

INTERNATIONAL STANDARD



GROUP SAFETY PUBLICATION

Safety of ~~power~~ transformers, ~~power supplies~~, reactors, power supply units and
~~similar products~~ combinations thereof –
Part 1: General requirements and tests

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Part 1: General requirements and tests

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SAFETY OF ~~POWER TRANSFORMERS, POWER SUPPLIES, REACTORS,~~
POWER SUPPLY UNITS AND ~~SIMILAR PRODUCTS~~
COMBINATIONS THEREOF –****Part 1: General requirements and tests**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61558-1 has been prepared by IEC technical committee 96: Transformers, reactors, power supply units and combinations thereof.

This third edition cancels and replaces the second edition published in 2005 and Amendment 1:2009. This edition constitutes a technical revision.

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

- a) fully insulated winding wires (FIW), new tables and aging tests for FIW constructions,
- b) overvoltage categories 1, 2, 3 and 4 for clearances and dielectric strength tests (new tables) are included,
- c) development of new symbols for the different overvoltage categories,
- d) symbol for maximum altitudes, if higher than 2 000 m,
- e) symbol for plug in power supply units, if the pins are damaged (tumbling barrel test),
- f) symbol for minimum temperature (even during the transportation),
- g) alternative temperature measurement, simulated load and back to back method according to IEC 60076-11,
- h) short circuit and overload protection, simulated load and back to back method according to IEC 60076-11,
- i) adjustment of temperatures in Table 2 according to CENELEC Guide 29,
- j) establishing partial discharge test above 750 V for FIW constructions,
- k) requirements for toroidal core constructions, division for basic and for supplementary isolation,
- l) modification of protection indexes for enclosures (IP-code),
- m) dimensioning of rectangular cross section connectors for transformers,
- n) repetition test, 80 % of required dielectric strength test voltage of Table 14,
- o) vibration test for vehicles and railway applications,
- p) two Y1 Capacitors for working voltages above 250 V and not exceeding 500 V with overvoltage category 3.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
96/466/FDIS	96/468/RVD

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

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

It has the status of a group safety publication in accordance with IEC Guide 104.

A list of all parts of the IEC 61558 series, published under the general title *Safety of transformers, reactors, power supply units and combination thereof*, 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.

In this document, the following print types are used:

- proper requirements: in roman type;
- *test specifications: in italic type*;
- explanatory matters: in smaller roman type.

In the text of the document, the words in **bold** are defined in Clause 3.

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- replaced by a revised edition, or
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INTRODUCTION

This document covers safety requirements for **transformers**. Where the term **transformer** is used, it covers **transformers**, **reactors** and **power-supplies supply units** where applicable.

During the development of this document, to the extent possible, the requirements of IEC 60364 (all parts) were taken into consideration, so that a **transformer** ~~may~~ can be installed in accordance with the wiring rules contained in that document. However, national wiring rules ~~may~~ can differ.

This document recognizes the internationally accepted levels of protection against the possible electrical, mechanical, and fire hazards caused by **transformers** operating under normal conditions in accordance with the manufacturer's instructions. It also covers abnormal conditions which ~~may~~ can occur in practice.

A **transformer** complying with this document will not necessarily be judged to comply with the safety principles of this document if, when examined and tested, it is found to have other features that impair the level of safety covered by these requirements.

A **transformer** employing materials or having forms of construction differing from those detailed in this document may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the safety principles of this document.

The document dealing with non-safety aspects of electromagnetic compatibility (EMC) of **transformers** is IEC 62041: ~~Power transformers, power supply units, reactors and similar products — EMC requirements~~. However, that document also includes tests that ~~may~~ can subject the **transformer** to conditions involving safety aspects.

The objective of IEC 61558-1 is to provide a set of requirements and tests considered to be generally applicable to most types of **transformers**, and which can be called up as required by the relevant part of IEC 61558-2. IEC 61558-1 is thus not to be regarded as a specification by itself for any type of **transformer**, and its provisions apply only to particular types of **transformers** to the extent determined by the appropriate part of IEC 61558-2. IEC 61558-1 also contains normative routine tests.

Each part of IEC 61558-2 in conjunction with this document contains all the necessary requirements for the **transformer** being covered and does not contain references to other parts of IEC 61558-2. For **transformers** with a protection index IP00 and associated **transformers**, it is possible to have circuits corresponding to different parts of IEC 61558-2 within the same construction (e.g. SELV output circuit according to IEC 61558-2-6 and a 230 V output circuit according to IEC 61558-2-4). However, if the **transformer** is covered by different parts IEC 61558-2, to the extent reasonable, the relevant part of IEC 61558-2 is applied to each function/application separately. If applicable, the effect of one function on the other is taken into consideration.

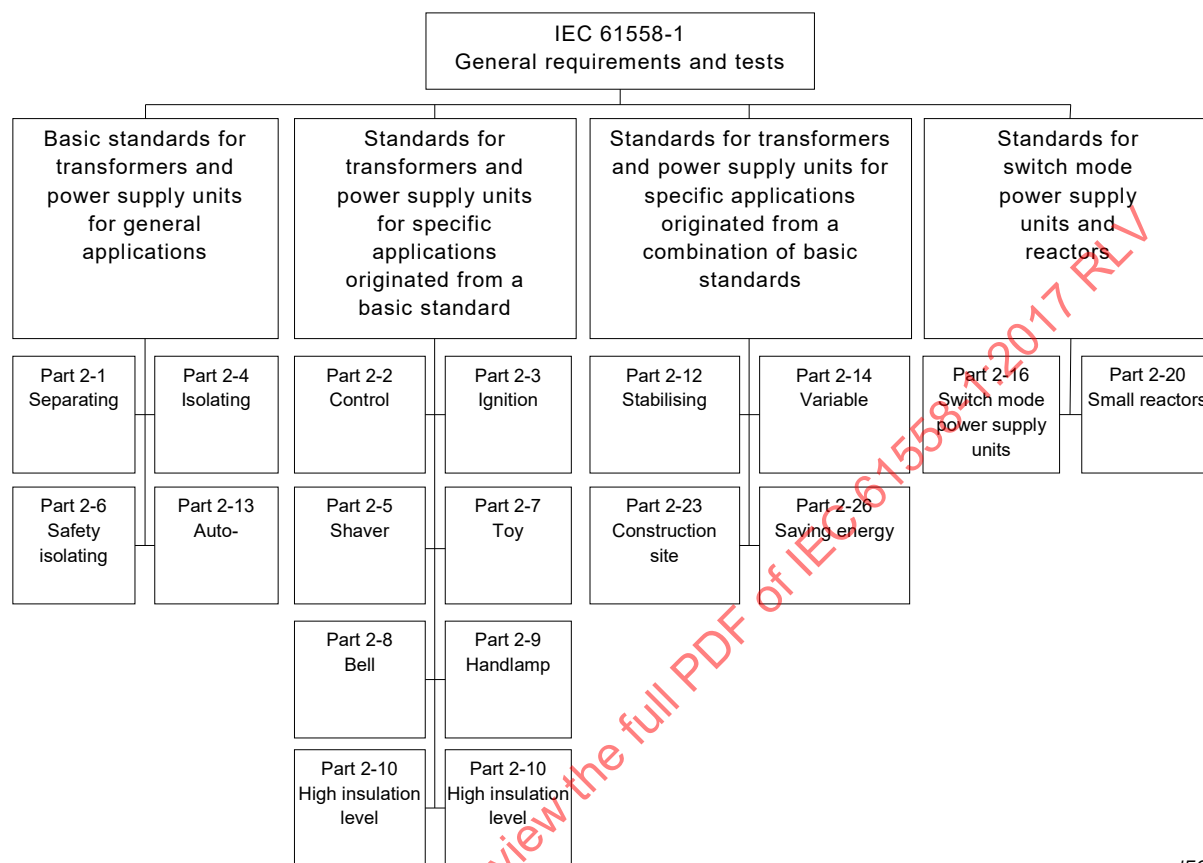
If an appropriate part of IEC 61558-2 does not exist for a particular **transformer** or group of **transformers**, the nearest applicable part may be used as a guide to the requirements and tests.

However, individual countries may wish to consider its application, to the extent reasonable, to transformers not mentioned in the IEC 61558-2 series, and to transformers designed on new principles.

Where the requirements of any of the clauses of a part of IEC 61558-2 refer to IEC 61558-1 by the phrase "This clause of Part 1 is applicable", this phrase means that all the requirements of that clause of IEC 61558-1 are applicable, except those requirements that are

clearly not applicable to the particular type of **transformer** covered by that part of IEC 61558-2.

The principle for the preparation of the different parts of IEC 61558-2 is as shown in Figure 1.



IEC

Figure 1 – IEC 61558 principle

Relevant clauses of this document (e.g. clauses dealing with thermal endurance test for windings) apply also to **transformers** forming an integral part of an appliance and which cannot be tested separately.

~~As an option, the thermal characteristics of **transformers** can be specified by the rated maximum operating temperature of the winding (symbol t_w) which shall not be exceeded to ensure a minimum lifetime as specified in Annex U. In addition, for **transformers** subjected to abnormal conditions as specified in Clause 15, the specified temperature limit shall not be exceeded when the **transformer** is built into an appliance or used as an independent **transformer**.~~

The IEC 61558 series consists of the following parts, under the general title *Safety of transformers, reactors, power supply units and combination thereof*:¹

Part 1: General requirements and tests

Part 2-1: Particular requirements and tests for separating transformers for general applications

Part 2-2: Particular requirements and tests for control transformers

¹ Some of the parts of this series published earlier appeared under the general title *Safety of power transformers, power supplies, reactors and similar products* or *Safety of power transformers, power supply units and similar* or *Safety of power transformers, power supply units and similar devices*. Future editions of these parts will be issued under the new general title indicated above.

- Part 2-3: Particular requirements and tests for ignition transformers for gas and oil burners
 - Part 2-4: Particular requirements and tests for isolating transformers
 - Part 2-5: Particular requirements and tests for shaver transformers and shaver supply units
 - Part 2-6: Particular requirements and tests for safety isolating transformers
 - Part 2-7: Particular requirements and tests for transformers for toys
 - Part 2-8: Particular requirements and tests for transformers for bells and chimes
 - Part 2-9: Particular requirements and tests for transformers for class III handlamps for tungsten filament lamps
 - Part 2-10: Particular requirements and tests for separating transformers with high insulation level and separating transformers with output voltages exceeding 1 000 V
 - Part 2-12: Particular requirements and tests for constant voltage transformers
 - Part 2-13: Particular requirements and tests for auto transformers
 - Part 2-14: Particular requirements and tests for variable transformers
 - Part 2-15: Particular requirements and tests for isolating transformers for the supply of medical locations
 - Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units
 - Part 2-20: Particular requirements and tests for small reactors
 - Part 2-23: Particular requirements and tests for transformers and power supply units for construction sites
 - Part 2-26: Particular requirements and tests for transformers and power supply units all for saving energy and other purposes
- Other parts are under consideration.

SAFETY OF ~~POWER TRANSFORMERS, POWER SUPPLIES, REACTORS,~~ POWER SUPPLY UNITS AND ~~SIMILAR PRODUCTS~~ COMBINATIONS THEREOF –

Part 1: General requirements and tests

1 Scope

This part of IEC 61558 deals with safety aspects of ~~power transformers, power supplies,~~ reactors, **power supply units** and ~~similar products~~ combinations thereof such as electrical, thermal and mechanical safety.

This document covers the following **independent or associated** stationary or portable types of **dry-type transformers, power-supplies supply units**, including **switch mode power supplies supply units, reactors** and combinations thereof in the field of safety. The windings ~~of which may~~ can be encapsulated or non-encapsulated. They are not forming a part of the distribution network.

NOTE 1 The distinction between transformers, power-~~supplies~~ **supply units** and switch mode power-~~supplies~~ **supply units** is as follows:

- for **transformers**, there is no change in frequency. However, **transformers** (e.g. constant voltage transformers) ~~may can~~ have an internal resonance frequency not exceeding 30 kHz;
- for **power-supplies supply units**, the **internal operational frequency** and waveform are different from the **supply frequency** and waveform, and the **internal operational frequency** does not exceed 500 Hz (see definition 3.1.19);
- for **switch mode power-supplies supply units**, the **internal operational frequency** and waveform are different from the **supply frequency** and waveform and the **internal operational frequency** exceeds 500 Hz and does not exceed 100 MHz.

The relevant parts of IEC 61558-2 ~~may can~~ be found in the introduction of this document.

a) Stationary or portable, single-phase or poly-phase, air-cooled (natural or forced), **isolating and safety isolating transformers, independent or associated, not forming a part of distribution networks and** with the following characteristics:

- **rated supply voltage** not exceeding 1 000 V AC;
- **rated supply frequency** not exceeding 500 Hz;

and complying with the following values, unless otherwise specified in the relevant part of IEC 61558-2:

- for **isolating transformers**:
 - **rated output** for single phase **transformers**, not exceeding 25 kVA, and for poly-phase **transformers** not exceeding 40 kVA;
 - **no-load output voltage** and the **rated output voltage** exceeding 50 V AC, and not exceeding 500 V a.c, or 1 000 V AC to be in accordance with the national wiring rules or for a special application.
- for **safety isolating transformers**:
 - **rated output** for single phase **transformers** not exceeding 10 kVA, and for poly-phase **transformers** not exceeding 16 kVA;
 - **no-load output voltage** and the **rated output voltage** not exceeding 50 V AC between conductors, or between any conductor and protective earthing.

NOTE 2 **Isolating** and **safety isolating transformers** are used where **double or reinforced insulation** between circuits is required by the installation rules or by the appliance specification (for example toys, bells, portable tools, handlamps).

a) **Stationary** or **portable**, single-phase or polyphase, air-cooled (natural or forced) **separating transformers**, **auto-transformers**, **variable transformers** and small **reactors**, **independent** or **associated**, ~~not forming a part of distribution networks and~~ with the following characteristics:

- **rated supply voltage** not exceeding 1 000 V AC;
- **rated supply frequency** not exceeding 500 Hz;

and complying with the following values, unless otherwise specified in the relevant part of IEC 61558-2:

- no-load output voltage or a rated output voltage for both independent and associated **transformers** not exceeding 15 kV AC, and for independent **transformers**, a rated output voltage not less than 50 V AC;
- **rated output** not exceeding the following values:
 - 1 kVA for single-phase **transformers**;
 - 2 kVAR for single-phase **reactors**;
 - 5 kVA for polyphase **transformers**;
 - 10 kVAR for polyphase **reactors**.

NOTE 3 **Separating transformers** are used where **double** or **reinforced insulation** between circuits is not required by the installation rules or by the appliance specification.

