to mounting surfaces, exceed the limit of 4.6.4.2 , the installation manual shall contain a warning to consider the combustibility of the mounting surface.

Where required by 4.6.3.1, the following marking shall appear on the *SMPS* and in the installation instructions: “suitable for mounting on concrete or other non-combustible surfaces only”.

6.3.6 Connections

6.3.6.1 General

Information shall be provided to enable the installer to make safe electrical connection to the *SMPS*. This shall include information for protection against hazards (for example, electric shock or availability of energy) that may be encountered during installation, operation or maintenance.

6.3.6.2 Interconnection and wiring diagrams

The installation and maintenance manuals shall include details of all necessary connections, together with a suggested interconnection diagram.

6.3.6.3 Conductor (cable) selection

The installation manual shall define the voltage and current levels for all connections to the *SMPS*, together with cable *insulation* requirements. These shall be worst-case values, taking into account short circuit and overload conditions and the possible effects of non-sinusoidal currents.

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6.3.6.4 Terminal capacity and identification

The installation and maintenance manuals shall indicate the range of acceptable conductor sizes and types (solid or stranded) for all terminals, and also the maximum number of conductors which can simultaneously be connected.

For *field wiring terminals*, the manuals shall specify the requirements for tightening torque values and also the *insulation* temperature rating requirements for the conductor or cable.

The identification of all *field wiring terminals* shall be marked on the *SMPS*, either directly or by a label attached close to the terminals.

The installation and maintenance manuals shall identify all external terminals relating to circuits protected by one of the methods of 4.4.6.4.

Addition:

6.3.6.4.100 Polarity identification

The polarity of DC ***mains supply*** terminals and DC outputs of ***SMPS*** shall be marked on the product or can be provided in the accompanying documents for component ***SMPS***.

If a single terminal is provided, both as a main ***protective earthing*** terminal in the equipment and for the connection to one pole of the DC ***mains supply***, it shall be marked as specified in the symbol IEC 60417-5019 (2006-08) (see Annex C), in addition to polarity marking.

These indications shall not be located on screws or other parts that might be removed when conductors are being connected.

6.3.6.4.101 Mains socket-outlets

Mains socket-outlet accepting standard mains plugs shall be marked with the voltage if it is different from the ***mains supply*** voltage. If the ***mains socket-outlet*** is for use only with specific equipment, it shall be marked to identify the equipment for which it is intended. If not, the maximum rated current or power shall be marked, or symbol ISO 7010–W001 shown in Table C.1 placed beside the ***mains socket-outlet*** with the full details included in the documentation.

Compliance is checked by inspection and by measurement of power or input current to check the marking of 6.2.100 d). The measurement is made after the current has reached a stationary stage (usually after 1 min) so as to exclude any initial inrush current. The ***SMPS*** shall be in the condition of maximum power consumption. Transients are ignored. The measured value shall not exceed the marked value by more than 10 %.

6.3.6.4.102 Field wiring terminal temperature marking

If the temperature of the terminals or the ***enclosure*** of a field-wiring terminal box or compartment exceeds 60 °C in normal condition at an ambient temperature of 40 °C, or the maximum rated ambient temperature if higher, there shall be a marking of the minimum temperature rating of the cable to be connected to the terminals. The marking shall be visible before and during connection, or be beside the terminals.

Compliance, in case of doubt, is checked by measurement and if applicable, by inspection of markings.

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6.3.7 Protection requirements

6.3.7.1 Accessible parts and circuits

The installation and maintenance manuals shall identify any accessible parts at voltages greater than *DVC As*, and shall describe the *insulation* and separation provisions required for protection.

The manuals shall also indicate the precautions to be taken to ensure that the safety of *DVC As* connections is maintained during installation.

Where a hazard is present after the removal of a cover, a warning label shall be placed on the equipment. The label shall be visible before the cover is removed.

The manual of a *SMPS* shall state the maximum voltage allowed to be connected to each *port*.

The manuals shall provide instructions for the use of *PELV circuits* within a *zone of equipotential bonding*.

6.3.7.2 Type of electrical supply system

The installation manual of the *SMPS* shall specify requirements for safe earthing including the permitted earthing *system* of the *installation* (see 4.4.7.1.4).

The unacceptable earthing *systems* shall be indicated as:

– not permitted; or
– with modification of values and/or safety levels which shall be quantified through *type test*.

6.3.7.3 Protective class

6.3.7.3.1 General

The installation manual of the *SMPS* shall declare the protective class specified for the *SMPS* and the product shall be marked according to the requirement of 6.3.7.3.2, 6.3.7.3.3, and 6.3.7.3.4.

6.3.7.3.2 Protective class I equipment

Terminals for connection of the *PE conductor* shall be clearly and indelibly marked with one or more of the following:

– the symbol IEC 60417-5019 (2011-01) (see Annex C); or
– with the letters PE; or
– the colour coding green or green-yellow.

6.3.7.3.3 Protective class II equipment

Equipment of *protective class II* shall be marked with symbol IEC 60417-5172 (2011-01) (see Annex C). Where such equipment has provision for the connection of an earthing conductor for functional reasons (see 4.4.6.3) it shall be marked with symbol IEC 60417-5018 (2011-01) (see Annex C).

6.3.7.3.4 Protective class III equipment

No marking is required on the product.

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6.3.7.4 Touch current marking

Where the *touch current* in the *PE conductor* exceeds the limits given in 4.4.4.3.3, this shall be stated in the installation and maintenance manuals. In addition, a warning symbol ISO 7010-W001 (2011-06) (see Annex C) shall be placed on the product, and a notice shall be provided in the installation manual to instruct the user that the minimum size of the *PE conductor* shall comply with the local safety regulations for high *PE conductor* current equipment.

Addition

6.3.7.4.100 Manual reference for high touch current

Where the touch current in the PE conductor exceeds the limits given in 4.4.4.3.3., in addition to 6.3.7.4 the markings ISO 7000-0434 and ISO 7000-1641 (see Table C.100) shall be provided.

6.3.7.5 Compatibility with RCD marking

The installation and maintenance manuals shall indicate compatibility with RCDs (see 4.4.8). When 4.4.8 b) applies, a caution notice and the symbol ISO 7010-W001 (2011-06) (see Annex C) shall be provided in the user manual, and the symbol shall be placed on the product. The caution notice shall be the following or equivalent: *“This product can cause a d.c. current in the PE conductor. Where a residual current-operated protective device (RCD) is used for protection against electrical shock, only an RCD of Type B is allowed on the supply side of this product.”* (See 6.4.3 for general requirements for labels, signs and signals.)

6.3.7.6 Cable and connection

Any particular cable and connection requirements shall be identified in the installation and maintenance manuals.

6.3.7.7 External protection devices

Where external protective devices are necessary to protect against hazards, the installation and maintenance manual shall specify the required characteristics (see also 5.2.4 and 4.3.2.1).

Addition:

6.3.7.7.100 Replacement fuse identification and rating markings

NOTE Requirements have been taken from IEC 62368-1.

If a fuse is replaceable by an ***operator,*** identification of a suitable replacement fuse shall be marked adjacent to the fuseholder. Identification shall include the fuse current rating and the following as appropriate:

– if the fuse needs a special breaking capacity to ensure safety, the appropriate symbol that indicates the breaking capacity;
– if the fuse can be replaced with a fuse of a different voltage rating, the fuse voltage rating;
– if the fuse is a time-delay fuse, and the time-delay is safety relevant, the appropriate symbol that indicates the time-delay.

If a fuse is replaceable by an ***operator,*** the codings of the relevant fuses shall be explained in the ***user*** instructions.

If a fuse is only replaceable by a service person:

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– identification of a suitable replacement fuse shall be marked adjacent to the fuse or shall be provided in the service instructions;
– if the fuse is, or could be, in the neutral of the ***mains supply***, the instruction shall state that the fuse is in the neutral, and that the ***mains supply*** shall be disconnected to de-energize the phase conductors.

If a fuse is not intended to be replaceable, fuse ratings need not be marked.

Compliance is checked by inspection.

6.3.8 Commissioning

If *commissioning tests* are necessary to ensure the electrical and thermal safety of a *SMPS*, information to support these tests shall be provided for each part of the *SMPS*. This information can depend on the specific *installation*, and close cooperation between manufacturer, installer, and user can be required.

Commissioning information shall include references to hazards that might be encountered during commissioning, for example those mentioned in 6.4 and 6.5.

6.4 Information for use

6.4.1 General

The user's manual shall include all information regarding the safe operation of the *SMPS*. In particular, it shall identify any hazardous materials and risks of electric shock, overheating, explosion, excessive acoustic noise, etc.

The manual should also indicate any hazards which can result from reasonably foreseeable misuse of the *SMPS*.

6.4.2 Adjustment

The user's manual shall give details of all safety-relevant adjustments intended for the user. The identification or function of each control or indicating device and overcurrent protective devices shall be marked adjacent to the item. Where it is not possible to do this on the product, the information shall be provided pictorially in the manual.

Maintenance adjustments may also be described in this manual, but it shall be made clear that they should only be made by qualified personnel.

Clear warnings shall be provided where excessive adjustment could lead to a hazardous state of the *SMPS*.

Any special equipment necessary for making adjustments shall be specified and described.

6.4.3 Labels, signs and signals

6.4.3.1 General

Labelling shall be in accordance with good ergonomic principles so that notices, controls, indications, test facilities, overcurrent protective devices, etc., are sensibly placed and logically grouped to facilitate correct and unambiguous identification.

All safety related equipment labels shall be located so as to be visible after installation or readily visible by opening a door or removing a cover.

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Where a symbol is used, the information provided with the *SMPS* shall contain an explanation of the symbol and its meaning.

Labels shall:

- wherever possible, use international symbols as given by ISO 3864-1, ISO 7000 or IEC 60417;
- if no international symbol is available, be worded in an appropriate language or in a language associated with a particular technical field;
- be conspicuous, legible and durable;
- be concise and unambiguous;
- state the hazards involved and give ways in which risks can be reduced.

When instructing the person(s) concerned as to

- what to avoid: the wording should include "no", "do not", or "prohibited";
- what to do: the wording should include "shall", or "must";
- the nature of the hazard: the wording should include "caution", "warning", or "danger", as appropriate;
- the nature of safe conditions: the wording should include the noun appropriate to the safety device.

Safety signs shall comply with ISO 3864-1.

The signal words indicated hereinafter shall be used and the following hierarchy respected:

- DANGER to call attention to a high risk, for example: "High voltage".
- WARNING to call attention to a medium risk, for example: "This surface can be hot."
- CAUTION to call attention to a low risk, for example: "Some of the tests specified in this standard involve the use of processes imposing risks on persons concerned."

Danger, warning and caution markings on the *SMPS* shall be prefixed with the word "DANGER", "WARNING", or "CAUTION" as appropriate in letters not less than 3,2 mm high. The remaining letters of such markings shall be not less than 1,6 mm high.´

6.4.3.2 Isolators

Where an isolating device is not intended to interrupt load current, a warning shall state:

DO NOT OPEN UNDER LOAD.

The following requirements apply to any supply isolating device which does not disconnect all sources of power to the *SMPS*.

- If the isolating device is mounted in an equipment *enclosure* with the operating handle externally operable, a warning label shall be provided adjacent to the operating handle stating that it does not disconnect all power to the *SMPS*.
- Where a control circuit disconnector can be confused with power circuit disconnectors due to size or location, a warning label shall be provided adjacent to the operating handle of the control circuit disconnector stating that it does not disconnect all power to the *SMPS*.

6.4.3.3 Visual and audible signals

Visual signals such as flashing lights, and audible signals such as sirens, may be used to warn of an impending hazardous event such as the driven equipment start-up and shall be identified.

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It is essential that these signals:

– are unambiguous;
– can be clearly perceived and differentiated from all other signals used;
– can be clearly recognized by the user;
– are emitted before the occurrence of the hazardous event.

It is recommended that higher frequency flashing lights be used for higher priority information.

NOTE IEC 60073 provides guidance on recommended flashing rates and on/off ratios.

6.4.3.4 Hot surfaces

Where required by 4.6.4.2 the warning symbol ISO 7010-W017 (2011-06) (see Annex C) shall be marked on or adjacent to parts exceeding the touch temperature limits of Table 15.