NOTE 4 Normally, the **transformers** of type b) are intended to be associated with the equipment to provide voltages different from the supply voltage for the functional requirements of the equipment. The protection against electric shock ~~may~~ can be provided or completed by other features of the equipment, such as the **body**. Parts of **output circuits** ~~may~~ can be connected to the **input circuit** or to the protective earthing.

b) **Stationary** or **portable**, single-phase or polyphase, air-cooled (natural or forced), **independent** or **associated power-supplies supply units** and **switch mode power supplies supply units** incorporating one or more **transformer(s)** of type a) or b), ~~not forming a part of distribution networks and~~ with the following characteristics:

- **rated supply voltage** not exceeding 1 000 V AC;
- **rated supply frequency** not exceeding 500 Hz;
- internal operational frequency for power ~~supplies~~ **supply units** not exceeding 500 Hz and for switch mode power ~~supplies~~ **supply units** not exceeding 100 MHz;

and with the following values, unless otherwise specified in the relevant part of IEC 61558-2:

- for power ~~supplies~~ **supply units** and switch mode power ~~supplies~~ **supply units** incorporating **isolating transformers**:
 - **rated output** for single- phase or polyphase **power-supplies supply units** or **switch mode power-supplies supply units** not exceeding 1 kVA;
 - **no-load output voltage** and the **rated output voltage** exceeding 50 V AC or 120 V ripple-free DC, and not exceeding 500 V AC or 708 V ripple-free DC, or 1 000 V AC or 1 415 V ripple- free DC to be in accordance with national wiring rules or for a special application;
- for **power-supplies supply units** and **switch mode power-supplies supply units** incorporating **safety isolating transformers**:
 - **rated output** for single- phase or polyphase **power-supplies supply units** and **switch mode power-supplies supply units** not exceeding 1 kVA;
 - **no-load output voltage** and **rated output voltage** not exceeding 50 V AC or 120 V ripple-free DC between conductors, or between any conductor and protective earthing.

NOTE 5 **Power-supplies supply units** and **switch mode power-supplies supply units** incorporating **isolating** and **safety isolating transformers** are used where **double** or **reinforced insulation** between circuits is required by the installation rules or by the appliance specification (for example toys, bells, portable **tools**, handlamps).

- for **power-supplies supply units** and **switch mode power-supplies supply units** incorporating **separating transformers**, **auto-transformers**, and **variable transformers**:
 - **rated output** for single-phase or polyphase **power-supplies supply units** and **switch mode power-supplies supply units** not exceeding 1 kVA;
 - **no-load output voltage** and **rated output voltage** for both, **independent** and **associated transformers** not exceeding 15 kV AC, and for **independent transformers**, a **rated output voltage** not less than 50 V AC.

NOTE 6 **Power-supplies supply units** and **switch mode power-supplies supply units** incorporating **separating transformers** are used where **double** or **reinforced insulation** between circuits is not required by the installation rules or by the appliance specification.

~~d) This standard is also applicable to t_w -marked transformers with a rated output not exceeding 1 000 VA and where the t_w temperature does not exceed 140°C ($t_w - 140$). However, t_w -marking of transformers is optional.~~

This document also applies to **transformers**, **power-supplies supply units**, **switch mode power-supplies supply units** and **reactors** incorporating electronic circuits.

This document is applicable to **transformers** without limitation of the **rated output** subject to an agreement between the purchaser and the manufacturer.

This document does not apply to external circuits and their components intended to be connected to the input ~~and~~ or output terminals or socket-outlets of the **transformers**, **power supplies supply units** and **switch mode power-supplies supply units**, and **reactors**.

NOTE Attention is drawn to the following:

- for **transformers** intended to be used in vehicles, on board ships, and aircraft, additional requirements (from other applicable standards, national rules, etc...) may be necessary;
- measures to protect the **enclosure** and the components inside the enclosure against external influences like fungus, vermin, termites, solar-radiation, and icing ~~should also be~~ **are** considered;
- the different conditions for transportation, storage, and operation of the **transformers** should also be considered;
- additional requirements in accordance with other appropriate standards and national rules ~~may~~ **can** be applicable to **transformers** intended for use in special environments, such as tropical environments.

NOTE Future technological development of **transformers** ~~may~~ **can** necessitate a need to increase the upper limit of the frequencies; until then this document ~~may~~ **can** be used as a guidance document.

2 Normative references

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

IEC 60065:2001 2014, *Audio, video and similar electronic apparatus – Safety requirements for mains operated electronic and related apparatus for household and similar general use*

~~IEC 60068-2-2:1974, Environmental testing – Part 2: Tests – Test B: Dry heat~~

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test FC: Vibration (sinusoidal)*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-31, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

~~IEC 60068-2-32, *Environmental testing – Part 2: Tests – Test Ed: Free fall*~~

IEC 60068-2-75, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60076-11:2004, *Power transformers – Part 11: Dry-type transformers*

IEC TR 60083, *Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC*

IEC 60085:1984 2007, *Electrical insulation – Thermal evaluation and ~~classification of electrical insulation~~ designation*

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

IEC 60127 (all parts), *Miniature fuses*

IEC 60127-3, *Miniature fuses – Part 3: Sub-miniature fuse-links*

IEC 60216 (all parts), *Electrical insulating materials – ~~Properties of~~ Thermal endurance properties*

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

IEC 60227-5:2011, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 5: Flexible cables (cords)*

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

IEC 60245-4:2011, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 4: Cords and flexible cables*

IEC 60269 (all parts), *Low voltage fuses*

IEC 60269-2:2013, *Low voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to K*

~~IEC 60269-2-1, *Low voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Sections I to VI: Examples of types of standardized fuses*~~

IEC 60269-3:2010, *Low voltage fuses – Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household ~~and~~ or similar applications) – Examples of standardized systems of fuses A to F*

~~IEC 60269-3-1, Low voltage fuses – Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications) – Sections I to IV: examples of types of standardized fuses~~

IEC 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes*

IEC 60317 (all parts), *Specifications for particular types of windings wires*

IEC 60317-0-7:2012, *Specifications for particular types of winding wires – Part 0-7: General requirements – Fully insulated (FIW) zero-defect enamelled round copper wire with nominal conductor diameter of 0,040 mm to 1,600 mm*

IEC 60317-56, *Specifications for particular types of winding wires – Part 56: Solderable fully insulated (FIW) zero-defect polyurethane enamelled round copper wire with nominal conductor diameter 0,040 mm to 1,600 mm, class 180*

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

IEC 60320-2-3, *Appliance couplers for household and similar general purposes – Part 2-3: Appliance couplers with a degree of protection higher than IPX0*

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-DB:2002²⁾, *Graphical symbols for use on equipment*
(available at <http://www.graphical-symbols.info/equipment>)

~~IEC 60449:1973, Voltage bands for electrical installations of buildings~~

IEC 60454 (all parts), ~~Specification for~~ *Pressure-sensitive adhesive tapes for electrical purposes*

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

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 60664-1:1992 2007, *Insulation coordination for equipment within low voltage systems – Part 1: Principles, requirements and tests*

IEC 60664-3:2003 2016, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

IEC 60691:2002 2015, *Thermal-links – Requirements and application guide*

IEC 60695-2-10:2013, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:2000 2014, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods –Glow-wire flammability test method for end-products*

~~IEC 60695-10-2, Fire hazard testing – Part 10-2: Abnormal heat – Ball pressure test~~

2) "DB" refers to the IEC on-line database.

IEC 60721-3-2, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 2: Transportation*

IEC 60730 (all parts), *Automatic electrical controls* ~~for household and similar use~~

IEC 60730-1: ~~1999~~ 2013, *Automatic electrical controls* ~~for household and similar use~~ – Part 1: *General requirements*

IEC 60851-3: ~~1996~~ 2009, *Winding wires – Test methods: Part 3: Mechanical properties*

IEC 60851-5: ~~1996~~ 2008, *Winding wires – Test methods: Part 5: Electrical properties*

IEC 60851-6: ~~1996~~ 2012, *Winding wires – Test methods: Part 6: Thermal properties*

IEC 60884-1:2002, *Plugs and socket-outlets for household and similar purposes – Part 1: General requirements*

IEC 60884-1:2002/AMD1:2006

IEC 60884-1:2002/AMD2:2013

IEC 60884-2-4, *Plugs and socket-outlets for household and similar purposes – Part 2-4: Particular requirements for plugs and socket-outlets for SELV*

IEC 60898 (all parts), *Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations*³⁾

IEC 60906-1, *IEC system of plugs and socket-outlets for household and similar purposes – Part 1: Plugs and socket-outlets 16 A 250 V a.c.*

IEC 60906-3, *IEC system of plugs and socket-outlets for household and similar purposes – Part 3: SELV plugs and socket-outlets; 16 A 6 V, 12 V, 24 V, 48 V, a.c. and d.c.*

IEC 60947-7-1, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

IEC 60990: ~~1990~~ 2016, *Methods of measurement of touch current and protective conductor current*

IEC 60998-2-1, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-1: Particular requirements for connecting devices as separate entities with screw-type clamping units*

IEC 60998-2-2, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units*

IEC 60999-1, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units* ~~for electrical copper conductors~~ – Part 1: *General requirements and particular requirements for clamping units for conductors from 0,5 to 35 mm² up to 35 mm² (included)*

IEC 61032: ~~1997~~, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61058-1: ~~2000~~ 2016, *Switches for appliances – Part 1: General requirements*

³⁾ IEC 60898-2 is published under the general title *Circuit-breakers for overcurrent protection for household and similar installations* (i.e. without the element of “Electrical accessories” in the title).

IEC 61058-1-1:2016, *Switches for appliances – Part 1-1: Requirements for mechanical switches*

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61373, *Railway applications – Rolling stock equipment – Shock and vibration tests*

~~ISO 4046-4:2002, Paper, board, pulp and related terms – Vocabulary~~

ISO 8820 (all parts), *Road vehicles – Fuse-links*

EN 50075:1990, *Specification for flat non-wirable two-pole plugs 2.5 A 250 V, with cord, for the connection of class II-equipment for household and similar purposes*

DIN 43671:1975, *Copper bus bars; design for continuous current*

DIN 43670:1975, *Aluminium bus bars; design for continuous current*

DIN 43670-2:1985, *Aluminium bus bars copper cladding; design for continuous current*

3 Terms and definitions

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

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>

NOTE Further definitions of **transformers** intended for particular use are indicated in the relevant parts of IEC 61558-2.

When the term **transformer** is used it covers **transformer**, **reactor** and **power supply unit** where applicable.

Unless otherwise specified, the terms “voltage” and “current” imply the RMS values of alternating voltage and current, and for direct voltage and current, they imply the corresponding arithmetic mean values.

“Ripple-free” is conventionally an RMS ripple voltage not more than 10 % of the DC component.

An index of often used terms and definitions is provided at the end of this document.

3.1 Transformers

3.1.1

~~(power)~~ transformer

static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power

Note 1 to entry: The term frequency also implies that the waveform remains the same.

[SOURCE: IEC 60050-421:1990, 421-01-01, modified – “power” deleted and “NOTE” added]

3.1.2

isolating transformer

transformer with **protective separation** between the **input winding(s)** and **output winding(s)**

3.1.3

safety isolating transformer

isolating transformer designed to deliver **SELV** (safety extra-low voltage) or **PELV** (protective extra-low voltage)

3.1.4

separating transformer

transformer with **input winding(s)** separated from the **output winding(s)** by at least **basic insulation**

3.1.5

Void

auto-transformer

transformer in which **input** and **output windings** have a common part

Note 1 to entry: **Auto-transformers** may have supplementary windings or tapings for adjustment purposes.

Note 2 to entry: Transformers with windings separated at least by functional insulation and electrically connected, will be treated as **auto-transformers**.

3.1.6

associated transformer

transformer designed to supply a specific appliance or equipment, or a part of them, and being either an **incorporated transformer** or a **transformer for specific use**

3.1.6.1

incorporated transformer

associated transformer designed to be built into a specific appliance or equipment, or into a part of them, and the **enclosure** of which provides protection against electric shock

3.1.6.2

transformer for specific use

associated transformer fixed to or delivered with the appliance or equipment, without being incorporated in this appliance or equipment and having its own **enclosure** which provides protection against electric shock

3.1.7

independent transformer

transformer designed to supply unspecified appliances and intended to be used without any additional **enclosure** which provides protection against electric shock

Note 1 to entry: Such a **transformer** can be either a portable **transformer** or a stationary **transformer**.

3.1.8

void

3.1.9

short-circuit proof transformer

transformer not exceeding the specified temperature limits when overloaded or short-circuited, and which continues to meet all the requirements of this document after removal of the overload or short-circuit and is not required to operate continuously under short-circuit or overload condition

Note 1 to entry: "Continues to meet all the requirements of this document" does not imply that all types of short-circuit proof **transformers** continue to operate.

3.1.9.1

non-inherently short-circuit proof transformer

short-circuit proof transformer equipped with a protective device or with an **intentional weak part** which opens the **input circuit** or the **output circuit**, or reduces the current in the **input circuit** or the **output circuit** when the **transformer** is overloaded or short-circuited, and continues to meet all the requirements of this document after removal of the overload or short circuit

3.1.9.1.1

non-inherently short-circuit proof transformer with resettable, self-resetting or replaceable protective device

short-circuit proof transformer equipped with a protective device which after resetting or replacing continues to operate

Note 1 to entry: Examples of self-resetting or non self-resetting protective devices are fuses, **overload relays**, thermal fuses, thermal links, **thermal cut-outs** and PTC resistors and automatic break-off mechanical devices.

3.1.9.1.2

non-inherently short-circuit proof transformer with non-self-resetting or non-replaceable protective device

short-circuit proof transformer equipped with a non-self-resetting or non-replaceable protective device or with a non-replaceable **intentional weak part**, which continues to meet all the requirements of this document after removal of the overload or short circuit, but does not continue to operate after the overload or short-circuit is removed

3.1.9.2

inherently short-circuit proof transformer

short-circuit proof transformer not equipped with any device for protection against overload or short circuit

Note 1 to entry: The **transformer**, by construction, does not exceed the specified temperature limits, and continues to operate and meet all the requirements of this document after the removal of the overload or short circuit.

3.1.10

non-short-circuit proof transformer

transformer intended to be protected against excessive temperature by means of a protective device, not provided with but stated on the **transformer**, and which continues to meet all the requirements of this document after the removal of the overload or short circuit and, if applicable, after resetting or replacing the protective device

3.1.11

fail-safe transformer

transformer equipped with a protective device or with an **intentional weak part**, which permanently fails to function by the interruption of the **input circuit** when the **transformer** is overloaded or short-circuited, but presents no danger to the user or surroundings

Note 1 to entry: It continues to meet all the requirements of this document after removal of the overload or short circuit.

Note 2 to entry: "Continues to meet all the requirements of this document" does not imply that the fail-safe **transformer** continues to operate. After failing it fulfils the dielectric strength test based on 35 % of the original values (see 15.5).

3.1.12

portable transformer

either a **transformer** which is moved while in operation, or a **transformer** which can easily be moved from one place to another while connected to the supply or being a plug-in **transformer**

3.1.13

flush-type transformer

transformer designed to be mounted in a flush-type mounting box

3.1.14

fixed transformer

transformer intended to be used while fastened to a support in a position which may be specified by the manufacturer

3.1.15

stationary transformer

either a **fixed transformer** or a **transformer** having a mass exceeding 18 kg and provided with no carrying handle(s)

3.1.16

hand-held transformer

portable **transformer** intended to be held in the hand during normal use

3.1.17

void

3.1.18

dry-type transformer

transformer incorporating non-liquid dielectric media, and the windings may be impregnated or encapsulated

3.1.19

power supply unit

electronic device incorporating **transformer(s)** and electronic circuitry(ies), that converts electrical power into single or multiple power outputs.

Note 1 to entry: It may also isolate the **input circuit** from the **output circuit**, and regulate and/or convert the output voltage and current. The device may consist of one or more individual units with identical or different waveforms and frequencies including DC output, and the **internal operating frequency** and waveform are different from the supply frequency and waveform and the **internal operating frequency** does not exceed 500 Hz

3.1.20

switch mode power supply unit

electronic device incorporating **transformer(s)** and electronic circuitry(ies), that converts electrical power into single or multiple power outputs

Note 1 to entry: It may also isolate the **input circuit** from the **output circuit**, and regulate and/or convert the output voltage and current. The device may consist of one or more individual units with identical or different waveforms and frequencies including DC output, and the **internal operating frequency** and waveform are different from the supply frequency and waveform and the **internal operating frequency** does exceed 500 Hz, but not exceed 100 MHz.

3.1.21

reactor

arrangement comprising one or more windings with an impedance depending on the frequency, working in accordance with the principle of self-induction whereby a magnetising current generates a magnetic field through a magnetically effective core or through air

Note 1 to entry: **Reactors** with toroidal cores are also included in this definition.

3.2 General terms

3.2.1

external flexible cable

external flexible cord

flexible cable or cord for external connection to the **input** or **output circuit**, fixed to or assembled with the **transformer** according to ~~one of the following methods of~~ type X, type Y or type Z attachment

3.2.1.1

type X attachment

method of attachment enabling easy replacement of the ordinary or especially prepared cable or cord

3.2.1.2

type Y attachment

method of attachment intended to be replaced only by the manufacturer, his service agent, or similar qualified person

Note 1 to entry: **Type Y attachments** may be used either with ordinary flexible cables or cords, or with special cables or cords.

3.2.1.3

type Z attachment

method of attachment preventing replacement of the flexible cable or cord without breaking or destroying a part of the transformer

3.2.2

power supply cord

external flexible cable or cord used to supply the **input circuit**

Note 1 to entry: **Power supply cords** are:

- fixed to or assembled with the **transformer** by type X, Y or Z attachment, or
- connected to the **transformer** by an appliance coupler.

3.2.3

connecting lead

lead connecting the end of a winding to the terminal of the **transformer**

Note 1 to entry: **Connecting leads** are considered as an internal wire.

3.2.4

body

accessible **conductive parts**, shafts, handles, knobs, grips and the like, accessible metal fixing screws and metal foil applied on accessible surfaces of insulating material

3.2.5

accessible part

parts which may be touched with the standard test finger after correct installation of the **transformer**

3.2.6

detachable part

part which can be removed without the aid of a **tool**

3.2.7

non-detachable part

part which can be removed only with the aid of a **tool**

3.2.8

tool

screwdriver, a coin, or any other object which may be used to operate a screw or similar fixing means

3.2.9

enclosure

~~part providing protection of the transformer against certain external influences and, in any direction, protection against direct contact~~

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

Note 1 to entry: Protection against for example mechanical impacts, corrosion, fungi, vermin, solar radiation, icing and moisture.

[SOURCE: ~~IEV 826-03-12:1982~~ IEC 60050-195:1998, 195-02-35, modified – “NOTE” added]

3.2.10

intermediate conductive part

non-accessible conductive part situated between **hazardous-live-parts** or the **body** and other **hazardous-live-part**

3.2.11

conductive part

~~metal parts and non-metal parts having a degree of conductivity equivalent to metal parts~~
part which can carry electric current

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

3.2.12

electronic component

part in which conduction is achieved principally by electrons moving through a vacuum, gas or semiconductor

Note 1 to entry: Neon indicators are not considered to be electronic components

3.2.13

electronic circuit

circuit incorporating at least one electronic component

3.2.14

void

3.2.15

electrical separation

separation between conductive parts by means of air and/or solid insulation

3.3 Operations and protections

3.3.1

all pole disconnection

disconnection of all ~~supply~~ live conductors by a single switching action

Note 1 to entry: **Protective earthing conductor** is not considered to be a supply conductor.

Note 2 to entry: A neutral conductor is considered to be a supply conductor.

Note 3 to entry: National wiring rules may or may not require the disconnection of the neutral conductor.

3.3.2

thermal cut-out

temperature sensitive device which limits the temperature of a **transformer**, or of parts of it, during abnormal operation by automatically opening the circuit or by reducing the current, and which is so constructed that its setting cannot be altered by the user

3.3.3

self-resetting thermal cut-out

thermal cut-out which automatically restores the current after the relevant part of the **transformer** has cooled down sufficiently, or the load has been removed

3.3.4

non-self-resetting thermal cut-out

thermal cut-out requiring manual resetting or replacement of a part to restore the current

3.3.5

thermal-link

thermal cut-out which operates only once

3.3.6

overload relay

current-operated switch which protects a circuit from overload by opening when the current in that circuit reaches a predetermined value and which remains in the open position

3.3.7

intentional weak part

part other than overload protective device (fuses, circuit-breaker, thermal cut-outs, etc.) intended to rupture under conditions of abnormal operation to prevent the occurrence of a condition which could impair compliance with this document

Note 1 to entry: Such a part may be a replaceable component, such as a resistor or a capacitor or a non replaceable part of a component such as an inaccessible weak point in a winding.

3.3.8

working voltage

highest RMS value of the AC or DC voltage which may occur (locally) across any insulation at **rated supply voltage** under no-load or normal operating conditions, transients being disregarded

Note 1 to entry: When considering the insulation system between windings not intended to be connected together, the **working voltage** is considered to be the highest voltage occurring on any of these windings.

Note 2 to entry: On three phase systems, the **working voltage** can be different from the nominal voltage.

3.3.9

short-circuit voltage

voltage to be applied to the **input winding**, when the windings are at ambient temperature, to produce in the short-circuited **output winding** a current equal to the **rated output current**

Note 1 to entry: The **short-circuit voltage** is usually expressed as a percentage of the **rated supply voltage**.

3.3.10

duty-type

continuous or conventional periodic duty consisting of one or more sets of loads remaining constant for the durations specified

3.3.10.1

continuous duty

operation for an unlimited period

3.3.10.2

short-time duty cycle

operation for a specified period, starting from cold, the intervals between each period of operation being sufficient to allow the **transformer** to cool down to approximately ambient temperature

3.3.10.3

intermittent duty cycle

operation in a series of specified identical cycles

3.3.11

protective earthing conductor

PE

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

[SOURCE: IEC 60050-195:1998, 195-02-09:11]

3.4 Circuits and windings

3.4.1

input circuit

circuit intended to be connected to the supply consisting of the **input winding** and the **internal circuits**

3.4.2

output circuit

circuit to which the distribution circuit, appliance or other equipment is to be connected, consisting of the **output winding** and the **internal circuits**

3.4.3

input winding

winding of the **input circuit**

3.4.4

output winding

winding of the **output circuit**

3.4.5

internal circuit

circuit which consists of components, interconnections and connections to the terminals and the windings, excluding protective earthing circuit

3.4.6

fully insulated winding wire

FIW

wire according to IEC 60317-0-7, IEC 60317-56 and tested according to IEC 60851-5:2008 which is a zero-defect wire construction

3.4.7

grade of FIW

range of overall diameter of a wire (FIW3 to FIW9)

3.4.8

insulated winding wire

~~wire with an insulation meeting the requirements of Annex K for use in windings~~
winding wire for basic-, supplementary-, or reinforced insulation

Note 1 to entry: Requirements are provided in Annex K.

3.4.9

extruded winding wire

TIW

winding wires with basic-, supplementary-, or reinforced insulation obtained by extrusion

Note 1 to entry: The term TIW is commonly used to cover all types of extruded winding wires.

3.5 Ratings

3.5.1

rated supply voltage

supply voltage (for polyphase supply, the phase-to-phase voltage) assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.2

rated supply voltage range

supply voltage range assigned to the **transformer** by the manufacturer, expressed by its lower and upper limits

3.5.3

rated frequency

frequency assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.3.1

rated supply frequency

frequency on the input of the **transformer** assigned by the manufacturer

Note 1 to entry: The supply frequency is the frequency of the mains.

3.5.3.2

internal operational frequency

highest internal frequency assigned by the manufacturer as the operating frequency of a **transformer** or other components built into a **power supply unit**

3.5.4

rated output current

output current at **rated supply voltage**, **rated supply frequency** and **rated output voltage**, at **rated power factor**, assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.5

rated output voltage

output voltage (for polyphase supply, the phase-to-phase voltage) at **rated supply voltage**, **rated supply frequency** and **rated output current**, at **rated power factor**, assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.6

rated power factor

power factor assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.7

rated output

product of the **rated output voltage** and the **rated output current** or, for three-phase transformers, $\sqrt{3}$ times the product of the **rated output voltage** and the **rated output current**

Note 1 to entry: If the **transformer** has more than one **output winding** or a tapped **output winding**, the **rated output** denotes the maximum sum of the products of **rated output voltage** and **rated output current** for **output circuits** intended to be loaded simultaneously.

3.5.8

rated ambient temperature

t_a

maximum temperature at which the **transformer** may be operated continuously under normal conditions of use

Note 1 to entry: The value of the **rated ambient temperature** (t_a) does not preclude temporary operation of the **transformer** at a temperature not exceeding ($t_a + 10$) °C.

3.5.9

rated minimum ambient temperature

t_{amin}

minimum temperature at which the **transformer** may be operated continuously under normal conditions of use

3.5.10

t_w

~~rated maximum operating temperature of a **transformer** winding – the winding temperature being assigned by the manufacturer as the highest temperature at which the **transformer** may be expected to have a specified service life during **continuous operation**~~

3.5.10

rated minimum temperature

t_{min}

minimum temperature only for transportation and storage

3.5.11

overvoltage category

numeral defining a transient overvoltage condition

Note 1 to entry: Overvoltage categories I, II, III and IV are used, see IEC 60664-1:2007, 4.3.3.2.

[SOURCE: IEC 60050-581:2008, 581-21-02, modified – “NOTE” added]

3.5.11.1

overvoltage category I

OVC I

equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level

Note 1 to entry: Examples of such equipment are those containing electronic circuits protected to this level. However, unless the circuits are designed to take the temporary overvoltages into account, equipment of overvoltage category I cannot be directly connected to the mains supply.

3.5.11.2

overvoltage category II

OVC II

energy-consuming equipment to be supplied from the fixed installation

Note 1 to entry: Examples of that equipment are transformers for household appliances, telecommunications, toys, and similar loads.

3.5.11.3

overvoltage category III

OVC III

equipment used in fixed installations and for cases where the reliability and the availability of the equipment is subject to special requirements

Note 1 to entry: Examples of such equipment are transformers in fixed installations and **transformers** for industrial use with permanent connection to the fixed installation.

3.5.11.4

overvoltage category IV OVC IV

equipment used at the origin of installation

Note 1 to entry: Examples of such equipment are **transformers** in fixed installations of power plants or immediate to such installations.

3.6 No-load values

3.6.1

no-load input

input of the **transformer** when connected to **rated supply voltage** at **rated supply frequency**, with no load on the output

3.6.2

no-load output voltage

output voltage when the **transformer** is connected to **rated supply voltage** at **rated supply frequency**, with no load on the output

3.7 Insulation

3.7.1

basic insulation

insulation ~~applied to hazardous~~ of live parts ~~to which~~ provides basic protection ~~against electric shock~~

Note 1 to entry: This concept does not ~~necessarily include~~ apply to insulation used exclusively for functional purposes, for example wire enamel.

[SOURCE: ~~IEC 61140, definition 3.10.1~~ IEC 60050-195:1998, 195-06-06, modified – “hazardous” deleted and “,for example wire enamel” added]

3.7.1.1

functional insulation

insulation between **conductive parts** ~~of different potential which, in general, is~~ necessary ~~only~~ for the proper functioning of the transformer

Note 1 to entry: For **transformers**, proper functioning **insulation** may have influence on the safety. **Functional insulation** is checked by the requirements of this document but additional requirements may exist in IEC 61558-2 (all parts).

NOTE 2 ~~Functional insulation~~ is only applicable inside the windings ~~between turns of the same winding.~~

[SOURCE: IEC 60050-195:1998, 195-02-41, modified – “transformer” replaces “equipment” and “NOTE” added]

3.7.2

supplementary insulation

independent insulation of **hazardous-live-parts** applied in addition to **basic insulation** ~~in order to provide protection against electric shock in the event of failure of the basic insulation~~, for fault protection

Note 1 to entry: Fault protection means in order to provide protection against electric shock in the event of a **basic insulation** failure.

[SOURCE: ~~IEC 61140, definition 3.10.2~~ IEC 60050-195:1998, 195-06-07, modified – “hazardous-live-parts” and “NOTE” added]

3.7.3

double insulation

insulation comprising **both basic insulation** ~~plus~~ and **supplementary insulation**

[SOURCE: ~~IEC 61140, definition 3.10.3, modified~~ IEC 60050-195:1998, 195-06-08]

3.7.4

reinforced insulation

~~single insulation system applied to~~ **insulation of hazardous-live-parts**, which provides a degree of protection against electric shock equivalent to **double insulation**

Note 1 to entry: ~~The term "insulation system" does not imply that the insulation is one homogeneous piece.~~ Reinforced insulation may comprise several layers which cannot be tested singly as supplementary or basic insulation.

[SOURCE: ~~IEC 61140, definition 3.10.4, modified~~ IEC 60050-195:1998, 195-06-09]

3.7.5

class I transformer

transformer 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,~~ such as a protective earthing terminal, ~~are provided~~ for the connection of accessible **conductive parts** to ~~the protective earth 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~~

Note 1 to entry: The protective earthing connection prevents that accessible **conductive parts** become live in the event of a **basic insulation** failure.

Note 2 to entry: **Class I transformers** may have parts with **double** or **reinforced insulation**.

3.7.6

class II transformer

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

Note 1 to entry: A **class II transformer** may be provided with means for maintaining the continuity of protective earthing circuits, provided that such means are inside the **transformer**, and are insulated from accessible surfaces according to the requirements of **class II**.

Note 2 to entry: In certain cases, it may be necessary to distinguish between "all insulated" and "metal encased" **class II transformers**.

Note 3 to entry: A **transformer** having a durable and substantially continuous **enclosure** of insulating material which envelops all **conductive parts**, with the exception of small **conductive parts**, such as nameplates, screws and rivets, which are isolated from **hazardous-live-parts** by insulation at least equivalent to **reinforced insulation**, is called an all insulated **class II transformer**.

Note 4 to entry: A **transformer** having a substantially continuous metal **enclosure**, in which **double insulation** is used throughout, except for those parts where **reinforced insulation** is used because the application of **double insulation** is manifestly impracticable, is called a metal encased **class II transformer**.

Note 5 to entry: If a **transformer** with **double insulation** and/or **reinforced insulation** throughout has a protective earthing terminal, it is deemed to be of **class I** construction.

Note 6 to entry: A **class II transformer** may be provided with functional earthing circuit.

3.7.7

class III transformer

transformer in which protection against electric shock relies on supply at **SELV**, and in which voltages higher than those of **SELV** are not generated

Note 1 to entry: The classification I, II or III does not refer to the insulation system between **input windings** and **output windings**.

3.7.8

clearance

CL

shortest distance in air between two **conductive parts**

Note 1 to entry: For the purpose of determining a **clearance** to **accessible parts**, the accessible surface of an insulating **enclosure** is to be considered conductive as if it were covered by a metal foil wherever it can be touched by the standard test finger (see Figure 4).

[SOURCE: IEC 60664-1:2007, 3.2, modified – “NOTE” added]

3.7.9

creepage distance

CR

shortest distance (through air) along the surface of an insulating material between two **conductive parts**

Note 1 to entry: For the purpose of determining a **creepage distance** from **transformer conductive parts** to **accessible parts**, the accessible surface of an insulating **enclosure** is to be considered conductive as if it were covered by a metal foil wherever it can be touched by the standard test finger (see Figure 4).