6.4.3.5 Control and device marking

The identification of each control or indicating device and overcurrent protective devices shall be marked adjacent to the item. Replaceable overcurrent protective devices shall be marked with their rating and time characteristics. Where it is not possible to do this on the product, the information shall be provided pictorially in the manual.

Appropriate identification shall be marked on or adjacent to each movable connector.

Test points shall be individually marked with the circuit diagram reference.

The polarity of any polarized devices shall be marked adjacent to the device.

The diagram reference and if possible the function shall be marked adjacent to each pre-set control in a position where it is clearly visible while the adjustment is being made.

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6.5 Information for maintenance

6.5.1 General

The *SMPS* shall be marked with the date code, or serial number from which the date of manufacture can be determined.

Safety information shall be provided in the installation and maintenance manuals including, as appropriate, the following:

– preventive maintenance procedures and schedules;
– safety precautions during maintenance;
– location of *live parts* that can be accessible during maintenance (for example, when covers are removed);
– adjustment procedures;
– sub-assembly and component repair and replacement procedures;
– any other relevant information.

NOTE 1 These can best be presented as diagrams.

NOTE 2 A list of special tools can be provided, when appropriate.

6.5.2 Capacitor discharge

When the requirements in 4.4.3.4 are not met, the warning symbol ISO 7010-W012 (2011-06) (see Annex C) and an indication of the minimum discharge time required for discharge under worst conditions (for example, discharge time 5 min) shall be placed in a clearly visible position on the *enclosure*, the capacitor protective barrier, or at a point close to the capacitor(s) concerned (depending on the construction). The symbol shall be explained and the time required for the capacitors to discharge after the removal of power from the *SMPS* shall be stated in the installation and maintenance manuals.

NOTE The value of the discharge time declared by the manufacturer may cover a range of *SMPS* taking into account the relevant tolerances for the complete range of *SMPS*.

6.5.3 Auto restart/bypass connection

If a *SMPS* can be configured to provide automatic restart or bypass connection, the installation, user and maintenance manuals shall contain appropriate warning statements.

A *SMPS* which is set to provide automatic restart or bypass connection, after the removal of power, shall be clearly identified at the *installation*.

6.5.4 Other hazards

The manufacturer shall identify, on the product, in the installation and maintenance manuals, as applicable, any components and materials of a *SMPS* which require special procedures to prevent hazards on the product.

6.5.5 Equipment with multiple sources of supply

In accordance with 4.8, where there is more than one source of supply energizing the *SMPS*, information shall be provided to indicate which disconnect device or devices are required to be operated in order to completely isolate the equipment.

Addition:

6.5.5.100 Electrical ratings (for multiple sources of supply)

If the equipment has multiple supply connections, each connection shall be marked with its rated current or rated power.

If the equipment has multiple supply connections, and if each connection has a different rated voltage than the other supply connections, each connection shall be marked with its rated voltage.

The overall system electrical rating need not be marked.

Compliance is checked by inspection.

Addition:

6.5.100 Disconnect device external to permanently connected equipment

Installation instructions shall state that an appropriate disconnect device shall be provided as part of the building ***installation***.

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6.5.101 Power cord acting as disconnecting device

The safety instructions shall state that the ***mains socket-outlet*** shall be easily accessible. For ***pluggable equipment*** intended for ***installation*** by an ***operator,*** the ***installation*** instructions shall be made available to the operator.

Addition:

7 Components

7.1 General

Where safety is involved, components shall comply either with the requirements of this document or, where specified in a requirements clause, with the safety aspects of the relevant IEC component standards.

NOTE An IEC component standard is considered relevant only if the component in question clearly falls within its scope.

Where use of an IEC component standard is permitted above, evaluation and testing of components shall be conducted as follows:

– a component shall be checked for correct application and use in accordance with its rating;

– a component that has been demonstrated to comply with a standard harmonized with the relevant IEC component standard shall be subjected to the applicable tests of this document, as part of the equipment, with the exception of those tests that are part of the relevant IEC component standard;

– a component that has not been demonstrated to comply with a relevant standard as above shall be subjected to the applicable tests of this document, as part of the equipment, and to the applicable tests of the component standard, under the conditions occurring in the equipment; and

– where components are used in circuits not in accordance with their specified ratings, the components shall be tested under the conditions occurring in the equipment. The number of samples required for test is, in general, the same as required by an equivalent standard.

Compliance is checked by inspection and by the relevant data or tests.

Table 103 shows an overview of the components requirements.

Table 103 – Component requirements

Component	Subclause
Switches	7.2
Overtemperature protection devices (thermal cut-offs or thermal links)	7.3
PTC thermistors	7.4
Overcurrent protective devices	7.5
Other protective devices requirements	7.6
Transformers	7.7
Motors	7.8
Mains supply cords	7.9
Surge protective devices (SPDs)	7.10
Wound components	7.11
IC current limiters	7.12

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Component	Subclause
Capacitors and RC units bridging insulation	7.13
Optocouplers bridging insulation	7.14
Relays	7.15
Electrolytic capacitors	7.16

7.2 Switches

7.2.1 General

7.2 specifies requirements for switches that are located in circuits directly connected to mains circuits.

NOTE Voltage selector devices typically used to change the supply voltage configuration of power supplies are not considered to be switches, as they are not operated under load.

7.2.2 Requirements for switches acting as disconnecting device

NOTE Requirements have been taken from IEC 61010-1 and IEC 62368-1.

A disconnect device shall be provided to disconnect the equipment from the supply.

A disconnect device may be:

– the plug on the power supply cord; or
– an appliance coupler; or
– an isolating switch; or
– a circuit breaker; or
– any equivalent means for disconnection.

For equipment intended to be powered from an ***AC mains*** that is overvoltage category I, overvoltage category II or overvoltage category III, or from a DC mains that is ***DVC C***, a disconnect device shall have a contact separation of at least 3 mm. For an ***AC mains*** that is overvoltage category IV, IEC 60947-1 shall apply.

When incorporated in the equipment, the disconnect device shall be connected as closely as practicable to the incoming supply.

Parts on the supply side of a disconnect device in the equipment, that remain energized when the disconnect device is switched off, shall be guarded to reduce the risk of accidental contact by ***service persons***. As an alternative, instructions shall be provided in the service manual.

A disconnect device shall simultaneously interrupt all phase conductors and the neutral conductor. The neutral conductor does not need to be switched, when it is possible to rely on the identification of the neutral in the mains.

For ***permanently connected*** equipment the disconnect device shall be incorporated in the equipment, unless the equipment is accompanied by ***installation*** instructions shall comply with 6.5.100.

NOTE External disconnect devices will not necessarily be supplied with the equipment.

Where a plug on the power supply cord is used as the disconnect device, the ***installation*** instructions shall comply with 6.5.101.

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An equipment switch or circuit-breaker employed as a disconnecting device shall meet the relevant requirements of IEC 60947-1 and IEC 60947-3 and be suitable for the application.

If the power supply switch or circuit-breaker is used as the disconnecting device, the off-position shall be clearly marked. Graphical symbols IEC 60417-5007 (2002-10) and IEC 60417-5008 (2002-10) (see Annex C) or IEC 60417-5268 (2002-10) and IEC 60417-5269 (2002-10) (see Annex C) for push-button switches.

A switch shall not be incorporated in a ***mains supply*** cord.

A switch or circuit-breaker shall not interrupt a protective earth conductor.

Compliance is checked by inspection.

7.2.3 Requirements for switches

A switch not complying with 7.2.1 may be tested separately or in the equipment and shall comply with all of the following:

– comply with the requirements of IEC 61058-1:2000/AMD1:2001/AMD2:2007, whereby the following applies:
  - 10 000 operating cycles (see 7.1.4.4 of IEC 61058-1:2000/AMD1:2001/AMD2:2007);
  - the switch shall be suitable for use in the pollution degree environment in which it is used, typically a pollution degree 2 environment

    (see 7.1.6.2 of IEC 61058-1:2000/AMD1:2001/AMD2:2007);
  - the switch have a glow wire temperature of 850 °C

    (see 7.1.9.3 of IEC 61058-1:2000/AMD1:2001/AMD2:2007);
  - the characteristics of the switch with regard to the ratings and classification (see IEC 61058-1) shall be appropriate for the function of the switch under normal operating conditions as given below:

    i) the ratings of the switch (see Clause 6 of IEC 61058-1:2000/AMD1:2001/AMD2:2007);

    ii) the classification of the switch according to:

      a) nature of supply (see 7.1.1 of IEC 61058-1:2000/AMD1:2001/AMD2:2007);

      b) type of load to be controlled by the switch (see 7.1.2 of IEC 61058-1:2000/AMD1:2001/AMD2:2007);

      c) ambient air temperature (see 7.1.3 of IEC 61058-1:2000/AMD1:2001/AMD2:2007);

    Compliance is checked according to IEC 61058-1:2000/AMD1:2001/AMD2:2007.
  - the switch shall be so constructed that it does not attain excessive temperatures under normal operating conditions. Compliance is checked in the on-position according to 16.2.2 d), l) and m) of IEC 61058-1:2000/AMD1:2001/AMD2:2007, except the current is the sum of the equipment current and the maximum current supplied to other equipment, if any.
  - a mains switch controlling connectors supplying power to other equipment shall withstand the electrical endurance test according to 17.2 of IEC 61058-1:2000/AMD1:2001/AMD2:2007, with an additional load according to Figure 9 of IEC 61058-1:2000/AMD1:2001/AMD2:2007. The total current rating of the additional load shall correspond to the marking of the connectors supplying power to other equipment. The peak surge current of the additional load shall have a value as shown in Table 104.

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Table 104 – Peak surge current

Current rating A	Peak surge current A
up to and including 0,5	20
up to and including 1,0	50
up to and including 2,5	100
over 2,5	150

7.2.4 Test method and compliance criteria

The tests of IEC 61058-1:2000/AMD1:2001/AMD2:2007 shall be applied with the modifications shown in 7.2.3.

After the tests, the switch shall show no deterioration of its ***enclosure*** and no loosening of electrical connections or mechanical fixings.

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7.3 Overtemperature protection devices (thermal cut-offs or thermal links)

NOTE Requirements have been derived from clause 6.10.1 of IEC 61010-1:2010.

Overtemperature protection devices are devices operating in ***single fault condition***. They shall meet all of the following requirements:

a) be constructed so that reliable function is ensured;

b) be rated to interrupt the maximum voltage and current of the circuit in which they are employed;

c) not operate in normal operation.

If a self-resetting overtemperature protection device is used to prevent a hazard in case of failure of a temperature control system (for example a thermostat), the protected part of the equipment shall require intervention before becoming operational again.

Compliance is checked by inspection of the circuit diagram, the data sheet for the overtemperature protection device, and the method in which it is installed in the equipment, and by the following tests, with the equipment operated in ***single fault condition***.

The number of operations is as follows:

1) self-resetting overtemperature protection devices are caused to operate 200 times;

2) non-self-resetting overtemperature protection devices, except thermal fuses, are reset after each operation and thus caused to operate 10 times;

3) non-resetting overtemperature protection devices are caused to operate once.

Forced cooling and resting periods are allowed to be introduced to prevent damage to the equipment. During the test, resetting overtemperature protection devices shall operate each time the single fault condition is applied and non-resetting overtemperature protection devices shall operate once. After the test, resetting overtemperature protection devices shall show no sign of damage which could prevent their operation in a further single fault condition.

7.4 PTC thermistors

NOTE 1 Derived from requirements of IEC 62368-1:2014.

PTC thermistors used for protection according to 4.6.5, shall comply with Clauses 15, 17, J.15 and J.17 of IEC 60730-1:2010 or shall provide IEC 60730-1 Type 2.A.L. action.

For PTC thermistors whose continuous power dissipation that appears at its maximum voltage at an ambient temperature of 25 °C or otherwise specified by the manufacturer for tripped state, determined as given in 3.38 of IEC 60738-1:2009, exceeds 15 W and with a size of 1 750 mm3 or more, the encapsulation or tubing shall be made of V-1 class material or equivalent material.

NOTE 2 Tripped state means the state in which PTC thermistors are shifted to a high resistance condition at a given temperature.

Compliance is checked by inspection and where applicable by the tests of IEC 60730-1.

7.5 Overcurrent protective devices

Overcurrent protective devices shall comply with their applicable IEC standards and be used according to their specification.

Compliance is checked by inspection.