[SOURCE: ~~IEC 60664-1, definition 1.3.3~~ IEC 60050-151:2001, 151-15-50, modified – “through air” and “NOTE” added]

3.7.10

pollution

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

[SOURCE: IEC 60664-1:2007, 3.11]

3.7.11

micro-environment

immediate environment of the insulation which particularly influences the dimensioning of the **creepage distances** or **clearances**

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

[SOURCE: IEC 60664-1:2007, 3.12.2, modified – “or clearances” and “NOTE” added]

3.7.12

degree of pollution

degree of pollution in the **micro-environment** established for the purpose of evaluating **clearances** and **creepage distances**

3.7.12.1

pollution degree 1

P1

pollution degree in which no **pollution** or only dry, non-conductive **pollution** occurs

Note 1 to entry: The **pollution** has no influence.

3.7.12.2

pollution degree 2

P2

pollution degree in which only non-conductive **pollution** occurs, except that occasionally a temporary conductivity caused by condensation is to be expected

Note 1 to entry: **Transformers** having a reasonably tight **enclosure** are considered to have **pollution degree 2** (P2), hermetic sealing is not required.

3.7.12.3

pollution degree 3

P3

pollution degree in which conductive **pollution** occurs, or dry non-conductive **pollution** occurs which becomes conductive due to the condensation which is to be expected

3.7.13

protective separation

separation between circuits by means of basic and supplementary protection (**basic insulation** plus **supplementary insulation** or **protective screening**) or by an equivalent protective provision (for example **reinforced insulation**) ~~(based on definition 3.24 of IEC 61140)~~

[SOURCE: IEC 60050-195:1998, 195-06-19, modified – “(electrically)” removed and definition redrafted]

3.7.14

protective screening

separation from **hazardous-live-parts** by means of an interposed conductive screen, connected to the means of connection for an external protective earthing conductor ~~(based on definition 3.22 of IEC 61140)~~

[SOURCE: IEC 60050-195:1998, 195-06-18, modified – “(electrically)” removed and definition redrafted]

3.7.15

ELV

extra-low voltage

voltage which does not exceed 50 V AC or 120 V ripple free DC between conductors, or between any conductor and **protective earthing** ~~(voltage band 1 of IEC 60449)~~

3.7.16

SELV

safety extra low voltage

ELV in a circuit which is isolated from the mains supply by such means as a **safety isolating transformer**

Note 1 to entry: Maximum voltage lower than 50 V AC or 120 V ripple-free DC may be specified in particular requirements, especially when direct contact with **live parts** is allowed.

Note 2 to entry: The maximum peak value does not exceed 140 V for a nominal 120 V ripple-free DC system and 70 V for a nominal 60 V ripple-free DC system.

3.7.17

SELV-circuit

ELV circuit with **protective separation** from other circuits, and which has no provisions for earthing of the circuit nor of the exposed **conductive parts**

3.7.18

PELV-circuit

protective extra low voltage

ELV circuit with **protective separation** from other circuits and which, for functional reasons, may be earthed and/or the exposed **conductive parts** of which may be earthed

Note 1 to entry: **PELV-circuits** are used where the circuits are earthed and **SELV** is not required.

3.7.19**FELV-circuit****functional extra low voltage-circuit**

ELV circuit having the **ELV** voltage for functional reasons and not fulfilling the requirements for **SELV** or **PELV**

3.7.20**live part**

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

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

Note 2 to entry: For definitions of PEM and PEL see IEC 60050-195:1998, 195-02-13 and 195-02-14

[SOURCE: IEC 60050-195:1998, 195-02-19, modified – “NOTE 2” added]

3.7.21**hazardous-live-part**

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

Note 1 to entry: In case of high voltage, a hazardous voltage may be present on the surface of solid insulation. In such a case, the surface is considered to be a **hazardous-live-part**

[SOURCE: IEC 60050-195:1998, 195-06-05, modified – “NOTE” added]

3.8 Touch current and protective earthing conductor current**3.8.1****touch current**

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

[SOURCE: IEC 60050-195:1998, 195-05-21]

3.8.2**protective earthing conductor current**

current which flows in a protective earthing conductor

Note 1 to entry: This current may have influence on the operation of RCDs (residual current protection devices) connected in the same circuit.

4 General requirements

4.1 Transformers shall be so designed and manufactured that when used, installed and maintained according to the manufacturer's instructions, they cause no danger which could reasonably be foreseen to persons or surroundings, even in the event of careless use as may occur in normal service.

In general, compliance is checked by carrying out all the relevant tests.

4.2 When associated transformers are used in an appliance or equipment for which a relevant appliance or equipment standard exists, they may be tested under the conditions present in the appliance or equipment for which they are intended.

*If a **transformer** is tested under the conditions present in the appliance or equipment for which it is intended, it shall comply with the following clauses or subclauses thereof of this document:*

1 – 2 – 3 – 4 – 5.1 – 5.2 – 5.3 – 5.4 – 5.5 – 5.6 – 5.7 – ~~5.12~~ – 7.1 – 7.2 – 7.5 – 7.6 – 7.8 – 8.2 – 8.11 – 14.1 – except for the requirements in Table 2 starting with the first: “external enclosures”..., 14.2 – 14.3 – 15.1, restricted to the first box of Table 5 – 18.1 – 18.2 – 18.3, ~~except items 3 and 4 of Table 8a~~ only between input and output circuits – 18.4 – 19.1 – 19.12 – ~~20.9~~ 20.10 – 26.1 – 26.2 – 26.3 – Annexes A, ~~C, D~~, G, L, M, N, P

Other clauses shall be taken from the relevant product standard. If the product standard does not fully cover the remaining clauses, the corresponding missing clauses of this **transformer** document shall be used instead.

4.3 For other hazards not covered by this document (e.g. EMF, functional safety linked to electric, magnetic and electromagnetic disturbances, etc.), the manufacturer has to perform a risk assessment.

5 General notes on tests

5.1 Tests according to this document are:

- type tests (defined from 8.1 up to Clause 28);
- routine tests (defined in Annex L).

*Each sample **transformer** shall comply with all the relevant tests. In order to reduce the testing time and allow for any tests which may be destructive, the manufacturer may submit additional **transformers** or parts of **transformers**, provided that they are of the same materials and designs as the original **transformer**, and that the results of the tests are the same as if carried out on an identical **transformer**. Where the test for compliance is shown as being “by inspection”, this shall include any necessary handling.*

Unless otherwise specified, the tests shall be carried out under steady-state conditions.

Transformers intended to be used with **non-detachable** flexible cables or cords are tested with the flexible cable or cord connected to the **transformer**.

5.2 Tests are carried out on specimens as delivered and installed as in normal use taking into account the manufacturer's installation instructions. If it is not necessary to do the tests of 14.3, 15.5, 16.4 and 26.2, the number of specimens is one for all **rated outputs**.

If the tests of 14.3 need to be performed, three additional specimens shall be used. Three more specimens are required if the tests need to be repeated.

If the tests of 15.5 need to be performed, three additional specimens shall be used. These specimens are used only for the tests of 15.5.

If the tests of 16.4 need to be performed, they are carried out on four additional specimens.

If the tests of 26.2 need to be performed, they are carried out on three additional specimens.

*For components tested under conditions prevailing in the **transformer**, the number of specimens is that required by the relevant standard.*

*For testing a series of **transformers**, see Annex B.*

All specimens shall withstand all the relevant tests, except as mentioned in 14.3.

NOTE 1 For **associated transformers**, the equipment standard ~~may~~ can prescribe other numbers of specimens to be tested.

NOTE 2 In case of non-replaceable and non-resettable protective devices, the compliance is checked on a specially prepared specimen.

5.3 Tests are carried out in the order of the clauses and subclauses, unless otherwise specified.

5.4 If the test results are not influenced by the temperature of the ambient air, the ambient temperature is, in general, maintained at $(20 \pm 5) ^\circ\text{C}$. Otherwise and if, however, the temperature attained by any part is limited by a temperature-sensitive device, or is influenced by the temperature at which a change of state occurs, the ambient temperature is, in case of doubt, maintained at $(23 \pm 2) ^\circ\text{C}$ or $(t_a \pm 2) ^\circ\text{C}$ for **transformers** with t_a marking.

The tests are carried out with the **transformer**, or any movable part of it, placed in the most unfavourable position that may occur in normal use.

5.5 For AC, test voltages are of substantially sinusoidal wave form, and, if not otherwise specified, have a frequency of 50 Hz or 60 Hz.

5.6 **Transformers** designed for more than one **rated supply voltage**, for a **rated supply voltage range** or for more than one **rated supply frequency**, are tested, unless otherwise specified in this document, at the supply voltage or supply frequency that results in the most severe test conditions for the **transformer**.

5.7 As far as possible, measurements are made with instruments which do not appreciably affect the values to be measured; if necessary, corrections shall be made.

5.8 Unless otherwise specified, **transformers** intended to be used with **external flexible cable or cords** are tested with a cord(s) (see 3.2.1) connected to the **transformer**.

5.9 If **class I transformers** have accessible conductive parts which are not connected to a protective earthing terminal or protective earthing contact, and are not separated from **hazardous-live-parts** by an **intermediate conductive part** that is connected to a protective earthing terminal or protective earthing contact, such parts are checked for compliance with the appropriate requirements specified for **class II transformers** in this document.

5.10 A **flush-type transformer** is tested with an appropriate flush-mount box of insulating material. This box is placed in an **enclosure** as indicated in Figure 2, made from plywood, with a thickness of 20 mm, the inside painted dull black, and the distance between the back of the mounting box and the rear wall of the **enclosure** being 5 mm.

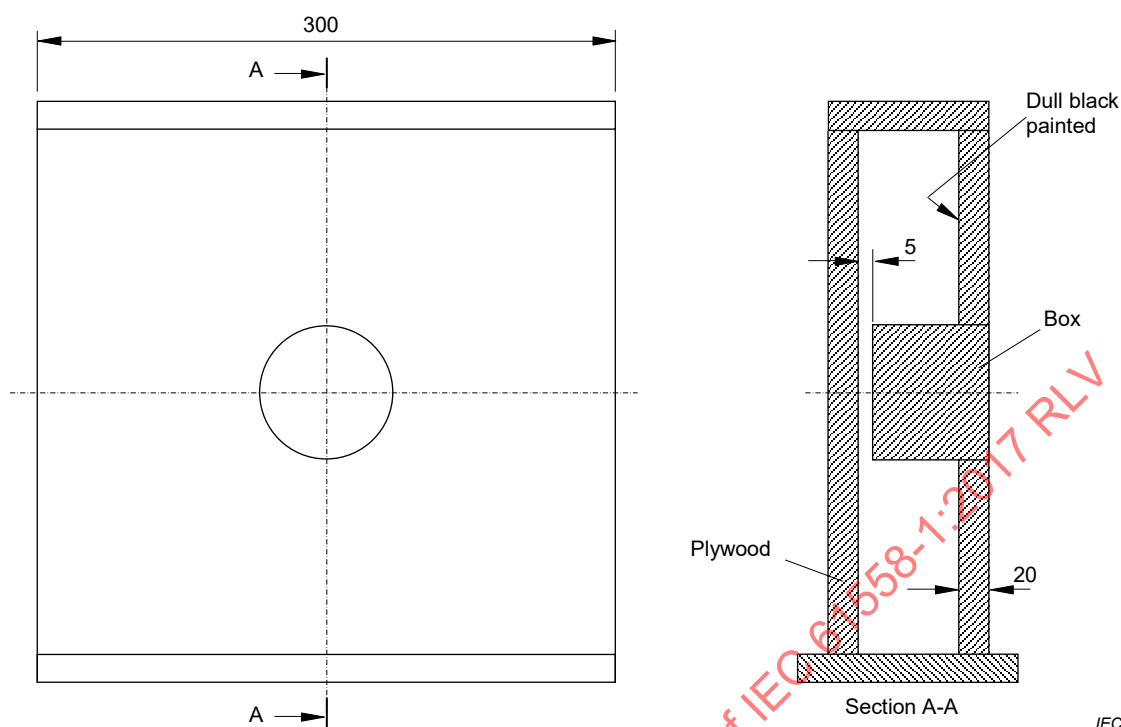


Figure 2 – Mounting box for flush-type transformer

5.11 Transformers for specific use for which there are no relevant appliance or equipment standards are tested as **transformers** for general use, their rating being considered as the power consumption and power factor of the appliance(s) or equipment for which they are designed.

5.12 Void

5.13 IP00 transformers with unknown end application, are tested without adding an enclosure.

For these **transformers**, the requirements of Clause 9 are not applicable. Furthermore, the test in 27.2 is not performed as the result can be influenced by the enclosure in the final application, for example on the fixing point of the **transformer** fixed on plastic support. For the fault condition test, if applicable, the product standard for the final product applies.

5.14 IP00 transformers, with known end application, are mounted and tested in accordance with the manufacturer's instructions.

5.15 The tests in Clauses 18 and 26 are based on an elevation of 2 000 m above sea level. If tested in elevations in excess of 2 000 m above sea level, Annex A of IEC 60664-1:2007 applies.

6 Ratings

Ratings are indicated in the relevant part of IEC 61558-2 for different types of **transformers** and in Annex U for **t_w-marked transformers**.

7 Classification

7.1 Transformers are classified according to their protection against electric shock:

- **class I transformers;**
- **class II transformers;**
- **class III transformers.**

NOTE **Incorporated transformers** are not classified; their degree of protection against electric shock is determined by the way in which the **transformer** is incorporated.

7.2 Transformers are classified according to the short-circuit ~~protection~~ **characteristic** or protection against abnormal use:

- **inherently short-circuit proof transformers;**
- **non-inherently short-circuit proof transformers;**
- **non-short-circuit proof transformers;**
- **fail-safe transformers.**

7.3 Transformers are classified according to the degree of protection ensured by the **enclosure** and defined in accordance with IEC 60529 (IP code) except IP1X.

NOTE For further information see Annex Q.

7.4 Transformers are classified according to their mobility:

- **stationary transformers;**
- **fixed transformers;**
- **portable transformers;**
- **hand-held transformers.**

7.5 Transformers are classified according to their duty type:

- **continuous duty;**
- **short-time duty cycle;**
- **intermittent duty cycle.**

7.6 Transformers are classified according to the intended use:

7.6.1 Associated

- **incorporated;**
- **for specific use.**

7.6.2 Independent

~~7.7 Optionally (only for t_w -marked transformers), according to the rated maximum operating temperature of the winding, t_w , and corresponding estimated life expectancy under specified conditions~~

- ~~— t_{w5} for 5 years continuous operation~~
- ~~— t_{w10} for 10 years continuous operation~~
- ~~— t_{wn} where n stands for number of years other than the above~~

7.7 Transformers are classified according to the environmental conditions where they are intended to be used:

- normal environment;
- special environments (e.g. arctic).

7.8 Transformers are classified according to their **transient overvoltage condition**:

- **overvoltage category I**;
- **overvoltage category II**;
- **overvoltage category III**;
- **overvoltage category IV**.

Transformers for general use are in **overvoltage category III** or higher.

Transformers e.g. for use in household appliances or audio/video, information and communication technology equipment are in **overvoltage category II** or higher.

8 Marking and other information

8.1 **Transformers** shall be marked with the following (for symbols see Table 1):

- a) rated supply voltage(s) or the rated supply voltage range(s) in volts;

Transformers having a range of rated values and able to operate without adjustment throughout the range shall be marked with the lower and the upper limits of the range separated by a hyphen.

NOTE 1 Example 115 V – 230 V: the **transformer** is suitable for any value between 115 V and 230 V.

Transformers having different rated values, and which have to be adjusted for use at a particular value by the user or installer, shall be marked with the different values separated by an oblique stroke.

NOTE 2 Example 1: 115 V / 230 V: the **transformer** is only suitable for 115 V or 230 V (e.g. a **transformer** with a selector switch or different sets of terminals).

NOTE 3 Example 2: 230 V/400 V: The **transformer** is only suitable for 230 V or 400 V where 230 V is for single-phase operation and 400 V for three-phase operation (e.g., a **transformer** with terminals for both supplies).

- b) **rated output voltage**(s) in volts or kilovolts;

For **transformers** incorporating a rectifier, the **rated output voltage** after the rectifier shall be marked with the arithmetic mean value, or the output voltage before the rectifier shall be expressed as RMS value.

NOTE 4 The RMS value is distinguished from an arithmetic mean value by the use of RMS in the marking.

- c) **rated output** in volt-amperes or kilovolt-amperes and volt-amperes reactive or kilovolt-amperes reactive for reactors;

NOTE 5 For **transformers** incorporating a rectifier, the **rated output** may be expressed in watts, instead of volt-amperes or kilovolt-amperes.

- d) **rated output current**(s) in amperes or milliamperes as an alternative to the marking of the **rated output**;
- e) rated supply frequency(ies) in hertz;
- f) **rated power factor**, if other than unity, for **transformers** rated above 25 VA;
- g) symbol or abbreviation AC for alternating current or DC for direct current output;
- h) symbol indicating the kind of **transformer** as indicated in the relevant part of IEC 61558-2; if an IP00 **transformer** or and **associated transformers** have circuits corresponding to different parts 2 in the same construction (e.g. **SELV output circuit** according to

IEC 61558-2-6 and 230 V **output circuit** according to IEC 61558-2-4) the relevant symbols have to be used;

- i) name or trade mark of the manufacturer or responsible vendor;
- j) model or type reference;
- k) vector group in accordance with IEC 60076-1 (for three-phase **transformers** if required);
- l) symbol for **class II** construction, for **class II transformers** only;
symbol for **class III** construction, for **class III transformers** only;
- m) indication of the protection index IP, if other than IP00;
- n) rated maximum ambient temperature t_a , if other than 25 °C;
NOTE It is recommended that the values of t_a are given in steps of 5 °C for $t_a \leq 50$ °C and in steps of 10 °C for $t_a > 50$ °C;
- o) **rated minimum ambient temperature** t_{amin} , if lower than +10 °C and if a temperature sensitive device is used;
NOTE It is recommended that the values of t_{amin} are given in steps of 5 °C;
- p) duty cycle, if any, unless the operating time is limited by the construction of the **transformer** or corresponds to the operating conditions specified in the relevant part of IEC 61558-2. The marking of **short-time duty cycle** or **intermittent duty cycle** shall correspond to normal use. The operating time for **transformers** with short-time duty shall be expressed in seconds (s) or minutes (min); the operating time and the resting time of **transformers** with intermittent duty cycle shall be expressed in seconds (s) or minutes (min), separated by an oblique stroke;
- q) symbol for overvoltage category, if other than OVC II;
- ~~r) declared values of the rated maximum operating temperature of the winding, increase in multiples of 5 °C and indication of the rated life expectancy, for t_w -marked **transformers** only~~
- r) **transformers** to be used with forced air cooling where the fan is not a part of the **transformer** shall be marked with "AF" followed by the air speed, expressed in m/s;
- s) in addition, the manufacturer shall be prepared to provide the purchaser with the following information (in the literature or otherwise):
 - for **stationary transformers** with a **rated output** exceeding 1 000 VA, the **short-circuit voltage** expressed as a percentage of the **rated supply voltage**;
 - the electrical function of the **transformer**.

NOTE 6 If the **transformer** has more than one output winding, the short-circuit voltage to be marked is the lowest value for the various windings.

NOTE Additional markings are allowed provided they do not give rise to misunderstanding.

All markings except those under i) and j) may be illustrated as QR Code according ISO/IEC 18004.

- t) symbol indicating the maximum altitude of installation, if higher than 2 000 m.

8.2 Transformers with protection index IP00, or **associated transformers**, may be marked with only the name (or trade mark) of the manufacturer or responsible vendor and the type reference (or catalogue reference). Other characteristics shall then be provided in the data sheets of the **transformer** or in the manufacturer's instruction sheet.

NOTE The name of the manufacturer or responsible vendor and the type reference may be replaced by a traceable code.

This information shall enable replacement of the original **transformer** with an equivalent **transformer**.

NOTE Equivalent implies electrically, mechanically, dimensionally and functionally interchangeable.

8.3 If the **transformer** can be adjusted for different **rated supply voltages**, the adjusted voltage shall be easily and clearly discernible.

8.4 Transformers with tapped or multiple **output windings** shall be marked with:

- the **rated output voltage** for each tapping or winding, unless the **transformer** is intended for special purposes involving frequent changes in output voltage;
- the **rated output** for each tapping or winding; if the **rated output** for all tapings or windings is the same, at least one tapping or winding shall be marked.

The arrangement of the connections necessary to obtain the various output voltages shall be clearly indicated on the **transformer**.

8.5 Non-inherently short-circuit proof transformers with incorporated fuses and **non-short-circuit proof transformers** designed to be protected by fuses shall, in addition, be marked with the rated current (amperes or milliamperes) of the protecting fuse-link, followed or preceded by the symbol for the time current characteristics of the fuses in accordance with the relevant publication, if applicable.

Non-inherently short-circuit proof transformers with incorporated replaceable protective devices other than fuses, and **non-short-circuit proof transformers** designed to be protected with protective devices other than fuses shall, in addition, be marked with the manufacturer's model or type reference of the protective device, and/or the ratings of the protective device.

NOTE 1 In addition, a symbol in accordance with Annex V can be used.

NOTE 2 **Non-inherently short-circuit proof transformers** with non-replaceable protective devices need no additional marking regarding the protective device.

The marking shall contain sufficient information to ensure proper replacement of the protective device.

When replaceable protective devices other than fuses are used, appropriate information about their replacement shall be provided in an instruction sheet, or the equivalent, accompanying the **transformer**.

8.6 Terminals intended exclusively for the neutral conductor shall be identified by the symbol for neutral.

Protective earthing terminals shall be identified by the symbol for protective earthing.

Terminals of **input** and **output windings** shall be clearly identified.

If any point of a winding or a terminal is connected to the frame or core, it shall be marked with the relevant symbol.

8.7 Transformer shall be provided with markings clearly indicating the manner in which the **transformer** is to be connected, unless it is evident from the design of the **transformer**.

8.8 For **transformers** with type **X**, **Y** and **Z attachments**, the instruction sheet shall contain the following information or the equivalent:

- for **type X attachments** having a specially prepared cord:
"If the **external flexible cable or cord** of this **transformer** is damaged, it shall be replaced by a special cord or assembly available from the manufacturer or their service agent";
- for **type Y attachments**:

"If the **external flexible cable or cord** of this **transformer** is damaged, it shall be replaced by the manufacturer or their service agent or a similarly qualified person in order to avoid a hazard";

– for **type Z attachments**:

"The **external flexible cable or cord** of this **transformer** cannot be replaced; if the cord is damaged, the **transformer** shall be scrapped".

8.9 Transformers for indoor use only shall be marked with the relevant symbol.

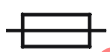
8.10 Class II transformers shall be marked with the graphical symbol IEC 60417-5172: ~~(DB:2002-10)~~ 2003-02 placed adjacent to the supply information (e.g. on the rating plate), such that it is obvious the symbol is part of the technical information and can in no way be confused with the manufacturer's name or any other identification (see 7.4.4 of IEC 61140:2016).

Class II transformers with parts to be mounted shall be delivered with all parts that make them class II after mounting according to the mounting instructions of the manufacturer and shall be marked with the class II symbol. Moreover, if the **transformer** can be mounted without the covers (e.g. on a distribution box), the marking for class II shall be placed on a part that effectively provides the class II characteristics (e.g., on a cover for terminals to connect to the supply).

8.11 When symbols are used on equipment or in instructions, they shall be as follows:

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Table 1 – Symbols used on equipment or in instructions

Symbol or graphical symbol	Explanation or title	Identification
V ^a	Volts	
A ^a	Amperes	
VA or (VAR) ^a	Volt amperes (or volt-amperes reactive for reactors)	
W ^a	Watts	
Hz ^a	Hertz	
PRI	Input	
SEC	Output	
===	Direct current	IEC 60417-5031:2002-10
N	Neutral	
~	Alternating current	IEC 60417-5032:2002-10
3~	Three-phase alternating current	IEC 60417-5032-1:2002-10
3N~	Three-phase alternating current with neutral conductor	IEC 60417-5032-2:2002-10
cos φ	Power factor	
	Class II equipment	IEC 60417-5172:2003-02
	Class III equipment	IEC 60417-5180:2003-02
	Equipment of overvoltage category I	IEC 60417-6348:2015-10
	Equipment of overvoltage category II	IEC 60417-6349:2015-10
	Equipment of overvoltage category III	IEC 60417-6350:2015-10
	Equipment of overvoltage category IV	IEC 60417-6351:2015-10
	Fuse (add symbol for time-current characteristics)	IEC 60417-5016:2002-10
t_a	Rated maximum ambient temperature Maximum temperature at which the transformer may be operated continuously under normal conditions of use	
t_{amin}	Rated minimum ambient temperature Minimum temperature at which the transformer may be operated continuously under normal conditions of use	
t_{min}	Rated minimum temperature Minimum temperature for transportation and storage	
	Frame or chassis (or core terminal)	IEC 60417-5020:2002-10
	Protective earth (ground)	IEC 60417-5019:2002-10 2006-08

Symbol or graphical symbol	Explanation or title	Identification
IPXX	IP number ^b	
	Earth (ground or functional earth)	IEC 60417-5017:2002-10 2006-08
	indoor use only	IEC 60417-5957:2004-12
~~t_{w5-yyy}~~	~~For t_w-marked transformer only with 5 years life expectancy yyy= Rated maximum operating temperature~~	
~~$t_{w10-yyy}$~~	~~For t_w-marked transformer only with 10 years life expectancy yyy= Rated maximum operating temperature~~	
~~t_{wx-yyy}~~	~~For t_w-marked transformer only where x= life expectancy yyy= Rated maximum operating temperature~~	
	To indicate that the appliance is intended to be usable up to the maximum altitude 3 000 m. The letter symbols "3 000" may be replaced by those for a different numerical value (in metres) in agreement with actual applications. The recommended value should be either 2 000, 3 000, 4 000, or 5 000 (metres).	IEC 60417-6343:2015-06
	To indicate that the power supply unit shall not be used, if pins of the plug part are damaged. NOTE See 8.8, attachment type C	IEC 60417-6352:2015-10
^a Multiple or submultiples are allowed (e.g. kV, mA...). ^b The X used in the IP number in this scheme indicates a missing numeral in the example, but both of the appropriate numerals shall be marked on the transformer , if applicable. Additional and supplementary letters mentioned in IEC 60529 may be used if necessary.		

8.12 The different positions of regulating devices and the different positions of switches shall be indicated by numbers, letters or other visual means.

If numbers are used for indicating the different positions, the "off" position shall be indicated by the number 0 and the position for a greater output, input, etc. shall be indicated by a higher number.

The number 0 shall not be used for any other indication. Indications used shall be comprehensible without the knowledge of languages, national standards, etc.

8.13 Marking shall not be placed on screws or other easily removable parts.

Marking shall, with the exceptions mentioned below, be clearly discernible when the **transformer** is ready for use.

Marking related to the terminals shall be so positioned that it is clearly discernible, if necessary after removal of the cover; it shall be such that there can be no confusion between input terminals and output terminals.

Marking related to the interchangeable protective devices shall be positioned adjacent to the bases of these devices, and shall be clearly discernible after removal of any cover and the protective device.

8.14 Visible information (symbols) shall be provided, when it is necessary to take special precautions for installation, transportation or use (in the catalogue, data sheet, instruction sheet or packaging):

- **non-inherently short-circuit proof transformer with non-self-resetting or non-replaceable protective device** and non-replaceable **intentional weak parts** shall have an information explaining the protective devices cannot be resetted or replaced after a short-circuit or an overload;
 - for **transformers** generating a **protective earthing conductor current** greater than 10 mA and are intended for permanent connection, the **protective earthing conductor current** shall be clearly stated in the instruction and indication shall be given that the installation shall be made according to the wiring rules;
 - ~~– for **associated transformers** and **IP00 transformers**, an informative note shall indicate that a 10 % over or under voltage may appear in the supply and the **rated output** of the **transformer** shall be selected accordingly;~~
 - for **stationary transformers** with a **rated output** exceeding 1 000 VA, the short-circuit voltage expressed as a percentage of the rated supply voltage;
 - the electrical function of the **transformer**;
 - the limiting temperature of the winding under abnormal conditions which shall be respected when the **transformer** is built into an appliance as information for appliance design;
 - ~~– for **t_w transformers**, the specified constant **S** other than 4 500, the symbol **S** together with its appropriate value in thousands, (e.g., “S6”, if **S** has a value of 6 000);~~
- ~~NOTE Preferred values of **S** are: 4 500, 5 000, 6 000, 8 000, 11 000 and 16 000;~~
- for **transformers** not designed for series and/or parallel connection with more than one output winding, that the **transformer** is not intended for series/parallel connection.

Compliance with the requirements of 8.1 to 8.14 is checked by inspection.

For **IP00 transformers**, if applicable, the test in 27.2 is not performed as the result may be affected by the **enclosure** in the final application.

8.15 Marking shall be durable and easily legible.

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

The petroleum spirit to be used for the test is aliphatic solvent hexane with an aromatic content of 0,1 % maximum, by volume, a kauributanol value of 29, initial boiling point approximately 65 °C, dry point approximately 69 °C and specific gravity of 0,68 g/cm³.

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

After all the tests of this document, the marking shall be easily legible, it shall not be possible to remove labels easily, and they shall show no curling.

8.16 Portable transformers with integrated plugs complying with EN 50075 (IEC plug type C), shall use the symbol IEC 60417-6352:2015-10.

The instruction sheet of the plug in transformer shall contain the following information, or equivalent:

if the pins of the plug parts are damaged, the plug-in power supply shall be scrapped.

NOTE The countries using this type of plug are mentioned under world plugs type C (available at <http://www.iec.ch/worldplugs/typeC.htm>).

Compliance with the requirements is checked by inspection.

9 Protection against electric shock

9.1 General

Transformers shall be enclosed and provided with adequate protection against contact with **hazardous-live-parts** and shall have no risk of an electric shock from stored charge on capacitors.

Compliance is checked by inspection and by the tests of 9.2.1, 9.2.2 and 9.3.

9.2 Protection against contact with hazardous-live-parts

9.2.1 Determination of hazardous-live-parts

9.2.1.1 A **live part** is not a **hazardous-live-part** if it is separated from the supply by **double** or **reinforced insulation** and the requirements of 9.2.1.2 or 9.2.1.3 are met when **the transformer** is supplied at **rated supply voltage**.

9.2.1.2 The voltage shall not exceed 35 V AC peak or 60 V ripple free DC.

Compliance is checked by measurements carried out between any two conductive parts.

9.2.1.3 Where the voltage exceeds 35 V (peak) AC or 60 V ripple free DC, the touch-current shall not exceed:

- for AC: 0,7 mA (peak);
- for DC: 2,0 mA.

Compliance is checked by measuring the touch current as stated in Annex J.

*In addition, when a capacitor is connected to the **live parts**:*

9.2.1.3.1 The discharge shall not exceed 45 μC for stored voltages between 60 V and 15 kV, or

9.2.1.3.2 The energy of discharge shall not exceed 350 mJ for stored voltages exceeding 15 kV.

Compliance of 9.2.1.3.1 and 9.2.1.3.2 is checked by measurements carried out with a load of 2 000 Ω .