7.6 Protective devices not mentioned in 7.2 to 7.5

7.6.1 Other protective devices requirements

Such protective devices (for example, fusing resistors, fuse-links not standardized in IEC 60127 (all parts) or miniature circuit breakers) shall have adequate rating including breaking capacity.

7.6.2 Compliance and test method

*Compliance is checked by inspection and by performing **single fault condition** testing as specified in 5.2.4.*

The test is carried out three times.

No failure is allowed.

7.7 Transformers

7.7.1 General

Transformers shall comply with one of the following:

– meet the requirements given in 7.7.2;
– meet the requirements of IEC 61558-1 and the relevant parts of IEC 61558-2 (all parts) with the following additions and limitations:
  - the limit values for ***DVC As*** of this document apply (see Table 5);
  - for ***working voltages*** above 1 000 V RMS, see 18.3 of IEC 61558-1:2005/AMD1:2009, using the test voltage specified in 4.4.7.10;
  - the overload test according to 5.2.4.100.

7.7.2 Insulation

7.7.2.1 Requirements

Insulation in transformers shall comply with the following requirements.

Windings and conductive parts of transformers shall be treated as parts of the circuits to which they are connected, if any. The insulation between them shall comply with the relevant requirements of 4.4.7 and pass the relevant electric strength tests, according to the application of the insulation in the equipment.

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Precautions shall be taken to prevent the reduction below the required minimum values of clearances and creepage distance that provide ***basic insulation***, ***supplementary*** insulation or reinforced insulation by

– displacement of windings, or their turns;
– displacement of internal wiring or wires for external connections;
– undue displacement of parts of windings or internal wiring, in the event of rupture of wires adjacent to connections or loosening of the connections;
– bridging of insulation by wires, screws, washers and the like should they loosen or become free.

It is not expected that two independent fixings will loosen at the same time. All windings shall have the end turns retained by positive means.

Examples of acceptable forms of construction are the following (there are other acceptable forms of construction):

– windings isolated from each other by placing them on separate limbs of the core, with or without spools;
– windings on a single spool with a partition wall, where either the spool and partition wall are pressed or moulded in one piece, or a pushed-on partition wall has an intermediate sheath or covering over the joint between the spool and the partition wall;
– concentric windings on a spool of insulating material without flanges, or on insulation applied in thin sheet form to the transformer core;
– insulation is provided between windings consisting of sheet insulation extending beyond the end turns of each layer;
– concentric windings, separated by an earthed conductive screen that consists of metal foil extending the full width of the windings, with suitable insulation between each winding and the screen. The conductive screen and its lead-out wire have a cross-section sufficient to ensure that on breakdown of the insulation an overload device will open the circuit before the screen is destroyed. The overload device may be a part of the transformer.

If a transformer is fitted with an earthed screen for protective purposes, the transformer shall pass the test of 5.2.4.3 between the earthed screen and the earthing terminal of the transformer.

No electric strength test applies to insulation between any winding and the core or screen, provided that the core or screen is totally enclosed or encapsulated and there is no electrical connection to the core or screen. However, the tests between windings that have terminations continue to apply.

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7.7.2.2 Compliance criteria

Compliance is checked by inspection, measurement and where applicable by test.

7.8 Motors

Motors that are used for air-handling only and where the air-propelling component is directly coupled to the motor shaft shall only be tested with locked rotor during fault conditions.

Motors connected to voltages other than ***DVC As*** have to be investigated to clearance and creepage distances according to this document or an IEC standard for motors covering spacing requirements.

AC motors with starting capacitors have to faulted by shorting and opening the starting capacitor.

A loss of phase test, according to 5.2.4.8, has to be conducted in the case of 3-phase AC motors.

NOTE The only motors considered in this document are motors for air-handling.

7.9 Mains supply cords

NOTE Requirements have been derived from clause 6.10.1 of IEC 61010-1:2010.

7.9.1 General

The following requirements apply to non-detachable ***mains supply*** cords and to detachable ***mains supply*** cords supplied with the equipment.

Cords shall be rated for the maximum current for the equipment and the cable used shall meet the requirements of the relevant parts of IEC 60227 (all parts) or IEC 60245 (all parts).

If a cord is likely to contact hot external parts of the equipment, it shall be made of suitably heat-resistant material.

If the cord is detachable, both the cord and the appliance inlet shall have adequate temperature ratings.

Conductors coloured green-and–yellow shall be used only for connection to protective conductor terminals.

Detachable ***mains supply*** cords with mains connectors according to the relevant parts of IEC 60320 (all parts) shall either meet the requirements of IEC 60799, or shall be rated at least for the current rating of the mains connector fitted to the cord.

Figure 106 explains the terminology for ***mains supply*** cords.

Compliance is checked by inspection and, where necessary, by measurement.

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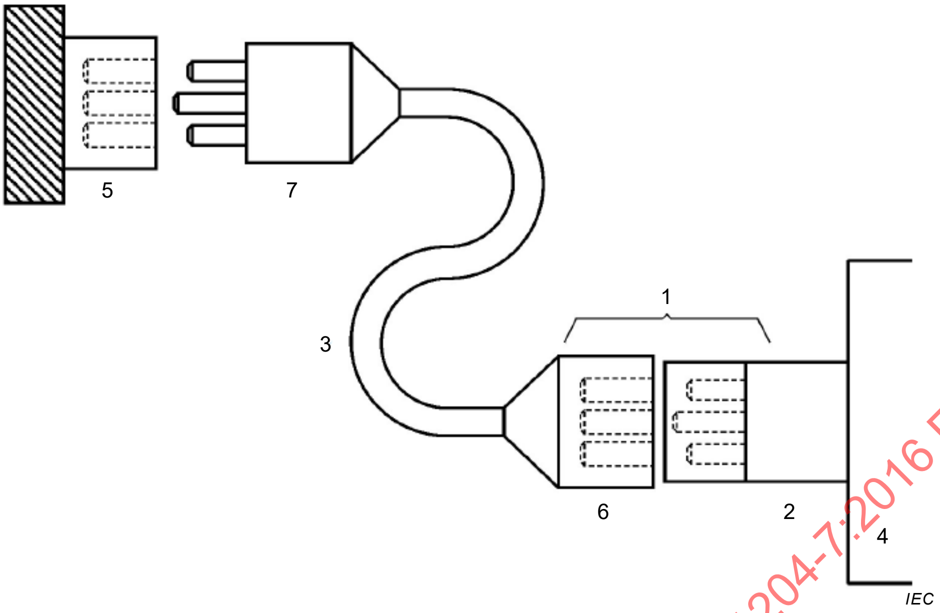

Key

1	Appliance coupler	5	Fixed mains socket-outlet
2	Appliance inlet	6	Mains connector
3	Cable	7	Mains plug
4	Equipment		

Figure 106 – Detachable mains supply cords and connections

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7.9.2 Fitting of non-detachable mains supply cords

7.9.2.1 Cord entry

Mains supply cords shall be protected against abrasion and sharp bends at the point where the cord enters the equipment, by one of the following means:

a) an inlet or bushing with a smoothly rounded opening;

b) reliably fixed flexible cord guard made of insulating material protruding beyond the inlet opening by at least five times the overall diameter of a cord with the largest cross-sectional area which can be fitted. For flat cords, the larger cross-sectional dimension is taken as the overall diameter.

Compliance is checked by inspection, and if needed by measurement of dimensions.

7.9.2.2 Cord anchorage

The cord anchorage shall relieve the conductors of the cord from strain, including twisting, where they are connected within the equipment, and shall protect the insulation of the conductors from abrasion. The protective earth conductor, if any, shall be the last to take the strain if the cord slips in its anchorage.

Cord anchorages shall meet the following requirements:

a) the cord shall not be clamped by a screw which bears directly on the cord;

b) knots in the cord shall not be used;

c) it shall not be possible to push the cord into the equipment to an extent which could cause a hazard;

d) failure of the cord insulation in a cord anchorage which has metal parts shall not cause accessible conductive parts to become ***hazardous-live-parts***;

e) it shall not be possible to loosen the cord anchorage without the use of a tool;

f) it shall be designed so that cord replacement does not cause a hazard, and it shall be clear how the relief from strain is provided.

A compression bushing shall not be used as a cord anchorage unless it is suitable for use with the mains supply cord supplied with it or specified for it by the manufacturer.

Compliance is checked by inspection and by the following push-pull test:

For each combination of cord and bushing, the cord is pushed into the equipment manually, as far as possible. It is then subjected 25 times to a steady pull of the value shown in Table 105, applied for 1 s each time in the least favourable direction. Immediately afterwards it is subjected for 1 min to a torque of the value shown in Table 105. The torque shall be applied as close as possible to the external end of the cord anchorage or bushing.

Table 105 – Strain relief test force

Mass of the equipment kg	**Force** N	**Torque for torque test** Nm
Up to and including 1	30	0,10
Over 1 up to and including 4	60	0,25
Over 4	100	0,35

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After the tests:

1) *the cord shall not have been damaged;*
2) *the cord shall not have been displaced longitudinally by more than 2 mm;*
3) *there shall be no signs of strain at the point where the anchorage clamps the cord;*
4) *clearances and creepage distances shall not have been reduced below the applicable values;*
5) *the cord shall pass the AC voltage test of 5.2.4.3 (without humidity preconditioning) with a duration of at least 1 min as follows:*
   a) *for equipment with a protective earth conductor, the test is made between the protective conductor and the line and neutral conductors joined together, with the test voltage according to 4.4.7.10 for basic insulation for the appropriate line-to-neutral voltage;*
   b) *for equipment without a protective earth conductor, the test is made between accessible conductive parts of the equipment and the line and neutral conductors joined together, with the test voltage according to 4.4.7.10 for reinforced insulation for the appropriate line-to-neutral voltage.*

7.9.2.3 Plugs and connectors

Plugs and connectors for connecting equipment to the ***mains supply***, including appliance couplers used to connect detachable ***mains supply*** cords, shall conform to the relevant specifications for plugs, ***mains socket-outlets*** and connectors.

If the equipment is designed to be supplied only at voltages below ***DVC As*** in normal condition or ***single fault condition***, or from a source used solely to supply that equipment, the plugs of the power supply cord shall not fit into the ***mains socket-outlets*** of ***mains supply*** systems at voltages above the rated supply voltage of the equipment. Mains-type plugs and sockets shall not be used for purposes other than connection of a ***mains supply***.

If plug pins of cord-connected equipment receive a charge from an internal capacitor, the pins shall be investigated to 4.4.5.103, and testing to 4.4.9 shall be conducted, if necessary.

On equipment with mains socket-outlets:

a) if the ***mains socket-outlet*** can accept a standard ***mains supply*** plug, there shall be a marking as specified in 6.3.6.4.101;
b) if the ***mains socket-outlet*** has a terminal contact for a protective earth conductor, the input ***mains supply*** connection to the equipment shall include a protective earth conductor connected to a protective conductor terminal.

Compliance is checked by inspection. For plugs receiving a charge from an internal capacitor, investigation to 4.4.5.103 has to be conducted.

7.10 Surge protective devices (SPDs)

NOTE Derived from requirements of IEC 62368-1:2014.

7.10.1 Use of an SPD connected to reliable earthing

Where a varistor is used between the mains and earth,

– the earth connection shall comply with 4.4.4.3.3, and
– the varistor shall pass the test of 7.10.4.

NOTE Pluggable equipment type A and pluggable equipment type B without a multi-conductor power cable with a minimum cross section of 2,5 mm² for the PE conductor are not considered to have a reliable earth connection (refer to 7.10.2).

7.10.2 Use of an SPD between mains and protective earth

Where an SPD is used between the mains and protective earth, it shall consist of a varistor and a GDT (gas discharge tube) connected in series, where the following applies:

– the varistor shall pass the test of 7.10.4;
– the GDT shall comply with:
  • the electric strength tests for ***basic insulation***; and
  • the external clearance and creepage distance requirements for ***basic insulation***.

NOTE 1 Some examples of SPDs are MOVs, varistors and GDTs. A varistor is sometimes referred to as a VDR or a metal oxide varistor (MOV).

The above requirements do not apply to SPDs

– intended for attenuating transient voltages from external circuits, and
– connected to reliable earth (see 7.10.1).