9.2.2 Accessibility to hazardous-live-parts

Transformers shall be constructed to provide adequate protection against accessibility to **hazardous-live-parts**.

Class I and II transformers shall be so constructed and enclosed that there is adequate protection against accidental contact **with hazardous-live-parts**.

For **class I transformers**, accessible parts shall be separated from **hazardous-live-parts** by at least **basic insulation**.

Class II transformers shall be so constructed and enclosed that there is adequate protection against accessibility to **basic insulation** and to **conductive parts** separated from **hazardous-live-parts** by **basic insulation** only. Only parts separated from **hazardous-live-parts** by **double** or **reinforced insulation** may be accessible.

Hazardous-live-parts shall not be accessible after removal of detachable parts except for:

- lamps having caps larger than B9 and E10;
- type D fuse-holders.

NOTE IP00 **transformers** shall comply with the end product standard after incorporation in the end product.

The insulating properties of lacquer, enamel, paper, cotton, oxide film on conductive parts and sealing compound shall not be considered as giving the required protection against accidental contact with **hazardous-live-parts** with the exception of **fully insulated winding wire (FIW)**.

NOTE 1 Self-hardening resins can be relied upon to give the required protection against accidental contact with **hazardous-live-parts**.

Shafts, handles, operating levers, knobs and the like shall not be **hazardous-live-parts**.

Compliance is checked by inspection and by the relevant tests of IEC 60529.

*In addition, openings in **class II transformers**, and openings in **class I transformers** other than those in **conductive parts** connected to a protective earthing terminal, are tested with the test pin shown in Figure 3.*

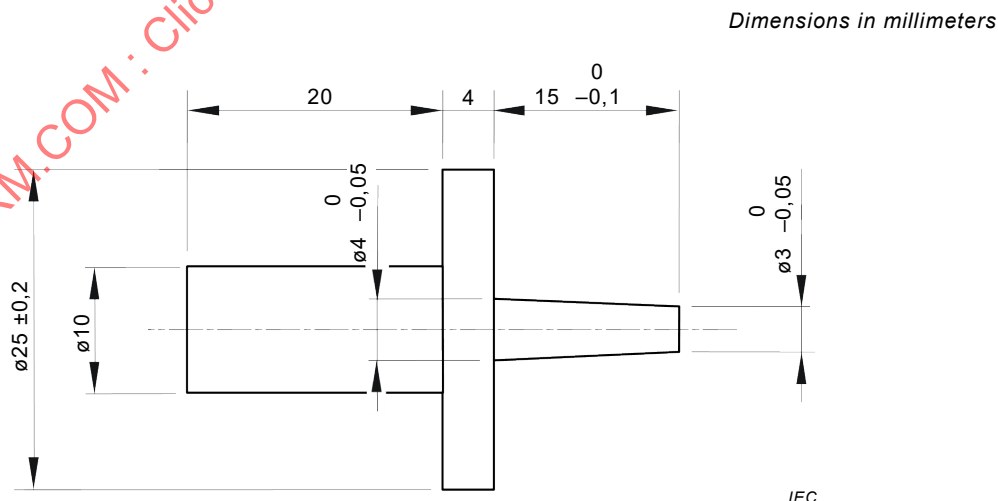


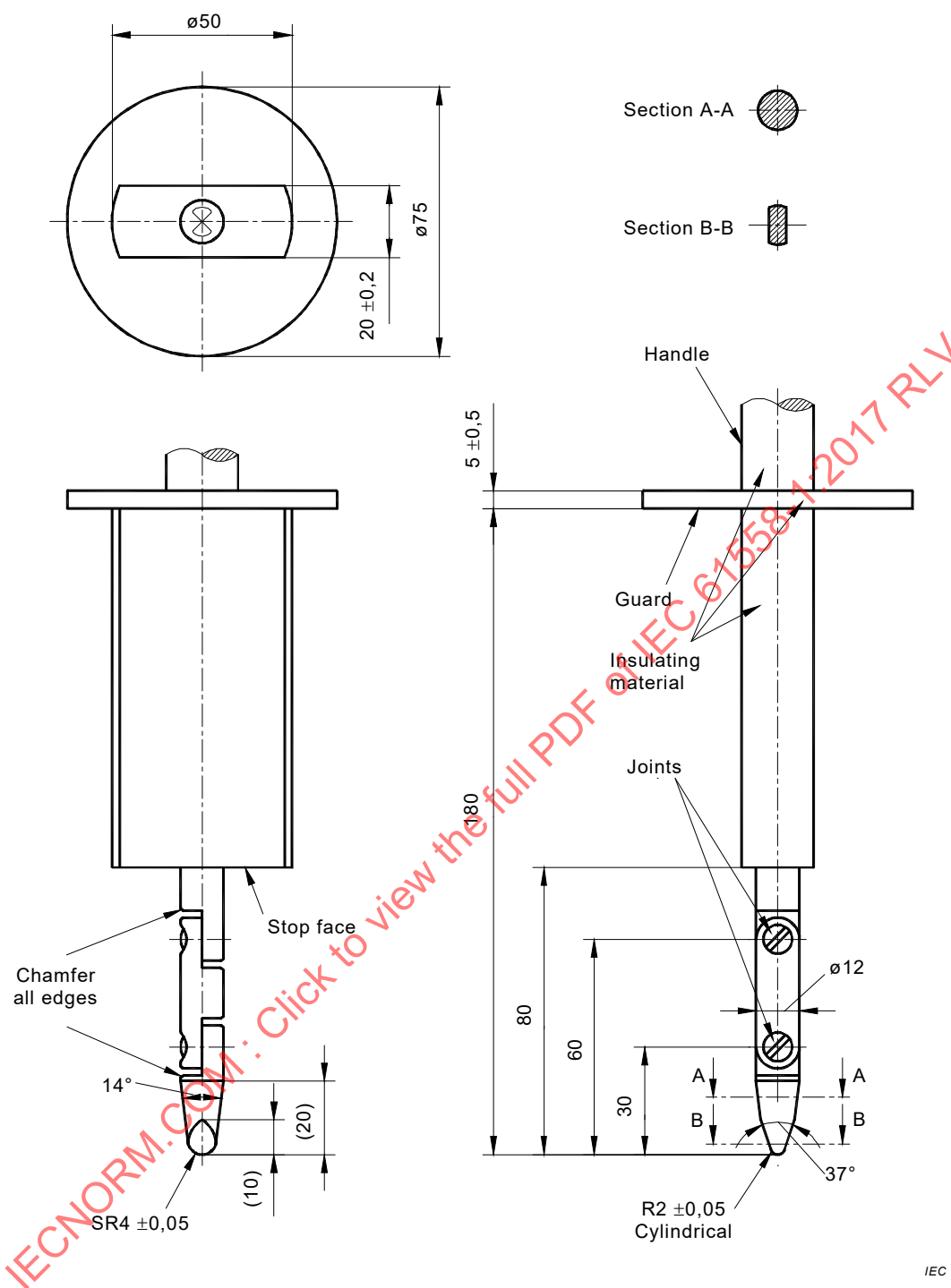
Figure 3 – Test pin (see IEC 61032, test probe 13)

The test finger and the test pin are applied, without appreciable force, in every possible position.

*The test finger of Figure 4 is applied without appreciable force, the **transformer** being in every possible position except that **transformers** normally used on the floor and having a*

mass exceeding 40 kg are not tilted. Through openings, the test finger is applied to any depth that the finger will permit and is rotated or angled before, during and after insertion to any position. If the opening does not allow the entry of the finger, the force on the finger in the straight position is increased to 20 N. If the finger then enters the opening, the test is repeated with the finger in the angled position.

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IEC

Material: metal, except where otherwise specified

Linear dimensions in millimetres

Tolerances on dimensions without specific tolerance:

on angles: 0/–10°

on linear dimensions:

– up to 25 mm: $\begin{matrix} 0 \\ -0,05 \end{matrix}$

– over 25 mm: ± 0,2

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

Figure 4 – Standard test finger (see IEC 61032, test probe B)

It shall not be possible to touch *with the test finger* bare **hazardous-live-parts** or **hazardous-live-parts** protected only by lacquer, enamel, paper, cotton, oxide film or sealing compound, with the ~~test finger~~ *exception of fully insulated winding wire (FIW)*.

~~For class II transformers, it shall not be possible to touch conductive parts separated from hazardous live parts by basic insulation only with the test finger.~~

There shall be no possibility to touch conductive parts of class II transformers with the test finger, which are separated from hazardous-live-parts only by basic insulation.

Moreover it shall not be possible to touch bare **hazardous live parts** with the test pin.

NOTE 2 This requirement does not apply to lamp caps or socket-outlets.

NOTE In case of doubt, an electrical contact indicator, with a voltage not less than 40 V, is used with a test pin.

9.2.3 Accessibility to non hazardous-live-part

Non **hazardous-live-parts** of the **output circuit** isolated from the **input circuit** by **double or reinforced insulation** may be accessible under the following conditions:

- for **no-load output voltages** not exceeding 35 V peak AC or 60 V ripple-free DC, both poles may be accessible;
- for **no-load output voltages** exceeding 35 V peak AC or 60 V ripple-free DC and not exceeding 250 V AC, only one of the poles may be accessible.

9.3 Protection against hazardous electrical discharge

For **transformers** with a primary supply plug, the pins of the plug shall not be hazardous-live measured 1 s after withdrawal of the plug.

For **transformers** without a primary supply plug, the terminals provided for connecting the **transformer** to the supply source shall not be hazardous-live measured 5 s after disconnection of the supply source.

NOTE For the purpose of this subclause, plug connectors and appliance inlets are regarded as mains plugs.

Compliance is checked by the following test:

If the nominal capacitance across the pins does not exceed 0,1 μ F, no test is conducted.

*The primary supply switch of the **transformer**, if any, is in the off-position, unless it is more unfavourable in the on-position.*

The test shall be carried out 10 times or with a device used to switch off at the most unfavourable electrical angle of the supply voltage.

The voltage is measured between the input terminals or between the supply leads or between the pins of the supply plug used for the connection to the supply source after 1 s or 5 s.

If the voltage exceeds 60 V ripple free DC, the discharge is measured in the same conditions and shall not exceed 45 μ C.

10 Change of input voltage setting

Transformers with more than one **rated supply voltage** shall be so constructed that the voltage setting cannot be changed without the aid of a **tool**.

NOTE As an example, the requirement concerning the voltage setting is met if a **tool** is needed to remove a cover before the voltage setting can be changed.

Transformers which can be set to different **rated supply voltages** shall be so constructed that the indication of the voltage for which the **transformer** is set is discernible on the **transformer** when it is ready for use.

Plug connected **transformers** provided with a device to select the input connections (e.g. by tapings) to adjust supply voltages within a range of not more than 10 % of the value corresponding with the midpoint of that range, are not considered to be **transformers** with more than one supply voltage.

Plug connected **safety isolating transformers** shall have only one **rated supply voltage** unless the **transformer** is not capable of producing an output voltage ~~in excess of~~ **exceeding** the ~~limits allowed in the scope~~ **output voltage limitation for safety isolating transformers** if the higher marked voltage is connected to the lower voltage winding.

Compliance is checked by measurement and inspection.

11 Output voltage and output current under load

11.1 When the **transformer** is connected to the **rated supply voltage**, at the **rated supply frequency**, and loaded with an impedance resulting in the **rated output** at the **rated output voltage** and, for AC current, at the **rated power factor**, the output voltage shall not differ from the rated value by more than:

- a) 10 % for the output voltage of **inherently short-circuit proof transformers** with one **rated output voltage**;
- b) 10 % for the highest output voltage of **inherently short-circuit proof transformers** with more than one **rated output voltage**;
- c) 15 % for the other output voltages of **inherently short-circuit proof transformers** with more than one **rated output voltage**;
- d) 5 % for the output voltages of other **transformers**.

For **transformers** with rectifiers, the above percentage values are raised by 5.

*Compliance is checked by measuring the output voltage when steady-state conditions are established, with the **transformer** connected to the **rated supply voltage**, at the **rated supply frequency**, and loaded with an impedance resulting in the **rated output**, at the **rated output voltage** and the **rated power factor**.*

*For **transformers** incorporating a rectifier, the output voltage is measured at the terminals of the DC circuit by means of a voltmeter giving the arithmetical mean value, unless the effective value RMS is specifically stated (see 8.1).*

*For **transformers** with more than one **rated supply voltage**, the requirement is applicable for each of the **rated supply voltages**.*

*For **transformers** with multiple **output windings**, the loads are applied to every multiple section simultaneously, unless otherwise declared.*

11.2 If a **transformer** is marked with the **rated output**, the **rated output voltage**, the **rated output current**, and the **rated power factor**, these values shall be substantially in agreement with each other.

If no **rated output current** is assigned to the **transformer**, the **rated output current** for the purpose of this specification can be calculated from the **rated output** and the **rated output voltage**.

Compliance is checked by calculation.

12 No-load output voltage

The relevant requirements for the **no-load output voltage** limitation are given in IEC 61558 Part 2 for the different types of **transformers**.

*For **transformers** incorporating a rectifier, the output voltages are measured at the input and output terminals of the rectifier if they are connected to terminals or terminations. The measurement at the input terminals of the rectifier is made if they are accessible to the user. The **output voltage** is measured at the terminals of the circuit with a voltmeter giving the arithmetic mean value, unless the effective value RMS is specifically stated (see 8.1).*

13 Short-circuit voltage

If there is a **short-circuit voltage** marking, the **short-circuit voltage** measured shall not deviate by more than 20 % from the value marked.

*Compliance is checked by measuring the **short-circuit voltage**, the **transformer** being at ambient temperature.*

14 Heating

14.1 General requirements

14.1.1 Temperature-rise test

Transformers and their supports shall not attain excessive temperature in normal use.

The manufacturer may choose the simulated load methods according to 14.1.2.1 or 14.1.2.2 instead of the direct load method that may be applied.

NOTE 1 The simulated load methods are according to IEC 60076-11:2004, 23.2.1 and 23.2.2.

Temperatures are determined under the following conditions when steady-state is established.

*The test and the measurements are made in a draught-free location having dimensions such that the test results are not influenced. If the **transformer** has a t_a rating, the test is conducted at $(t_a \pm 5) ^\circ\text{C}$.*

NOTE 2 The heating test is carried out taking into consideration only the t_a (and not t_{amin}).

Portable transformers are placed on a dull black painted plywood support. **Stationary transformers** are mounted as in normal use, on a dull black painted plywood support. The support is approximately 20 mm thick, and has dimensions which are at least 200 mm in excess of those of the orthogonal projection of the specimen on the support.

Transformers which are provided with integral pins intended to be introduced into fixed socket-outlets are tested in a flush-mounted socket-outlet mounted in a box on a dull black painted plywood support as indicated in Figure 2.

Flush type **transformers** are tested as described in 5.10.

Transformers with a protection index other than IP00 are tested in their **enclosure**.

Transformers with a protection index IP00, the application of which is not known, are tested as described in 5.13

NOTE 3 In the case of **transformers** with a protection index IP00, the temperature of the support is measured, but the values given in Table 2 and Table 5 are not considered.

Transformers with terminals for **type X attachment** with a specially prepared cord and for **type Y** and **type Z attachments** shall have the connections subjected to a pull of 5 N immediately before the heating test is carried out.

Transformers are supplied at the **rated supply voltage** and loaded with impedance producing the **rated output**, at the **rated output voltage** and, for AC current, at the **rated power factor**. The value of the output current is measured when steady-state is established. Then the supply voltage is increased by 10 % and the output current is adjusted to the same value measured before. The output current is not adjusted for **independent transformer**. After this no change is made in the circuit. The test is repeated under no-load condition if this is a more unfavourable situation.

Associated transformers are operated under the conditions occurring when the appliance or other equipment is operated under the conditions of normal use as indicated in the relevant specifications. **Transformers** with intermittent ratings shall be tested at the intermittent ratings, until steady-state conditions are established.

The temperatures of windings are determined by the change of resistance method.

NOTE 4 One of the methods consists of measuring each winding separately, and of determining the resistance of windings at the end of the test by taking resistance measurements, as soon as possible after switching off, and then at short intervals, so that a curve of resistance against time can be plotted to ascertain the resistance at the instant of switching off.

The value of the temperature rise of a winding is calculated with Formula (1):

$$\Delta t = \frac{(R_2 - R_1)}{R_1} (x + t_1) - (t_2 - t_1) \quad (1)$$

Alternative calculation of the maximum temperature in reference to the ambient temperature is calculated with Formulae (2) and (3):

$$T = t_a + \frac{(R_2 - R_1)}{R_1} (x + t_1) - (t_2 - t_1) \quad (2)$$

$$\text{or} \quad T = t_a + \Delta t \quad (3)$$

where

$x = 234,5$ for copper;

$x = 225$ for aluminium;

Δt is the temperature rise, above t_2 so that the maximum temperature equals $\Delta t + t_2$;

R_1 is the resistance at the beginning of the test, at temperature t_1 ;
 R_2 is the resistance at the end of the test, when steady conditions have been established;
 t_1 is the ambient temperature at the beginning of the test;
 t_2 is the ambient temperature at the end of the test;
 t_a is the ambient temperature;
 T is the maximum temperature.

At the beginning of the test, the windings shall be at ambient temperature.

When determining the temperature of the windings, the ambient temperature is measured at such a distance from the specimen so as not to influence the temperature reading. At this point, the ambient temperature shall not vary by more than 10 °C during the test. For **transformers** the test temperature equals $\Delta t + t_a$.

For **transformers** with more than one **input** or **output winding**, or a tapped **input** or **output winding**, the results to be considered are those showing the highest temperature.

Transformers with a winding resistance less than 50 mΩ can also be measured by thermocouples. The thermocouples shall only be mounted on accessible surfaces of the transformer windings. The maximum values of Table 2 for winding temperatures shall be reduced by 10 °C for the thermocouple measurements.

Other temperatures are determined by means of thermocouples so chosen and positioned that they have the minimum effect on the temperature of the part under test.

Thermocouples used for determining the temperature of the surface of supports are attached to the back of small blackened discs of copper or brass 1 mm thick and 15 mm in diameter which are flush with the surface.

The temperature of electrical insulation (other than that of windings) is determined on the surface of the insulation at places where failure could establish a contact between **hazardous-live-parts** and accessible **conductive parts**, or a reduction of **creepage distances** or **clearances** below the values specified in Clause 26. In addition, thermocouples shall be placed at the hottest points of the insulating material to avoid a risk of fire.

During the test, the temperature shall not exceed the values shown in Table 2 when the **transformer** is operated at its **rated ambient temperature** (25 °C or t_a). In those cases where the temperature in the test area differs from the **rated ambient temperature**, this difference shall be taken into account when applying the limits in Table 2 and when establishing the test temperatures in 27.2 and 27.5.

14.1.2 Alternative temperature-rise test

14.1.2.1 Simulated load method

This method is applicable for an enclosed or non-enclosed or totally enclosed dry type unit with natural air or forced air cooling.

Temperature rise is established by combining the short-circuited test (load loss) and the open circuit test (no-load loss).

The temperature of the **transformer** shall be stabilized with that of the test laboratory environment. The resistance of the primary and secondary windings shall be measured, these values will be used as reference values for the calculation of the temperature rise of the two windings. The ambient temperature of the test laboratory shall also be measured and registered.

For three-phase **transformers**, the resistance measurements shall be made between the central and an outer phase line terminals.

The location of the measuring points (that is, the ambient temperature thermometers and sensors on the **transformer**, if any), shall be the same for the reference and final measurements.

The winding short-circuited test shall be performed with rated current flowing in one winding and the other winding short-circuited and shall continue until the steady-state condition of the windings and magnetic core are reached. The winding temperature rise, $\Delta\theta_c$, shall be established by the rise in resistance method or by superposition.

The open-circuit test, at rated voltage and **rated frequency**, shall be continued until steady-state condition of the winding and magnetic core is obtained, individual winding temperature rises, $\Delta\theta_e$, shall then be measured.

The test procedure shall be either:

- the winding short-circuited test carried out until stabilisation of the core and the winding temperature. Subsequently, an open-circuit test shall be carried out until stabilisation of the core and winding temperature is reached.

or

- the open-circuit test carried out until stabilisation of the core and the winding temperature. Subsequently, the winding short-circuited test shall be carried out until stabilisation of the core and winding temperature is reached.

The total winding temperature rise, $\Delta\theta'_c$ of each winding, with rated current in the winding and normal excitation of the core, is calculated with Formula (4):

$$\Delta\theta'_c = \Delta\theta_c \left[1 + \left(\frac{\Delta\theta_e}{\Delta\theta_c} \right)^{1/K1} \right]^{K1} \quad (4)$$

where

$\Delta\theta'_c$ is the total winding temperature rise;

$\Delta\theta_c$ is the winding temperature rise at the short-circuited test;

$\Delta\theta_e$ is the individual winding temperature rise at the open-circuited test;

$K1 = 0,8$ for natural air cooling and $0,9$ for forced air cooling.

14.1.2.2 Back-to-back method

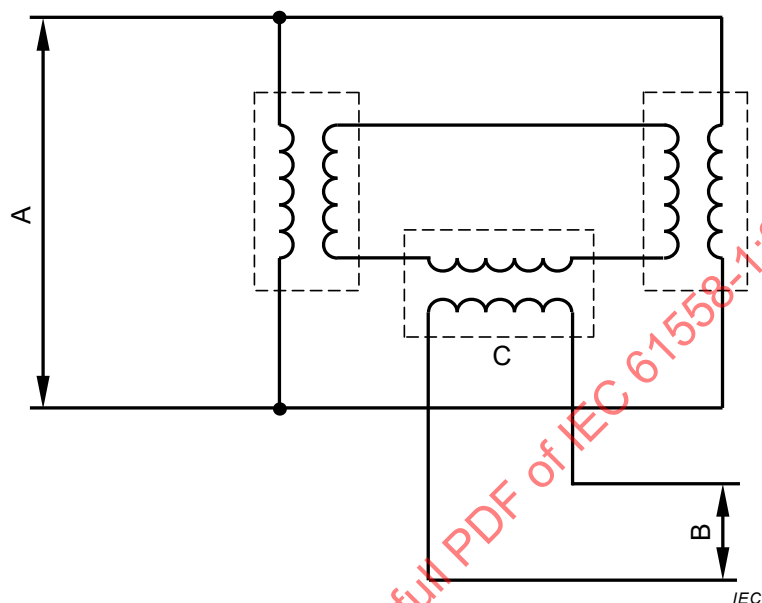
This method is appropriate when there are two similar **transformers** and the necessary test equipment is available. It is applicable for enclosed or non-enclosed dry-type units with natural air or forced air cooling.

The temperature of the **transformer** shall be stabilised with that of the test laboratory environment. The resistance of the high voltage and low voltage windings shall be measured, these values will be used as reference values for the calculation of the temperature rise of the two windings. The ambient temperature of the test laboratory shall also be measured and registered.

The location of the measuring points shall be the same for the reference and final measurements.

Two **transformers**, one of which is the **transformer** under test, are connected in parallel, and preferably the inner windings are excited at the rated voltage of the **transformer** under test. By means of different voltage ratios or an injected voltage, the rated current is made to flow in the **transformer** under test until stabilisation of the core and winding temperatures. See Figure 5 and Figure 6.

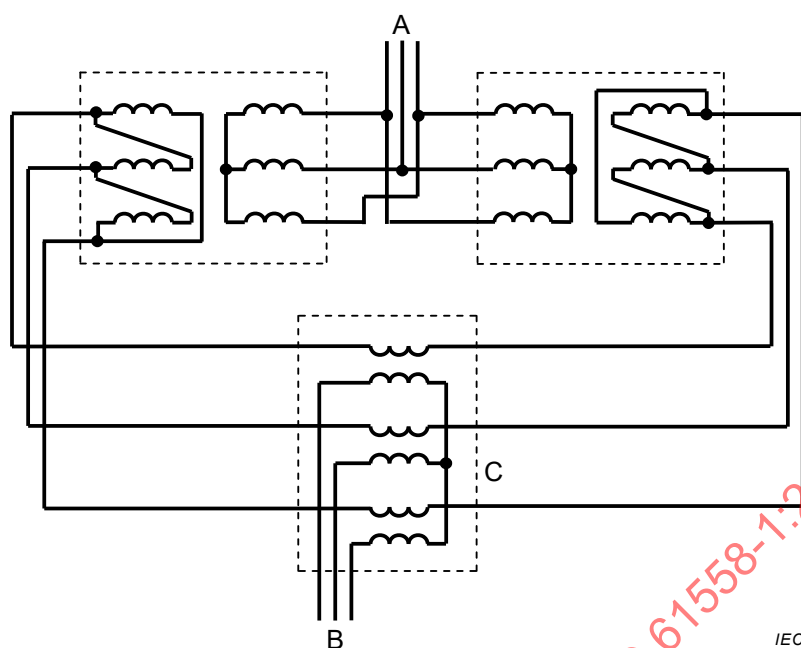
The duration of the test may be reduced by exciting the core for a period of time (preferably not less than 12 h) prior to the application of test current to the windings.



Key

- A = Voltage source at rated frequency for no-load losses
- B = Source for rated current at rated frequency for load losses
- C = Booster transformer

Figure 5 – Example of back-to-back method – Single phase



Key

- A = Voltage source at rated frequency for no-load losses
- B = Source for rated current at rated frequency for load losses
- C = Booster transformer

Figure 6 – Example of back-to-back method – Three phase

14.1.3 Determination of steady-state conditions

The ultimate temperature rise is reached when the temperature rise becomes constant; this is considered to have been achieved when the temperature rise does not vary by more than 1 K per hour.

For the purpose of determining when steady-state conditions have been achieved, thermocouples shall be applied to the following surfaces:

- *For all types of transformers defined in Clause 3: centre of top yoke and as close as practicable to the innermost winding at the top of the winding, the measurement being on the centre leg of a three-phase transformer.*

Table 2 – Values of maximum temperatures in normal use

Parts ^a	Temperature °C
Windings, if the insulation system (i.e. bobbins and any other insulating materials that are in contact with the winding) is:	
– of class A ^b	100
– of class E ^b	115
– of class B ^b	120
– of class F ^b	140
– of class H ^b	165
– of other classes ^c	–
External enclosures ^{d,f} (which can be touched with the standard test finger) of stationary transformers , if of:	
– bare metal	65
– metal covered by lac or varnish	70
– other material	80
External enclosures ^{d,f} (which cannot be touched with the standard test finger) of stationary transformers	85
External enclosures ^{d,f} , handles and the like of portable transformers :	
– if, in normal use, these parts are continuously held (for example for hand held transformers):	
• of metal	55 48
• of other material	75 48
– if, in normal use, these parts are not continuously held:	
• of metal	60
• of other material	80
Terminals for external conductors and terminals of switches	70
Insulation of internal and external wiring ^e :	
– of rubber	65
• of polyvinyl chloride	70
Parts the deterioration of which could affect safety ^e :	
– of rubber (other than insulation of wiring)	75
• of phenolformaldehyde	105
• of ureaformaldehyde	85
• of impregnated paper and fabric	85
• of impregnated wood	85
• of polyvinyl chloride (other than insulation of wiring), polystyrene and similar thermo-plastic material	65
• of varnished cambric	75
Supports	85
Printed ~~circuit~~ boards ^e :	
– bonded with phenol-formaldehyde, melamine-formaldehyde, phenol-furfural or polyester	105
• bonded with epoxy	140
^a If other materials are used, they shall not be exposed to temperatures in excess of those which have been proved permissible for these materials.	
^b The classification is in accordance with IEC 60085 and IEC 60216 (all parts); however, the values have been adjusted to take into account the fact that, in these tests, the temperatures are mean and not hot-spot values.	
^c If other insulating materials than those covered by IEC 60085 and IEC 60216 (all parts) are used, the insulation system shall withstand the test of 0.	
^d If any component is part of the external surface of the transformer, the temperature of that component shall not exceed the value specified for the appropriate external enclosure.	
^e The grades of rubber and polyvinyl chloride insulation are those covered by IEC 60245 (all parts) and IEC 60227 (all parts), respectively.	
^f If the surface temperature limit of accessible parts exceeds the required values the warning symbol IEC 60417-5041 (2002-10) shall be used.	

An explanation of the appropriate hot-spot reduction for the maximum winding temperature can be found in Table 3 for each insulation classification according to IEC 60085.

Table 3 – Explanation of the maximum winding temperatures required in Table 2

Insulation classification according to IEC 60085	Maximum temperatures of Table 2	Hot spot reduction	Maximum final temperature according to IEC 60085
	°C	K	°C
Class A	100	5	105
Class E	115	5	120
Class B	120	10	130
Class F	140	15	155
Class H	165	15	180
The measuring of the winding temperature is based on the resistance method. So the measured values are mean values of the windings temperature. To cover also the peak values inside the winding, the hot spot reduction is necessary.			

The temperature rise on the heating elements of protective devices touching insulating material shall also be measured.

Immediately after the test, the specimen shall withstand a dielectric strength test as specified in 18.3, the values are specified in Table 14 and the test voltage being applied between **input** and **output circuits** only.

During and after the test, the electrical connections shall not be loose, **creepage distances** and **clearances** shall not be reduced to less than the values specified in Clause 26, sealing compound shall not melt, and overload protective devices shall not operate.

NOTE According to IEC 60038 the nominal voltage tolerance of $\pm 10\%$ is also applicable for an AC voltage value up to 1 000 V and a DC voltage value up to 1 415 V.

14.2 Application of 14.1 or 14.3 according to the insulation system

The following apply to the windings.

14.2.1 If the manufacturer has stated which class of insulation system has been used, the measured temperature of the winding shall not exceed the relevant value given in Table 2 (considering t_a if stated).

14.2.2 If the manufacturer has not stated which class of insulation system has been used the measured temperature of the winding shall not exceed the value given in Table 2 for class A insulation system (considering t_a if stated).

14.2.3 If the manufacturer has not stated which class of insulation system has been used and the measured temperature of the winding exceeds the value given in Table 2 for class A insulation system (considering t_a if stated), the **live parts of transformers** (core and windings) are subjected to the tests of 14.3. The temperature of the heating cabinet is chosen according to Table 4, taking the value of t_a into account. The temperature value to be chosen in Table 4 is the next highest value to the calculated temperature value.

14.3 Accelerated ageing test for undeclared class of insulation system

14.3.1 General

When applicable (see 14.2, 19.12.3 and 26.3), the **live parts** of the transformer (core and windings) are subjected to the following ageing test, each cycle consisting of a heat run, vibration, and a moisture treatment. Measurements are made according to 14.3.5.

The number of specimens is as indicated in 5.2. The specimens are subjected to 10 test cycles.

14.3.2 Heat run

Depending on the type of insulation system, the specimens are kept in a heating cabinet for the combinations of time and temperature recommended by the manufacturer in accordance with Table 4. The 10 cycles are carried out with the same combination.