NOTE 2 It is not a requirement of this document that surge suppressors comply with any particular component standard. However, attention is drawn to the IEC 61643 series of standards, in particular:

– IEC 61643-21 (surge suppressors in telecommunications application),
– IEC 61643-311 (gas discharge tubes),
– IEC 61643-321 (avalanche breakdown diodes),
– IEC 61643-331 (metal oxide varistors).

7.10.3 Bridging of supplementary, double or reinforced insulation by a SPD

It is not permitted to bridge ***supplementary insulation***, ***double insulation*** or ***reinforced insulation*** by a SPD.

Compliance is checked by inspection.

7.10.4 Circuits or components used as transient voltage limiting devices

NOTE Derived from requirements in IEC 61010-1:2010, 14.8.

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Transient overvoltages in a circuit may be limited by circuits or components. Components suitable for this purpose include varistors, spark gaps on printed wiring boards, and ceramic capacitors, in some cases combined with impedances or gas-filled surge arresters.

Any overvoltage limiting component or circuit that forms part of the equipment shall have adequate strength to limit likely transient overvoltages.

Compliance is checked by applying 5 positive and 5 negative impulses with the applicable impulse withstand voltage of Table 9, with an interval of up to 1 min , from a hybrid impulse generator (see IEC 61180-1). The generator shall produce an open-circuit voltage waveform of 1,2/50 μs, a short-circuit current waveform of 8/20 μs, with an output impedance (peak open-circuit voltage divided by peak short-circuit current) of 12 Ω (resistance may be added in series if needed to raise the impedance). The test impulse shall be applied while the circuit is working under conditions during normal operation, in combination with the ***mains supply***. The mains voltage is the maximum rated line-to-neutral mains voltage.

The test voltage is applied between each pair of ***mains supply*** terminals of the equipment where voltage limiting devices are present.

No hazard shall arise in the event that the component ruptures or overheats during the test. If a rupture occurs, no part of the component shall bridge safety-relevant insulation. If the component overheats, it shall not heat other materials to their self-ignition points. Tripping the circuit breaker of the ***mains supply*** is an indication of failure.

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7.11 Wound components

Refer to 4.4.7.8.5.

7.12 IC current limiters

7.12.1 General

NOTE Derived from requirements of IEC 62368-1:2014.

IC current limiters used for current limiting in power sources to limited power source (4.6.5) are not shorted from input to output if all of the following conditions are met:

– the IC current limiters limit the current to manufacturer's defined value (not to be more than 5 A) under normal operating conditions with any specified drift taken into account;

– the IC current limiters are entirely electronic and have no means of manual operation or reset;

– the IC current limiters are supplied by a source whose output does not exceed 250 VA;

– the IC current limiters output current is limited to 5 A or less;

– the IC current limiters limit the current or voltage to the required value with the manufacturer's defined drift, as applicable, taken into account after each of the conditioning tests.

At the choice of the manufacturer, the conditioning tests shall be conducted in accordance with a test program outlined in 7.12.2, 7.12.3 or 7.12.4.

Compliance criteria:

After each of the tests below, the device shall limit the current in accordance with its specification as applicable or the device shall become open circuit. The open circuited device is replaced with a new sample and tests continued as applicable.

IC current limiters that meet the test program of either 7.12.2, 7.12.3 or 7.12.4 are considered to comply with the above requirements.

A different sample may be used for each test.

NOTE The power source for the tests should be capable of delivering 250 VA minimum unless the IC current limiter is tested in the end product.

7.12.2 Test program 1

Test program 1 consists of the following:

- 10 000 cycles of turning enable on and off with a 100 Ω ±5 Ω resistor and a 425 µF ±10 µF capacitor in parallel with the output;
- 10 000 cycles of turning enable on and off with a ferrite-core inductor having 0,35 mH ±0,1 mH inductance at 1 kHz and a DC resistance not exceeding 1 Ω;
- 10 000 cycles of turning enable on and off with the input connected to a capacitor rated 425 µF ±1 µF and shorting the output;
- 10 000 cycles of turning the input pin on and off with a capacitor rated 425 µF ±1 µF connected to the input supply while keeping enable active and shorting the output;
- 10 000 cycles of turning the input pin on and off with a ferrite-core inductor having 0,35 mH ±0,1 mH inductance at 1 kHz and a DC resistance not exceeding 1 Ω connected to the input supply and return while keeping enable active and shorting the output;
- 50 cycles with the enable pin held active with the output open-circuited, each cycle consisting of shorting the output and then opening the output;
- 50 cycles with the enable pin held active while applying a short to the output, each cycle consisting of turning the power on and off;
- 50 cycles with the enable pin held active while power is applied, each cycle consisting of shorting the output, removing power, reapplying power, removing the short, followed by removal of power.

7.12.3 Test program 2

Test program 2 consists of the following:

- 50 cycles with the enable pin held active with the output open-circuited; each cycle consisting of shorting the output and then opening the output;
- 50 cycles with the enable pin held active while applying a short to the output; each cycle consisting of turning the power on and off;
- 50 cycles with the enable pin held active with the output loaded to maximum power, each cycle consisting of turning the power on and off;
- 50 cycles with the enable pin held active while power is applied, each cycle consisting of shorting the output, removing power, reapplying power, removing the short, followed by removal of power;
- 3 cycles of exposing the device (not energized) to 70 °C ±2 °C for 24 h; followed by at least 1 h at room ambient; followed by at least 3 h at – 30 °C ±2 °C; followed by 3 h at room ambient;
- 10 cycles of exposing the device (while energized) to 50 °C ±2 °C for 10 min; followed by 10 min at 0 °C ±2 °C with a 5 min period of transition from one state to the other;
- 7 days with the output short-circuited and the device wrapped in a double layer of cheesecloth. A quick acting 5 A fuse kept in series with the output shall not open and a current meter shall not show a current of more than 5 A.

7.12.4 Test program 3

Test program 3 consists of the following:

- Subclause H.17.1.4.2 of IEC 60730-1:2010;
- 10 000 cycles of turning enable on and off with a 100 Ω resistor and 425 µF capacitor in parallel with the output;

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– 10 000 cycles of turning enable on and off with a ferrite-core inductor having 0,35 mH ±0,1 mH inductance at 1 kHz and a DC resistance not exceeding 1 Ω connected in the output circuit;
– 10 000 cycles of turning enable on and off while input connected to a capacitor rated 425 μF and shorting the output;
– 10 000 cycles of turning input pin on and off while a capacitor rated 425 μF to the input supply keeping enable active and shorting the output;
– 10 000 cycles of turning input pin on and off with a ferrite-core inductor having 0,35 mH ±0,1 mH inductance at 1 kHz and a DC resistance not exceeding 1 Ω connected to the input supply keeping enable active and shorting the output;
– 50 cycles with enable pin held active and applying short to output with power on and off;
– 50 cycles with enable pin held active and output loaded to maximum power with power on and off;
– 50 cycles with enable pin held active and applying power, apply short to output; remove power, apply power, remove short, remove power;
– 3 cycles of exposing the device (not energized) to 70 °C for 24 h; followed by at least 1 h at room ambient; followed by at least 3 h at –30 °C; followed by 3 h at room ambient;
– 10 cycles of exposing the device (while energized) to 49 °C for 10 min; followed by 10 min at 0 °C with a 5 min period of transition from one state to the other.

7.13 Capacitors and RC units bridging insulation

7.13 specifies selection requirements for capacitors and RC units, complying with IEC 60384-14, acceptable for ***basic insulation, supplementary insulation*** or ***reinforced insulation***.

The following conditions are applied when evaluating a capacitor or an RC unit to the requirements of IEC 60384-14:

a) The duration of the damp heat, steady-state test as specified in 4.12 of IEC 60384-14:2013, shall be 21 days at a temperature of 40 °C ± 2°C and a relative humidity of 93 % ± 3 %.
b) Capacitors subjected to a duration that is longer than 21 days during the above test are considered acceptable.

The appropriate capacitor subclass shall be selected from those listed in Table 106, according to the rules of application in the table.

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Table 106 – Capacitor ratings according to IEC 60384-14

Capacitor subclass according to IEC 60384-14:2013	Rated voltage of the capacitor V RMS	Type test impulse voltage of the capacitor kV peak	Type test RMS test voltage of the capacitor kV RMS
Y1	Up to and including 500	8	4
Y2	Over 150 up to and including 500	5	1,5
Y4	Up to and including 150	2,5	0,9
X1	Up to and including 1 000	4[a]	-
X2	Up to and including 1 000	2,5[a]	-

Rules for the application of this table.

1) The voltage rating of the capacitor shall be at least equal to the RMS working voltage across the insulation being bridged.

2) For a single capacitor (X type) serving as functional insulation, failure of the capacitor shall not result in the failure of any protection, and the type test impulse voltage shall be at least equal to the required impulse voltage.

3) A higher grade capacitor than the one specified may be used, as follows:
   – subclass Y1 if subclass Y2 is specified;
   – subclass Y1 or Y2 if subclass Y4 is specified;
   – subclass Y1 or Y2 if subclass X1 is specified;
   – subclass X1, Y1 or Y2 if subclass X2 is specified.

4) Two or more capacitors may be used in series in place of the single capacitor specified, as follows:
   – subclass Y1 or Y2 if subclass Y1 is specified;
   – subclass Y2 or Y4 if subclass Y2 is specified;
   – subclass X1 or X2 if subclass X1 is specified.

5) If two or more capacitors are used in series they shall pass the electric strength tests of 4.4.7.8.3.4, taking into account the total working voltage across the capacitor(s) and RC unit, as applicable and comply with the other rules above.

[a] For capacitance values of more than 1 μF, this test voltage is reduced by a factor equal to $\sqrt{C}$, where C is the capacitance value in μF.

NOTE In Norway, due to the IT power system used, capacitors are required to be rated for the applicable line-to-line voltage (230 V).

Class X capacitors may be used as a ***basic insulation*** in circuits isolated from the mains but shall not be used as a:

– ***basic insulation*** in circuits connected to the ***mains supply***; or
– supplementary insulation.

A series of X capacitors may be used as basic insulation of mains circuits provided that:

– the capacitor series is connected to a reliable earth (see 4.4.4.3.3 and 7.10.1);
– both have the same classification;
– both are of same nominal capacitance;
– both have the same rated voltage, and
– the series of X capacitors comply with the impulse test in 7.10.4 for basic insulation.

The rated voltage of the capacitors shall not be less than the rated voltage of an appropriate Y capacitor.

The sum of the rated impulse voltages of the X capacitors shall not be less than that of an appropriate Y capacitor.

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Class X capacitors shall not be used as a ***reinforced insulation***.

Capacitors and RC units that serve as ***(electrical) insulation*** shall comply with IEC 60384-14. RC units may consist of discrete components.

Under ***single fault condition***s, if a capacitor or RC unit consists of more than one capacitor, the voltage on each of the remaining individual capacitors shall not exceed the voltage rating of the relevant individual capacitors. When multiple capacitors are used, the relevant test voltages are multiplied by the number of capacitors used.

Compliance is checked by inspection and if necessary by measurement.

7.14 Optocouplers bridging insulation

7.14 specifies compliance requirements for optocouplers serving as ***basic insulation***, ***supplementary insulation*** or ***reinforced insulation***.

Optocouplers shall comply with the requirements of IEC 60747-5-5:2007. In the application of IEC 60747-5-5:2007,

– the voltage $V_{\text{ini,a}}$ for ***type testing*** as specified in 7.4.3 of IEC 60747-5-5:2007, and
– the voltage $V_{\text{ini,b}}$ for ***routine testing*** as specified in 7.4.1 of IEC 60747-5-5:2007

shall be the appropriate value of the test voltage in 5.2.3.4 of this document.

NOTE The above constructions can contain cemented joints, in which case 4.4.7.9 of this document also applies.

Compliance is checked by inspection.

7.15 Relays

7.15 specifies requirements for relays that are located in circuits other than limited power circuits.

The relay may be tested separately or in the equipment.

For resistance to heat and fire, see Clause 16 in IEC 61810-1:2008.

A relay shall comply with the requirements of IEC 61810-1, taking into account the following:

– 10 000 operating cycles for endurance (see 5.5 of IEC 61810-1:2008) and during the electric endurance test (see clause 11 of IEC 61810-1:2008), no temporary malfunction shall occur;

  NOTE A temporary malfunction is an event that has to be eliminated during the test at latest after one additional energization cycle without any external influence (see clause 11 of IEC 61810-1:2008).

– the relay shall be suitable for use in the applicable pollution situation (see clause 13 of IEC 61810-1:2008);
– for mains relays the speed of contact making and breaking shall be independent of the rate of rise of the coil voltage;
– characteristics of the relay with regard to the ratings and classification (see IEC 61810-1), shall be appropriate for the function of the relay under normal operating condition as given below:
  • rated coil voltage and rated coil voltage range (see 5.1 of IEC 61810-1:2008);
  • rated contact load and the type of load (see 5.7 of IEC 61810-1:2008);
  • AC or DC relay (see 5.3 of IEC 61810-1:2008);

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  - the ambient air temperature and upper and lower limit of the temperature (see 5.8 of IEC 61810-1:2008);
  - only relay technology category RT IV and RT V shall be considered to meet pollution degree 1 environment (see 5.9 of IEC 61810-1:2008);
- electric strength (see 10.3 of IEC 61810-1:2008), except the test voltages shall be the highest of the AC or DC voltages, according to 5.2.3.4;
- clearances in accordance with this document, if the required impulse withstand voltage (referred to as impulse withstand voltage in IEC 61810-1) exceeds 12 kV;
- creepage distances in accordance with this document, if the RMS ***working voltage*** (referred to as voltage RMS in IEC 61810-1) exceeds 500 V;
- solid insulation in accordance with 13.3 of IEC 61810-1:2008 or with 4.4.7.8 of this document.

Compliance is checked according to IEC 61810-1 and the requirements of this document.

7.16 Electrolytic capacitors

Electrolytic capacitors shall have adequate clearances for venting in accordance with the capacitor manufacturer's specifications.

Electrolytic capacitors shall be at least short circuited and disconnected as a single fault, but it is sufficient to conduct worst case testing on individual capacitors or components of capacitor protection circuitry, if more than one electrolytic capacitor is provided (series connections of capacitors or capacitor banks).

Compliance is checked by inspection.

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Annex A
(normative)

Additional information for protection against electric shock

The provisions of Annex A of IEC 62477-1:2012 apply, except as follows.

A.1 General

Replacement:

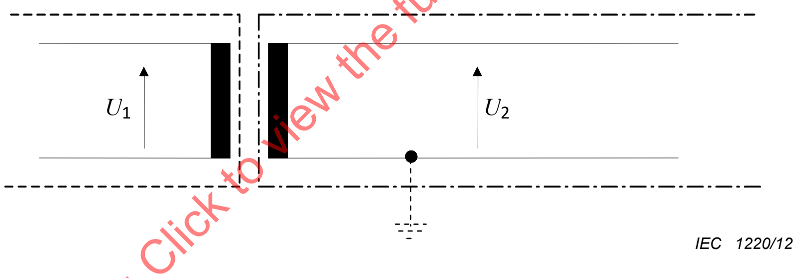
Figure A.1 to Figure A.3 show examples of the methods used for protection against electric shock in ***protective class III*** equipment and circuits (see 4.4.6.4).

Basic insulation

Supplementary insulation

A.2 Protection by means of DVC As

(see 4.4.2.2)



Key

U_1: hazardous voltage, earthed or unearthed

U_2: ≤ *DVC As* from Table 5

Figure A.1 – Protection by *DVC As* with *protective separation*

A.3 Protection by means of protective impedance

(see 4.4.5.4)

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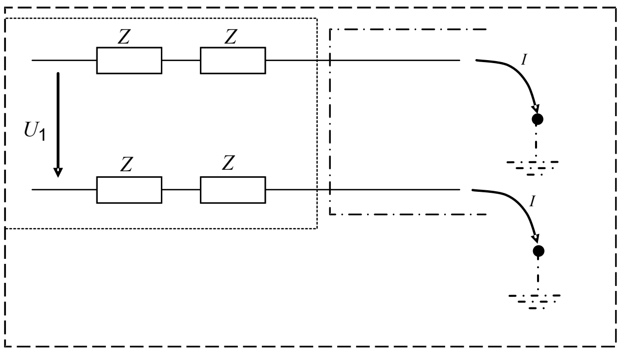


Key

Z resistor

U_1 hazardous voltage, earthed or unearthed

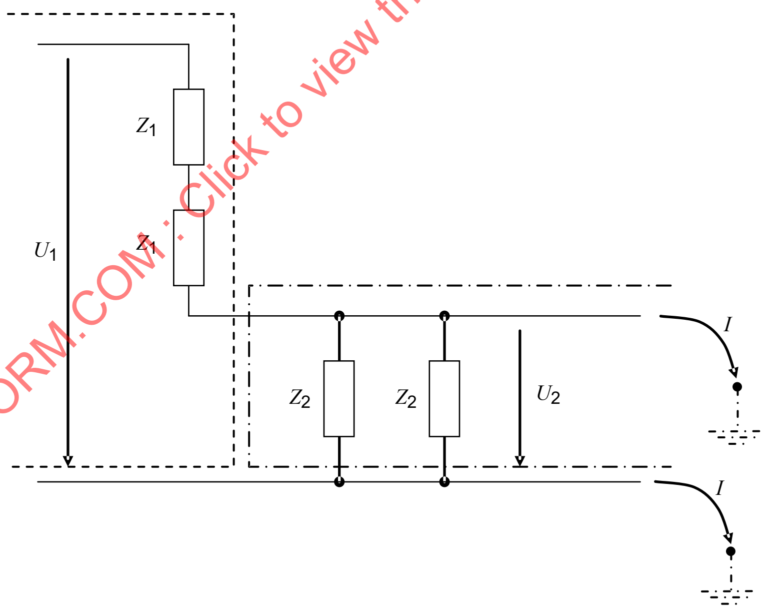
$I \leq$ 3,5 mA a.c., 10 mA d.c.

NOTE To provide protection in single-fault conditions, use the following equation $I = \frac{U_1}{Z}$

Figure A.2 – Protection by means of *protective impedance*

A.4 Protection by using limited voltages

(see 4.4.5.4)



Key

Z: resistor

U_1: hazardous voltage, earthed

$U_2 \leq$ *DVC As* from Table 5.

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NOTE To provide protection in single-fault conditions, use equations: $U_2 = \frac{U_1 Z_2}{2Z_1 + Z_2}$ or. $U_2 = \frac{U_1 Z_2}{2(Z_1 + Z_2/2)}$

Figure A.3 – Protection by using limited voltages

A.5 Evaluation of working voltage and selection of DVC for touch voltage, PELV and SELV circuits

The provisions of Clause A.5 of IEC 62477-1:2012 and its subclauses **do not** apply.

NOTE This clause is obsolete due to modification of Table 2 and Table 5.

A.6 Evaluation of the working voltage of circuits

A.6.1 General

Determination of the *working voltage* for

– a.c. r.m.s. (U_{AC});
– a.c. recurring peak (U_{ACP}); and
– d.c. (average)

is done with the method set out below. Three cases of waveforms are considered as an example.

Figures A.20 to A.22 show typical waveforms for the evaluation of *working voltage*.

A.6.2 AC working voltage

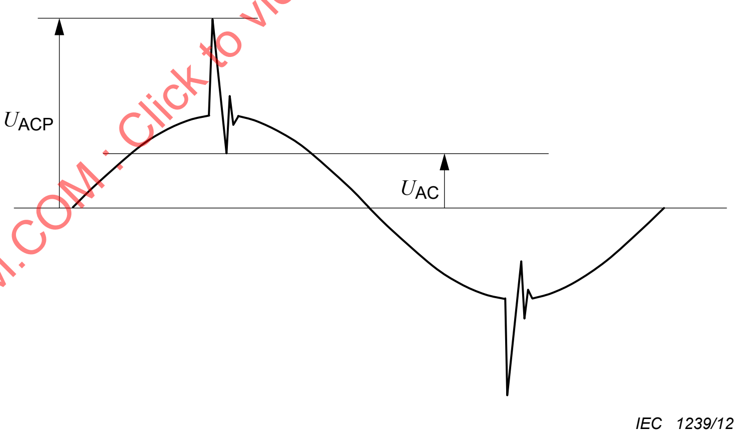

Figure A.20 – Typical waveform for a.c. *working voltage*

The *working voltage* has an r.m.s. value U_{AC} and a recurring peak value U_{ACP}.

The *DVC* is that of the lowest voltage row of Table 5 for which both of the following conditions are satisfied:

– $U_{AC} \leq U_{ACL}$
– $U_{ACP} \leq U_{ACPL}$

Example with values:

U_{AC} = 39 V --> is lower than U_{ACL} = 50 V --> *DVC B*

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U_{ACP} = 91 V --> is higher than U_{ACPL} = 71 V --> *DVC C*

The rule for determination of *DVC* of the voltage is to select the highest *DVC*.

Result: --> this *working voltage* becomes *DVC C*.

A.6.3 DC working voltage

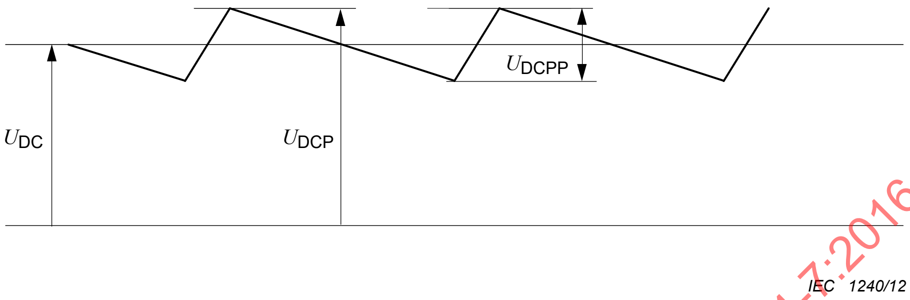

Figure A.21 – Typical waveform for d.c. *working voltage*

The *working voltage* has a mean value U_{DC} and a recurring peak value U_{DCP}, caused by a ripple voltage of r.m.s. value not greater than 10 % of U_{DC}.

The *DVC* is that of the lowest voltage row of Table 5 for which both of the following conditions are satisfied:

– $U_{DC} \leq U_{DCL}$
– $U_{DCP} \leq 1{,}17 \times U_{DCL}$

A.6.4 Pulsating working voltage

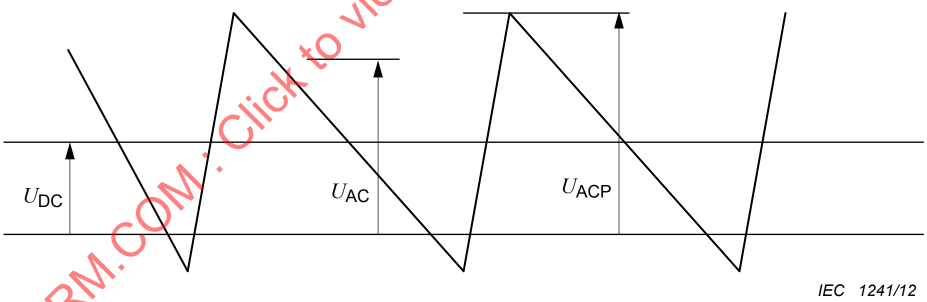

Figure A.22 – Typical waveform for pulsating *working voltage*

The *working voltage* has a mean value U_{DC} and a recurring peak value U_{ACP}, caused by a ripple voltage of r.m.s. value U_{AC} greater than 10 % of U_{DC}.

The *DVC* is that of the lowest voltage row of Table 5 for which both of the following conditions are satisfied:

$$\frac{U_{AC}}{U_{ACL}} + \frac{U_{DC}}{U_{DCL}} \leq 1$$

$$\frac{U_{ACP}}{U_{ACPL}} + \frac{U_{DC}}{1{,}17 \times U_{DCL}} \leq 1$$

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A.7 Examples of the use of elements of protective measures

Protection against electric shock shall be achieved by means of:

- combination of *basic protection* according to 4.4.3 and *fault protection* according to 4.4.4; or
- *Enhanced protection* according to 4.4.5.

Table A.4 provides examples of typical combinations of those measures.

The grade of *insulation* depends on:

- the *DVC* of the *live parts* according *to* Table 5;
- the *insulation* requirement between *adjacent circuits* according to Table 6;
- the connection of accessible conductive parts to earth by *protective equipotential bonding* according to Table 6; and
- non conductive accessible parts.

As an alternative to solid *insulation*, a clearance according to 4.4.7.4, shown by L_1 and L_2 in Table A.4 may be provided.

In Table A.4, three cases are considered:

Case a):

Accessible parts are conductive and are connected to earth by *protective equipotential bonding*.

- *Basic insulation* is required between accessible parts and the *live parts*. The relevant voltage is that of the *live parts* (see Table A.4, cells 1a, 2a, 3a).

Cases b) and c):

Accessible parts are non-conductive (case b) or conductive but not connected to earth by *protective equipotential bonding* (case c). The required *insulation* is:

- Double or reinforced *insulation* between accessible parts and *live parts* of *DVC C*. The relevant voltage is that of the *live parts* (see Table A.4, cells 1b), 1c), 2b) and 2c)).
- Supplementary *insulation* between accessible parts and *live parts* of circuits of *DVC A* or B which are separated by *basic insulation* from *adjacent circuits* of *DVC C*. The relevant voltage is the highest voltage of the *adjacent circuits* (see Table A.4, upper cells 3b), 3c)).
- *Basic insulation* between accessible parts and *live parts* of circuits of *DVC B* which have protective *separation* from *adjacent circuits* of *DVC C*. The relevant voltage is that of the *live parts* (see Table A.4, lower cells 3b), 3c)).

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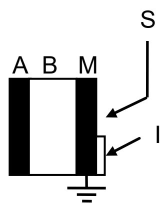
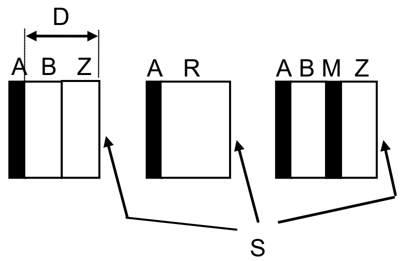
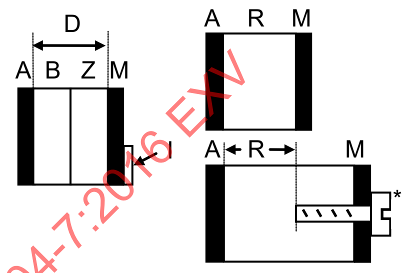
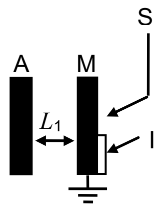
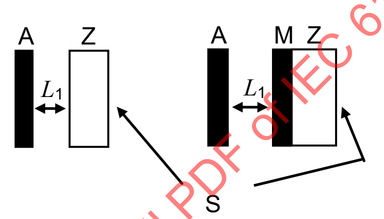
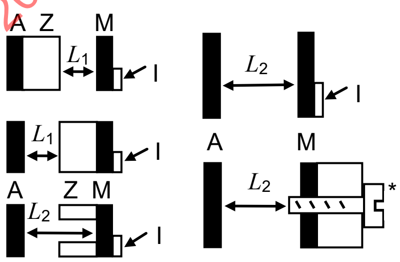
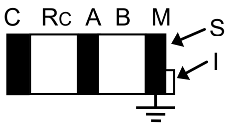
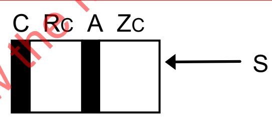
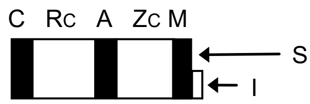
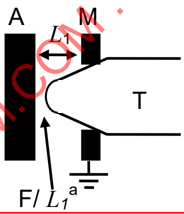
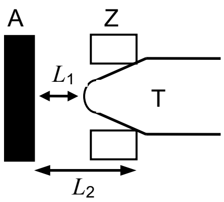
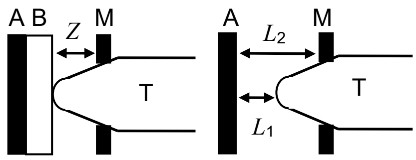
Table A.4 – Examples for protection against electrical shock

Type of *insulation*	*Insulation* configuration		
	a Accessible conductive parts connected to earth by *protective equipotential bonding*	b Accessible parts not conductive	c Accessible parts conductive, but NOT connected to earth by *protective equipotential bonding*
1. Solid			
2. Totally or partially by air clearance			
3. *Insulation* for *adjacent circuits*: **Circuit A: lower voltage circuit** **Circuit C: higher voltage circuit; *DVC C***			
4. Requirements for apertures in *enclosures*			

A	*live part*	L_1	clearance for *basic insulation*	T	test finger (Clause 12 of IEC 60529:1989)
B	*basic insulation* for circuit A	L_2	clearance for *reinforced insulation*	Z	*supplementary insulation* for circuit A
Bc	*basic insulation* for circuit C	M	conductive part	Zc	*supplementary insulation* for circuit C
C	*adjacent circuit*	R	*reinforced insulation* for circuit A	*	also applies to plastic screws
D	*double insulation* for circuit A	Rc	*reinforced insulation* for circuit C	F	*functional insulation* for circuit A
I	*insulation* less than B	S	surface of equipment		

NOTE 1 In column c) a plastic screw is treated like a metal screw because a user could replace it with a metal screw during the life of the equipment.

NOTE 2 In row 4, the insertion of the test finger is considered to represent the first fault.

[a] *Functional insulation* is sufficient if the opening is covered during normal operation. It shall not be possible to remove the cover without the use of a tool or key. If the opening is not covered during normal operation, *basic insulation* is required.

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Annex B
(informative)

Considerations for the reduction of the pollution degree

B.1 Introduction

The objective of this annex is to give an overview of what factors should be considered to reduce the pollution degree for electrical equipment in order to allow for a reduction of the clearance and creepage distances. As the measures to be taken depend heavily on the nature of pollution, no comprehensive guidance can be given on how to achieve the goal of a lower pollution degree for the equipment.

B.2 Factors influencing the pollution degree

The following factors influence the pollution degree:

– Pollution:
  - no pollution;
  - dry non-conductive pollution;
  - dry non-conductive pollution that can become conductive, when moist;
  - conductive pollution.

NOTE Pollution may be external or may be internally generated or present internally at the conclusion of manufacturing.

– Moisture:
  - no or low moisture without condensation;
  - temporary condensation;
  - permanent moisture;
  - rain or snow.

B.3 Reduction of influencing factors

Following are some measures that may be applied to reduce the influencing factors. The described measures to meet the requirements are only illustrative. There may be other possibilities.

– Coating (see 4.4.7.6);

– IP5X (dust test according to IEC 60529);

– IPX4.. IPX8 depending on the environment.

When hermetically sealing an electrical equipment, it should be ensured that the moisture level will be at the required low level when resealing the equipment after opening the enclosure (e.g. for service).

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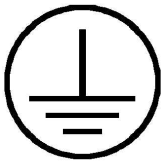
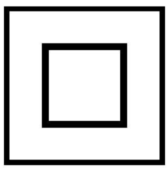
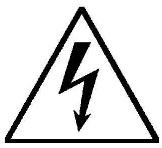
Annex C
(informative)

Symbols referred to in IEC 62477-1

Table C.1 – Symbols used

Symbol	Standard reference	Description	Subclauses
	IEC 60417–5019 (2011-01)	*PE conductor* terminal	4.4.4.3.2, 6.3.7.2
	ISO 7010–W001 (2011-06)	Caution, refer to documentation	4.4.4.3.3, 4.4.8, 6.3.7.2
	IEC 60417-5018 (2011-01)	Functional earthing terminal	4.4.6.3
	IEC 60417–5172 (2011-01)	Class II (double insulated) equipment	4.4.6.3
	IEC 60417-6042 (2012-05)	Caution, risk of electric shock	4.4.9, 6.5.2
	IEC 60417-5041 (2012-05)	Caution, hot surface	4.6.4.2, 6.4.3.4

In addition, additional symbols are outlined in Table C.100.

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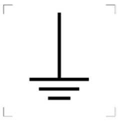
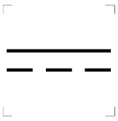
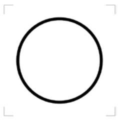
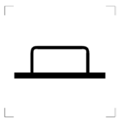
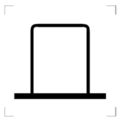
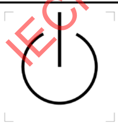
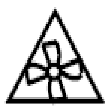
Table C.100 – Symbols

Symbol	Publication	Description
	IEC 60417-5017 (2002-10)	Earth (ground), bonding to earth
	IEC 60417-5031 (2002-10)	Direct current
	IEC 60417-5032 (2002-10)	Alternating current
	IEC 60417-5033 (2002-10)	Both direct and alternating current
	IEC 60417-5032-1 (2002-10)	Three-phase alternating current
	IEC 60417-5007 (2002-10)	On (supply)
	IEC 60417-5008 (2002-10)	Off (supply)
	IEC 60417-5268 (2002-10)	In position of a bistable push control
	IEC 60417-5269 (2002-10)	Out position of a bistable push control
	ISO 7000-0434 (2004-01) and ISO 7000-1641 (2004-01)	A symbol or set of symbols such as ISO 7000-0434 and ISO 7000-1641 to refer to text in an accompanying document. These symbols may be combined.
	IEC 60417-5009 (2015-03)	Symbol used for “stand-by” condition.
	Not existing in IEC 60417.	Either the symbol, or a similar symbol, combined with the triangle shaped warning sign from ISO 3864-2:2004 can be used.

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Annex D
(normative)

Evaluation of clearance and creepage distances

D.1 Measurement

Clearance and creepage distances shall be evaluated as illustrated in the examples contained in Examples D.1 to D.14.

For paths consisting of parts with different pollution degrees, as for example when including a cemented joint that provides protection type 1 (IEC 60664-3) in a pollution degree 2 environment, the clearance and creepage distances are determined according to Table 10 and Table 11, using the following rules:

– In general a creepage distance may be split in several portions of different materials and/or have different pollution degrees if one of the creepage distances is dimensioned to withstand the total voltage or if the total distance is dimensioned according to the material having the lowest CTI and the highest pollution degree.

– For creepage distances for *functional insulation* on PWB and components assembled on PWB, designed for pollution degree 1 and 2, the sum of the determining voltages of each part of the path shall not be less than the determining voltage of the circuits involved. The distances for each portion of the creepage distance under consideration shall comply with the minimum distances according to Table D.1.

D.2 Relationship of measurement to pollution degree

The "X" values are a function of pollution degree and shall be as specified in Table D.1. If the associated permitted clearance is less than 3 mm, the X value is one third of the clearance.

Table D.1 – Width of grooves by pollution degree

Pollution degree	X value mm
1	0,25
2	1,0
3	1,5

D.3 Examples

In the Examples D.1 to D.14 below, clearance and creepage distances are denoted as follows:

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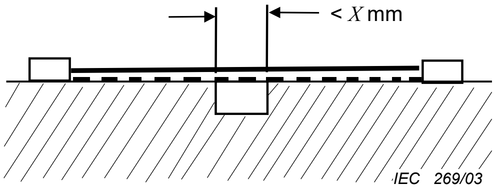
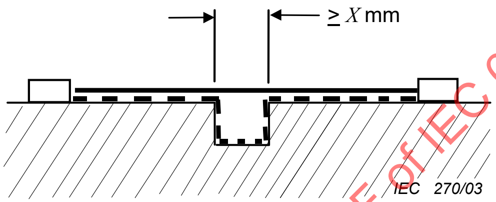


Condition: The path under consideration includes a parallel, diverging or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

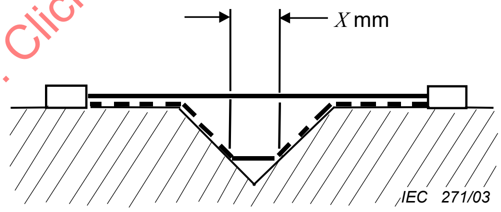
Example D.1



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

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

Example D.2



Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove but "short circuits" the bottom of the groove by X mm link.

Example D.3

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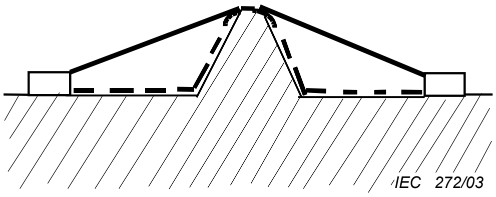
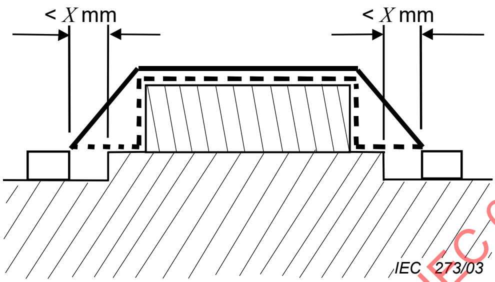


Condition: Path under consideration includes a rib.

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

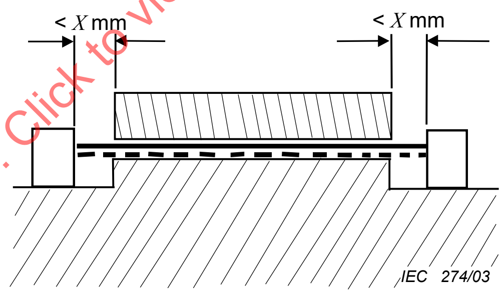
Example D.4



Condition: Path under consideration includes a cemented joint that provides protection of type 2 with grooves less than X mm wide on each side.

Rule: Clearance is the shortest air path over the top of the joint. Creepage distance is measured directly across the grooves and follows the contour of the joint.

Example D.5



Condition: Path under consideration includes an uncemented joint or a cemented joint that provides protection of type 1 with grooves less than X mm wide on each side.

Rule: Creepage and clearance path is the "line of sight" distance shown.

Example D.6

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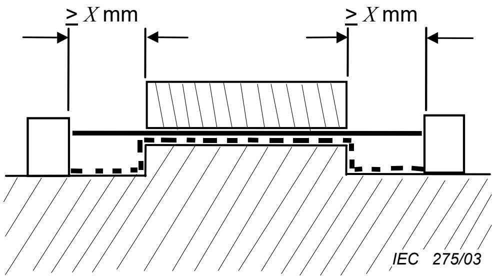
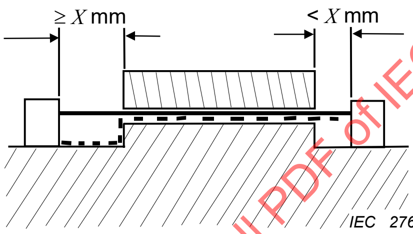


Condition: Path under consideration includes an uncemented joint or a cemented joint that provides protection of type 1 with grooves equal to or more than X mm wide on each side.

Rule: Clearance is the “line of sight” distance. Creepage path follows the contour of the grooves.

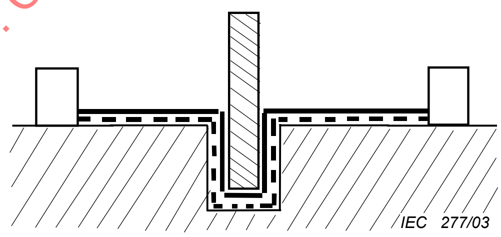
Example D.7



Condition: Path under consideration includes an uncemented joint or a cemented joint that provides protection of type 1 with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage paths are as shown.

Example D.8



Condition: Path under consideration includes an uncemented barrier or a cemented joint that provides protection of type 1 when path under the barrier is less than the path over the barrier.

Rule: Clearance and creepage paths follow the contour under the barrier.

Example D.9

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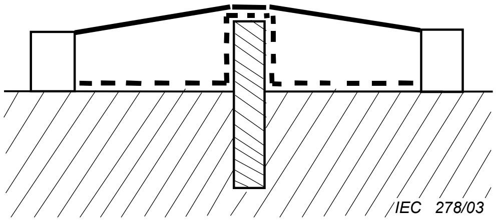
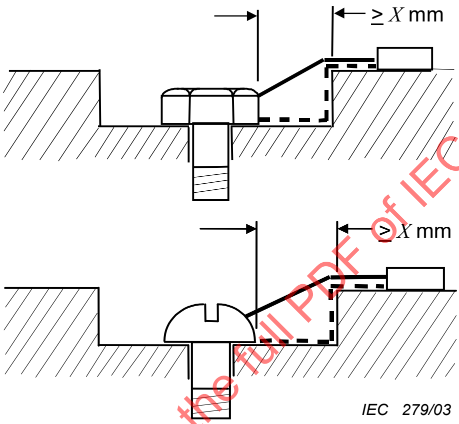


Condition: Path under consideration includes an uncemented or a cemented barrier when path over the barrier is less than the path under the barrier.

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

Example D.10



Condition: Path under consideration includes a gap between head of screw and wall of recess which is equal to or more than X mm wide.

Rule: Clearance is the shortest air path through the gap and over the top surface. Creepage path follows the contour of the surfaces.

Example D.11

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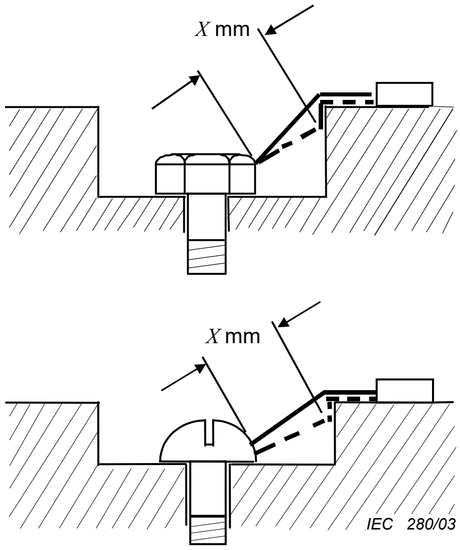
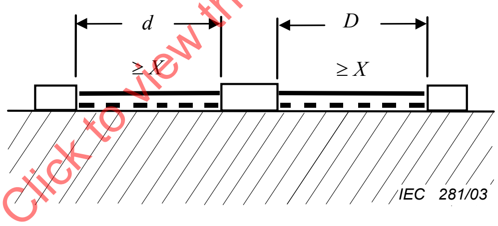


Condition: Path under consideration includes a gap between head of screw and wall of recess which is less than X mm wide.

Rule: Clearance is the shortest air path through the gap and over the top surface. Creepage path follows the contour of the surfaces but "short circuits" the bottom of the recess by X mm link.

Example D.12



Condition: Path under consideration includes an isolated part of conductive material.

Rule: Clearance and creepage paths are the sum of d plus D.

Example D.13

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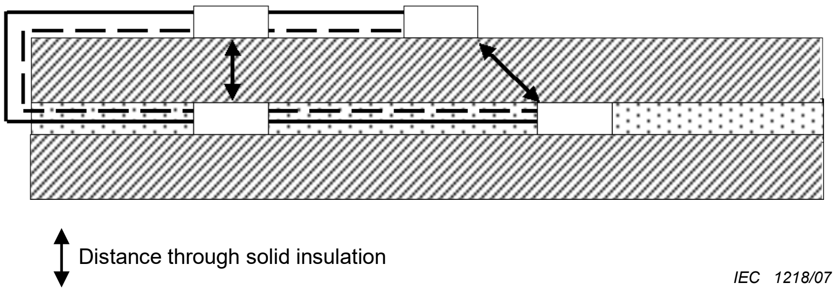
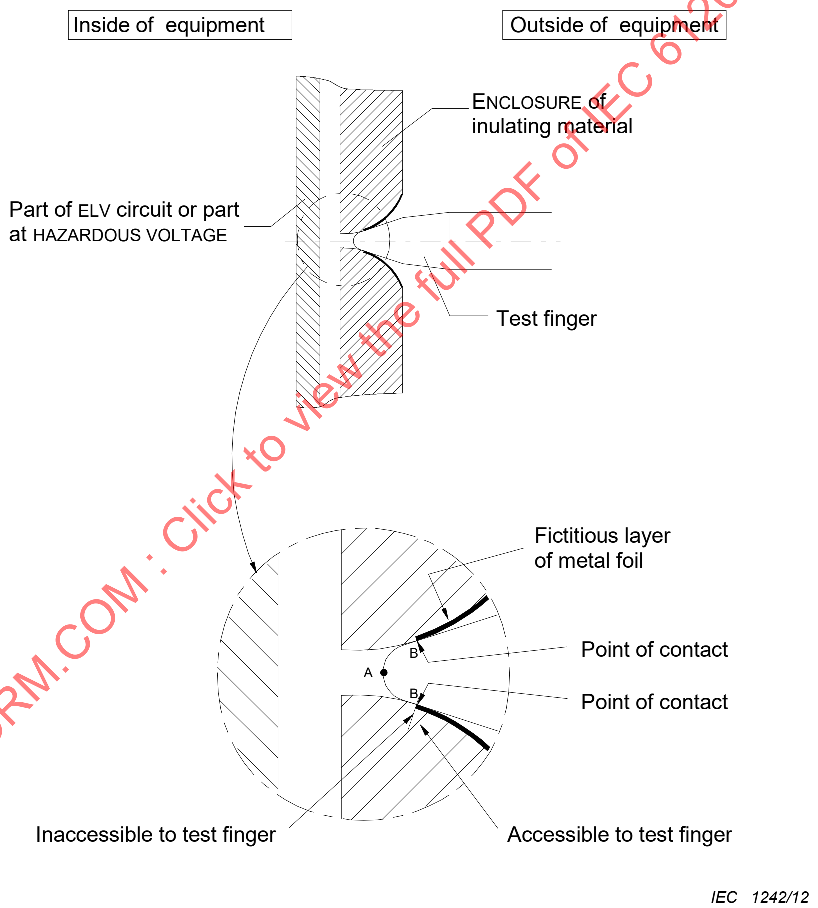


Condition: Path under consideration includes inner layer of PWB.

Rule: For the inner layer(s), the distance between adjacent tracks on the same layer is treated as creepage distance for pollution degree 1 and clearance as in air (see 4.4.7.8.4.1).

Example D.14



Point A is used for determining the air gap to a part inside the *enclosure*.

Point B is used for measurements of clearance and creepage distance from the outside of an *enclosure* of insulating material to a part inside the *enclosure*.

Example D.15 – Example of measurements in an *enclosure* of insulating material

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Annex E
(informative)

Altitude correction for clearances

Refer to 4.4.7.4.1 in combination with the correction factor from Table E.1 for clearances at altitudes between 2 000 m and 20 000 m.

Table E.1 – Correction factor for clearances at altitudes between 2 000 m and 20 000 m

Altitude m	Normal barometric pressure kPa	Multiplication factor for clearances
2 000	80,0	1,00
3 000	70,0	1,14
4 000	62,0	1,29
5 000	54,0	1,48
6 000	47,0	1,70
7 000	41,0	1,95
8 000	35,5	2,25
9 000	30,5	2,62
10 000	26,5	3,02
15 000	12,0	6,67
20 000	5,5	14,50

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Table E.2 – Test voltages for verifying clearances at different altitudes

Impulse voltage (from Table 9) kV	Impulse test voltage at sea level kV	Impulse test voltage at 200 m altitude kV	Impulse test voltage at 500 m altitude kV
0,33	0,36	0,36	0,35
0,50	0,54	0,54	0,53
0,80	0,93	0,92	0,90
1,50	1,8	1,7	1,7
2,50	2,9	2,9	2,8
4,00	4,9	4,8	4,7
6,00	7,4	7,2	7,0
8,00	9,8	9,6	9,4
12,00	15	14	14

NOTE 1 Explanations concerning the influencing factors (air pressure, altitude, temperature, humidity) with respect to electric strength of clearances are given in 6.1.2.2.1.3 of IEC 60664-1:2007.

NOTE 2 When testing clearances, associated solid *insulation* will be subjected to the test voltage. As the impulse test voltage is increased with respect to the rated impulse voltage, solid *insulation* will have to be designed accordingly. This results in an increased impulse withstand capability of the solid *insulation*.

NOTE 3 Values given above have been rounded from the calculation in 6.1.2.2.1.3 of IEC 60664-1:2007.

The voltage values of Table E.2 apply for the verification of clearances only.

Annex F
(normative)

Clearance and creepage distance determination for frequencies greater than 30 kHz

NOTE No further considerations made by the product committee in respect to F.4.3.

F.1 General influence of the frequency on the withstand characteristics

The *insulation* requirement for clearance, creepage and solid *insulation* as mentioned in 4.4.7 are given for frequencies up to and including 30 kHz. For higher frequencies, a reduction of the withstand capability of any type of *insulation* needs to be expected and taken into account for dimensioning.

For frequencies greater than 30 kHz and up to 10 MHz, IEC 60664-4 needs to be applied together with IEC 60664-1, for the design of clearance and creepage distances as well as solid *insulation*.

This annex provides detailed information for the design of clearance, creepage and solid *insulation* based on the requirement from IEC 60664-4.

The following situation needs to be considered for the design:

– clearance distance for inhomogenous fields (see F.2.2);

– clearance distance for approximately homogenous fields (see F.2.3);

– creepage distance (see F.3);

– solid *insulation* (see F.4).

The result of the investigation for frequencies above 30 kHz shall be compared to the investigation in 4.4.7 and the greater value of the two investigations shall be chosen.

F.2 Clearance

F.2.1 General

The withstand voltage capability within the scope of IEC 60664-4 will only be influenced by the frequency for periodic voltages. For transient overvoltages, dimensioning according to 4.4.7.4 shall be used.

For frequencies exceeding 30 kHz within the scope of IEC 60664-4, the withstand voltage capability of clearances with homogenous and approximately homogenous field distribution can be reduced by up to 25 %.

The requirement for clearance will depend on the field distribution of the *insulation* under investigation.F.2.2 will give the requirement for clearance distance for inhomogenous fields and F.2.3 provides design criteria for clearance distance for approximately homogenous fields.

For frequencies exceeding 30 kHz, an approximately homogeneous field is considered to exist when the radius of curvature r of the conductive parts is equal or greater than 20 % of the clearance. The necessary radius of curvature can only be specified at the end of the dimensioning procedure.

The result of the investigation of clearance for frequencies above 30 kHz shall be compared to the investigation in 4.4.7.4 and the greater value of the two investigations shall be chosen.

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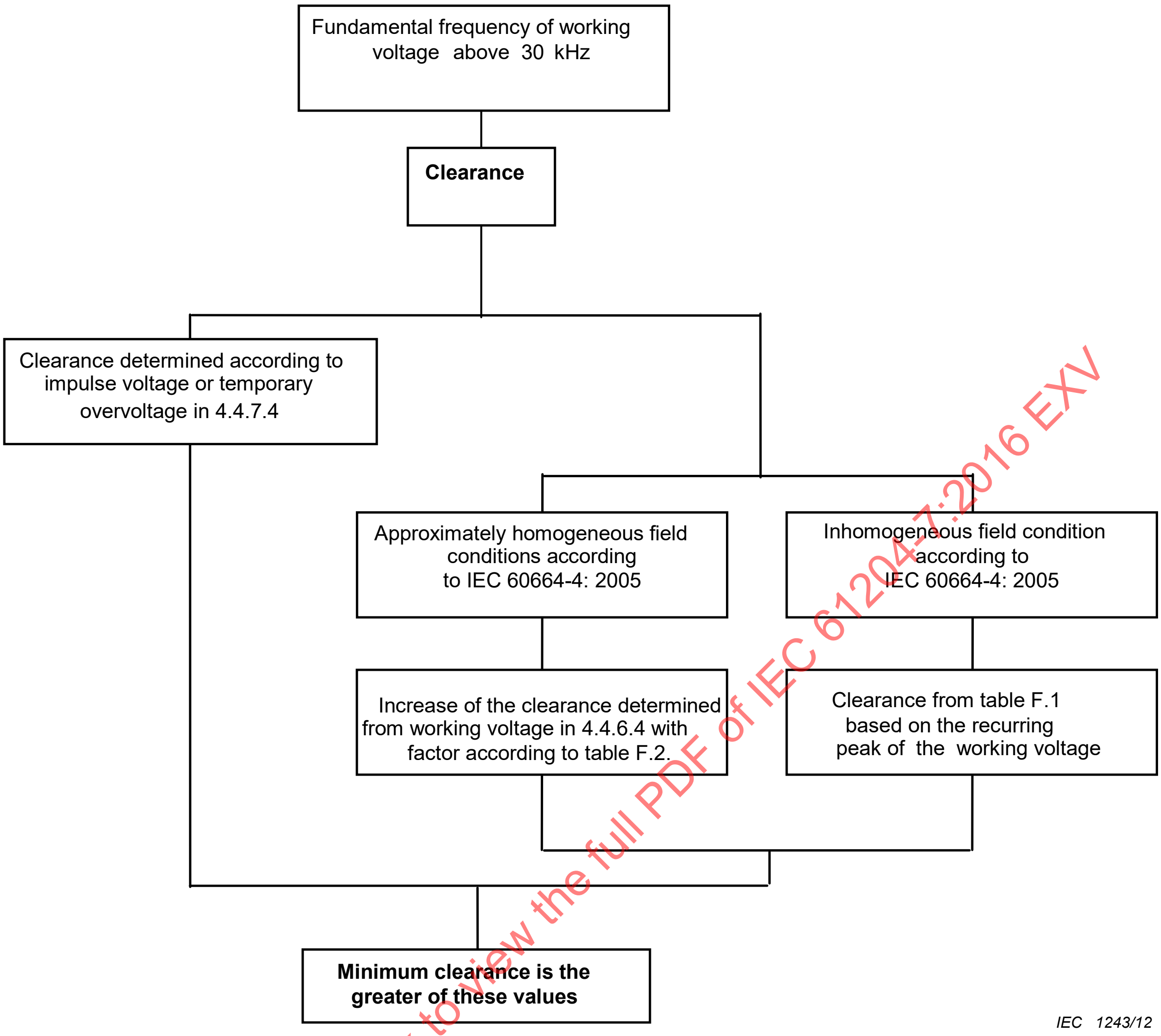

Figure F.1 – Diagram for dimensioning of clearances

F.2.2 Clearance for inhomogenous fields

For frequencies exceeding 30 kHz, an inhomogeneous field is considered to exist when the radius of curvature of the conductive parts is less than 20 % of the clearance. For inhomogeneous field distribution, the reduction of the withstand voltage capability of clearances can be much higher.

Dimensioning for inhomogeneous field distribution is done for the required withstand voltage of the clearance according to the values in Table F.1. No withstand voltage test other than the requirement in 4.4.7 is required.

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Table F.1 – Minimum values of clearances in air at atmospheric pressure for inhomogeneous field conditions (Table 1 of IEC 60664-4:2005)

Peak voltage [a] kV	Clearance mm
≤ 0,6 [b]	0,065
0,8	0,18
1,0	0,5
1,2	1,4
1,4	2,35
1,6	4,0
1,8	6,7
2,0	11,0

[a] For voltages between the values stated in this table, interpolation is permitted.

[b] No data is available for peak voltages less than 0,6 kV.

The dimensioning for inhomogeneous field and high voltage stress (>1 kV condition) leads to impractical distances. It is therefore preferable to choose a design improving the field distribution (approximately homogeneous field distribution).

F.2.3 Clearance for approximately homogenous fields

For clearance with approximately homogenous fields conditions the clearance found in table Table 10, where the clearance is determined on the *working voltage* or recurring peak voltage (column 2 or 3), is increased by a multiplication factor depending on the fundamental frequency. The multiplication factors are indicated in Table F.2.

Table F.2 – Multiplication factors for clearances in air at atmospheric pressure for approximately homogeneous field conditions

Fundamental frequency kHz	Multiplication factor
$30 < f_{\text{fundamental}} \leq 500$	1,05
$500 < f_{\text{fundamental}} \leq 1\,000$	1,10
$1\,000 < f_{\text{fundamental}} \leq 2\,000$	1,20
$2\,000 < f_{\text{fundamental}} \leq 3\,000$	1,25

NOTE 1 The multiplication factors are determined based on calculations as per IEC 60664-4:2005, 4.3.3. More precise calculation can be determined using the equation in IEC 60664-4:2005, 4.3.3.

NOTE 2 Circuits where the clearance is designed based on the impulse withstand voltage (Table 10, column 1), will normally not be affected by these considerations.

The dimensioned clearance, for approximately homogenous field conditions, is applicable for frequencies above the critical frequency calculated by means of following equation taking into account the new distance from Table F.2:

$$f_{\text{crit}} \approx \frac{0{,}2}{d}\left(\frac{\text{MHz}}{\text{mm}}\right)$$

F.3 Creepage distance

For frequencies of the voltage greater than 30 kHz, in addition to tracking, thermal effects need to be taken into account with respect to the withstand capability of creepage distances.

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Dimensioning is performed both for the required r.m.s. withstand voltage of the creepage distance according to the values in Table 11 and for the required peak withstand voltage according to the values in Table F.3. This peak withstand voltage is the highest value of any periodic peak of the voltage across the creepage distance. The greater of the distances is applicable. The dimensioning according to Table F.3 is applicable for all insulating materials which can deteriorate due to thermal effects. This includes typical base materials for printed circuit boards made from epoxy resin. For materials which cannot deteriorate due to thermal effects and where no tracking needs to be expected, dimensioning according to the clearance requirements, as described in 4.4.7.5, is sufficient.

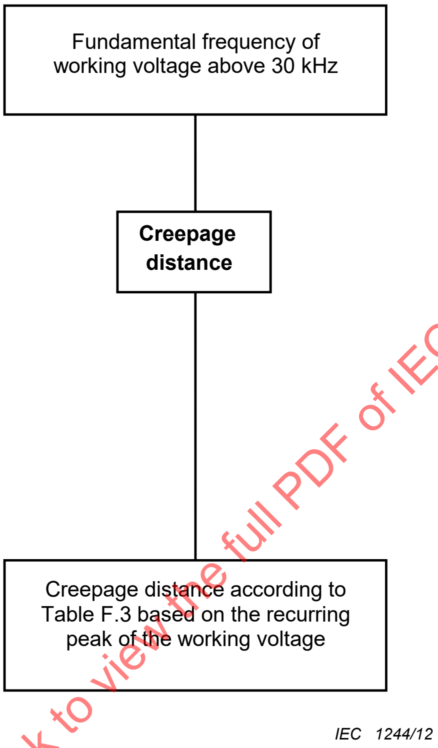

Figure F.2 – Diagram for dimensioning of creepage distances

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Table F.3 – Minimum values of creepage distances for different frequency ranges (Table 2 of IEC 60664-4:2005)

Peak voltage kV	Creepage distance [a] [b] mm						
	30 kHz < f ≤ 100 kHz	f ≤ 0,2 MHz	f ≤ 0,4 MHz	f ≤ 0,7 MHz	f ≤ 1 MHz	f ≤ 2 MHz	f ≤ 3 MHz
0,1	0,0167						0,3
0,2	0,042					0,15	2,8
0,3	0,083	0,09	0,09	0,09	0,09	0,8	20
0,4	0,125	0,13	0,15	0,19	0,35	4,5	
0,5	0,183	0,19	0,25	0,4	1,5	20	
0,6	0,267	0,27	0,4	0,85	5		
0,7	0,358	0,38	0,68	1,9	20		
0,8	0,45	0,55	1,1	3,8			
0,9	0,525	0,82	1,9	8,7			
1	0,6	1,15	3	18			
1,1	0,683	1,7	5				
1,2	0,85	2,4	8,2				
1,3	1,2	3,5					
1,4	1,65	5					
1,5	2,3	7,3					
1,6	3,15						
1,7	4,4						
1,8	6,1						

[a] The values for the creepage distances in the table apply for pollution degree 1. For pollution degree 2, a multiplication factor of 1,2 and for pollution degree 3 a multiplication factor 1,4 should be used.

[b] Interpolation between columns is permitted.

F.4 Solid insulation

F.4.1 General

Due to increased heating effects and accelerated deterioration in solid *insulation* further consideration is needed, when using solid *insulation* across *insulation* affected by frequencies above 30 KHz.

F.4.2 Approximately uniform field distribution without air gaps or voids

For solid *insulation* where uniform field distribution is present and no air gaps or voids are present in the solid *insulation*, the maximum field distribution shall be calculated as following:

– For thick layers of solid *insulation* of $d_1 \geq$ 0,75 mm the peak value of the field strength E needs to be equal or less than 2 kV/mm.

– For thin layers of solid *insulation* of $d_2 \leq$ 30 µm the peak value of the field strength needs to be equal or less than 10 kV/mm.

– For $d_1 > d > d_2$ Equation (1) is used for interpolation for a certain thickness d (see also Figure F.3):

$$E = \left(\frac{0{,}25}{d} + 1{,}667\right)\left(\frac{\text{kV}}{\text{mm}}\right) \tag{1}$$

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