The temperature in the heating cabinet is maintained within a tolerance of ± 3 °C.

Table 4 – Test temperature and testing time (in days) per cycle

Test temperature °C	Testing time for the thermal class of the insulation system (days)				
	100 °C	115 °C	120 °C	140 °C	165 °C
220					4
210					7
200					14
190				4	
180				7	
170				14	
160			4		
150		4	7		
140		7			
130	4				
120	7				
Corresponding classification according to IEC 60085 and IEC 60216 (all parts)	A	E	B	F	H

After the heat tests, the specimens are allowed to cool down to ambient temperature before the vibration is conducted.

14.3.3 Vibration

Specimens are fastened in their normal position of use to the vibration generator, as specified in IEC 60068-2-6 by means of straps round the **enclosure**. The direction of vibration is vertical, and the severity is:

- duration: 30 min;
- amplitude: 0,35 mm;
- frequency range: 10 Hz, 55 Hz, 10 Hz;
- sweep rate: approximately one octave per minute.

14.3.4 Moisture treatment

The specimens are subjected for two days (48 h) to a moisture treatment according to 17.2.

14.3.5 Measurements

All the following measurements and tests are made and conducted before the cycling and after each complete cycle:

- the no-load input current or its ohmic value.
The no-load input current or the ohmic component of the no-load input current shall not be more than 30 % greater than the corresponding value obtained during the initial measurement;
- the insulation resistance is measured according to 18.1 and 18.2;
- a dielectric strength test according to 18.3 and 18.4. However, the values of the test voltages are reduced to 35 % of the specified values and the testing time is doubled;
- the following test only for **transformers** with a **rated supply frequency** of 50 Hz or 60 Hz. After the dielectric strength test, one **input circuit** is supplied by a test voltage of at least 1,2 times the **rated supply voltage** at double the **rated supply frequency** for 5 min. No load is connected to the **transformer**. During the test, polyfilar windings, if any, are connected in series. A higher test frequency than the double supply frequency may be used; the duration of the period of connection, in minutes, being equal to 10 times the **rated supply frequency** divided by the test frequency, but not less than 2 min.

During the above tests, there shall be no breakdown of the insulation between the turns of a winding, between **input** and **output circuits**, between adjacent **input** or **output circuits**, or between the windings and any conductive core.

If, after the completion of all 10 cycles, one or more specimens fail, the **transformer** is considered as not having complied with the accelerated ageing test.

15 Short circuit and overload protection

15.1 General requirements

15.1.1 Short circuit and overload test method

Transformers shall not become unsafe due to short circuits and overloads that may occur in normal use.

Compliance is checked by inspection and by the following tests, which are carried out immediately after the test according to 14.1 at the same ambient temperature, and without changing the position of the **transformer**, at 1,1 times the **rated supply voltage**, or, for **non-inherently short-circuit proof transformers**, at any value of the supply voltage between 0,9 times and 1,1 times the **rated supply voltage**:

- for **inherently short-circuit proof transformers**, by the tests of 15.2;
- for **non-inherently short-circuit proof transformers**, by the tests of 15.3;
- for **non-short-circuit proof transformers**, by the tests of 15.4;
- for **fail-safe transformers**, by the tests of 15.5;
- for **transformers** combined with a rectifier, the tests of 15.2 or 15.3 are carried out twice, once with the short circuit applied on the input terminals of the rectifier, and again with the short circuit applied on the output terminals of the rectifier;
- for **transformers** with more than one **output winding** or a tapped **output winding**, the results to be considered are those showing the highest temperature. In the first case, all windings intended to be loaded at the same time are loaded at the **rated output** and then the selected **output winding** is short-circuited.

For the tests of 15.2, 15.3 and 15.4, the temperatures shall not exceed the values given in Table 5 when the **transformer** is operated at its **rated ambient temperature** (25 °C or t_a). In

the cases where the temperature in the test area differs from the **rated ambient temperature**, this difference shall be taken into account when applying the limits in Table 5.

Table 5 – Maximum values of temperatures under short-circuit or overload conditions

Insulation classification	A	E	B	F	H
	Maximum temperature °C				
Winding protected inherently Subclause 15.2	150	165	175	190	210
Winding protected by protective device:					
a) Subclauses 15.3.2 – 15.3.3 – 15.3.4 – during the time required or the time <i>T</i> given in Table 6 ^a	200	215	225	240	260
b) Subclause 15.3.1 – during the first hour, peak value	200	215	225	240	260
– after the first hour, peak value	175	190	200	215	235
– after the first hour, arithmetic mean value ^b	150	165	175	190	210
c) Subclause 15.3.5	175	190	200	215	235
External enclosures (which can be touched with the standard test finger)	105				
Rubber insulation of wiring	85				
PVC insulation of wiring	85				
Supports (i.e. any area on the pine plywood surface covered by the transformer)	105				

^a The maximum temperature to be considered is the maximum temperature reached during and after the test due to the thermal inertia of the **transformer**.

^b The arithmetic mean value is determined as follows:

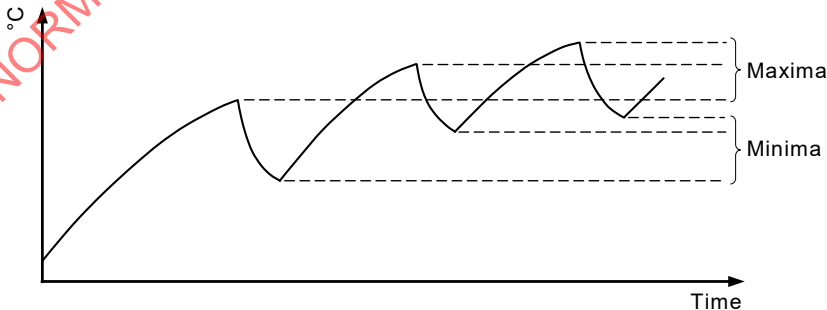
The graph of temperature versus time, while the power to the **transformer** is cycling on and off, is plotted for a period of test under consideration. The arithmetic average temperature (*t_A*) is determined by Formula (5):

$$t_A = (t_{\max} + t_{\min})/2 \tag{5}$$

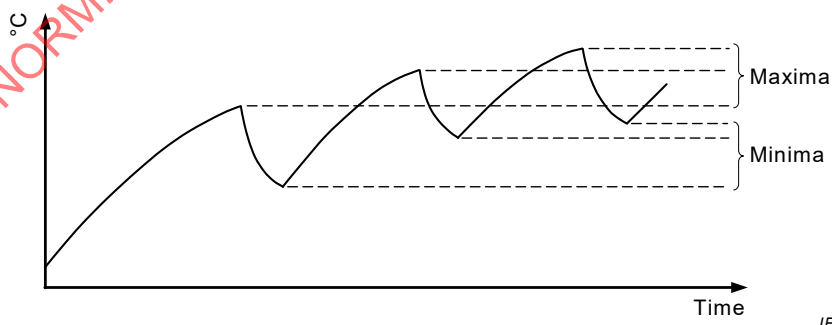
where

t_{max} is the average of the maxima;

t_{min} is the average of the minima.



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During the test, the **transformer** shall not emit flames, molten metal, poisonous or ignitable gas in hazardous amounts, and temperatures shall not exceed the values shown in Table 5.

During and after all the tests, the **transformer** shall comply with Clause 9.

After the tests, the insulation system, when it has cooled down to approximately ambient temperature, shall withstand the dielectric strength test in 18.3.

NOTE The humidity treatment of 17.2 is not applied before this dielectric strength test.

15.1.2 Alternative short circuit and overload test method

The manufacturer may choose to apply any of the following methods described in 14.1.2.1 and 14.1.2.2. These test procedures are according to IEC 60076-11:2004, 23.2.1 and 23.2.2.

15.2 Inherently short-circuit proof transformers

Inherently short-circuit proof transformers are tested by short-circuiting the **output windings** until steady-state conditions are reached.

15.3 Non-inherently short-circuit proof transformers

Non-inherently short-circuit proof transformers are tested as follows:

15.3.1 The output terminals are short-circuited. The incorporated overload protective device shall operate before the temperature exceeds the values shown in Table 5 for any value of the supply voltage between 0,9 times and 1,1 times the **rated supply voltage**.

15.3.2 If protected by a fuse in accordance with either IEC 60269-2 or IEC 60269-3, or a technically equivalent fuse, the **transformer** is loaded for a time T and with a current equal to k times the current marked on the **transformer** as the rated current of the protective fuse-link, where k and T have the values shown in Table 6. The current in the fuse shall be kept constant during the test. The fuse-link is replaced by a link of negligible impedance.

Table 6 – Values of T and k for fuses

Values marked as rated current I_n of protective fuse-link for gG and gTr A	T h	k
$I_n \leq 4$	1	2,1
$4 < I_n \leq 16$	1	1,9
$16 < I_n \leq 63$	1	1,6
$63 < I_n \leq 160$	2	1,6
$160 < I_n \leq 200$	3	1,6
$200 < I_n \leq 1\,000$	2	1,5
NOTE 1 For cylindrical fuses gG type B for use by unskilled persons according to IEC 60269-3:2010, and for fuses for use by authorised persons with fuse-links for bolted connections according to IEC 60269-2:2013, the value of k is 1,6 for $I_n < 16$ A.		
NOTE 2 For D-type fuses for use by unskilled persons according to IEC 60269-3:2010 for a rated current of 16 A, the value of k is 1,9.		

15.3.3 If protected by miniature fuses in accordance with IEC 60127 (all parts), or by road vehicle blade type electric fuse-links according to ISO 8820 (all parts), or by a technically equivalent fuse, the **transformer** is loaded for a period corresponding to the longest pre-arcing time with the relevant current as specified in the appropriate standard sheet. The current in the fuse shall be kept constant during the test. The fuse-link is replaced by a link of negligible impedance.

NOTE A technically equivalent fuse is a fuse-link having the same time-current characteristics as one of those indicated in IEC 60127 (all parts) or in ISO 8820 (all parts).

If the **transformer** is protected by miniature fuses in accordance to IEC 60127 (all parts), an additional overload test shall be performed at 1,5 times the rated fuse current until steady-state condition.

15.3.4 If protected by a circuit-breaker in accordance with IEC 60898 (all parts), or a technically equivalent circuit-breaker, the **transformer** is loaded for the time indicated in IEC 60898 (all parts) with a current equal to 1,45 times the value of the rated current of the circuit-breaker. The current in the fuse shall be kept constant during the test. The circuit breaker is replaced by a link of negligible impedance.

15.3.5 If protected by:

- an overload protective device other than a fuse according to IEC 60127 (all parts) or IEC 60269 (all parts), or a circuit-breaker or
- an **intentional weak part**

the **transformer** is loaded by a current equal to 0,95 times the value of the lowest current which causes the protective device to operate, until steady-state conditions are reached. The lowest current causing the protective device to operate is determined by initially operating the transformer at 100 % of the **rated output**, and gradually increasing the output current in steps of 2 %, (each step is maintained until steady-state condition is achieved) until the protective device operates.

If the protective device is an **intentional weak part**, the above test is repeated on two new samples. During the test on the first sample, the weak part shall operate in the same manner and place as above. During the test on the second sample, the temperatures shall not exceed the values in Table 5 in the steady-state condition.

15.4 Non-short-circuit proof transformers

Non-short-circuit proof transformers are tested as indicated in 15.3 with the appropriate protective device specified by the manufacturer installed in the relevant **input** or **output circuit**.

Associated **non-short-circuit proof transformers** are tested under the most unfavourable conditions of normal use with the appropriate protective device specified by the manufacturer installed in the **input** or **output circuit**, and in the most unfavourable load conditions for the type of equipment or circuit for which the **transformer** is designed. Examples of unfavourable load conditions are: continuous, short-time, or intermittent functioning.

15.5 Fail-safe transformers

15.5.1 Three additional new specimens are used only for the following test.

During this test when the **transformer** fails, the interruption shall be in the **input circuit**.

Each of the three specimens is mounted as in normal use on a 20 mm thick dull black painted plywood surface and heated in accordance with 14.1 until the temperatures stabilise. Each **transformer** is then operated at 1,1 times the **rated input voltage**, the **output winding** which produced the highest temperature during the test of 14.1 being initially loaded with 1,5 times the **rated output current** (or, if this is not possible, the maximum value of the output current obtainable) until steady-state conditions are reached, or the **transformer** fails (whichever occurs first).

If the **transformer** fails, it shall comply, during and after the tests, with the criteria given in 15.5.2.

If the **transformer** does not fail, the time to reach steady-state conditions is noted, and the chosen **output winding** is then short-circuited. The test is continued until the **transformer**

fails. For this part of the test, each specimen shall fail within the time duration being no longer than the time necessary to reach steady-state conditions, but not exceeding 5 h.

*The **transformer** shall fail safely and comply, during and after the tests, with criteria given in 15.5.2.*

15.5.2 At any time during the tests of 15.5.1:

- the temperature of any part of the **enclosure** of the **transformer** which can be touched with the standard test finger *Figure 4* shall not exceed 175 °C;
- the temperature of the plywood support shall nowhere exceed 125 °C;
- the **transformer** shall not emit flames, molten material, glowing particles, or burning drops of insulating material.

After the tests of 15.5.1, and after cooling down to ambient temperature:

- the **transformer** shall withstand a dielectric strength test, the test voltage being 35 % of the values according to Clause 18, Table 14. The test is made input-to-body for all kinds of **transformers** and, in addition, input-to-output for **safety isolating, isolating and separating transformers**;
- **enclosures**, if any, shall have no holes allowing the standard test finger (*Figure 4*) to touch **hazardous-live-parts**. In case of doubt, contact with **hazardous-live-parts** is detected by means of an electrical contact indicator, the voltage being not less than 40 V.

*If the **transformer** fails any part of this subclause, the **transformer** is considered as not complying with the above test.*

16 Mechanical strength

16.1 General

Transformers shall have adequate mechanical strength, and be so constructed as to withstand rough handling as may be expected in normal use.

*Compliance is checked by the tests of 16.2 for **stationary transformers** and by the tests of 16.2, 16.3 and 16.4, as appropriate, for **portable transformers**.*

*After the tests, the **transformer** shall show no damage in accordance with the requirements of this document. In particular, **hazardous-live-parts** shall not become accessible, when checked as described in 9.2.2. Insulating barriers shall not be damaged, and handles, levers, knobs and the like shall not move on their shafts.*

NOTE 1 Damage to the finish, small dents which do not reduce **creepage distances** or **clearances** below the values specified in Clause 26, and small chips which do not adversely affect the protection against electric shock or moisture, are ignored.

NOTE 2 Cracks not visible with normal vision or corrected vision without magnification, and surface cracks in fibre reinforced mouldings and the like are ignored.

In addition, in regard to the test of 16.4, bending of the pins during the test is ignored.

16.2 Stationary transformers

*The **transformer**, with covers and the like fitted, is held firmly against a rigid support and is subjected to three blows from a spring-operated impact hammer according to test *Ehb* of IEC 60068-2-75 with an energy of $(0,5 \pm 0,05)$ J applied to every point of the exterior that protects **hazardous-live-parts** and is likely to be weak, including handles, levers, switch knobs and the like, by pressing the hammer nose perpendicularly to the surface. Before*

applying the blows, the fixing screws of bases and covers are tightened with a torque equal to two-thirds of that specified in Table 18.

If there is a doubt as to whether a defect has occurred by the application of the preceding blows, the defect is neglected, and the group of three blows is applied to the same place on a new sample which shall then withstand the test.

*Parts of IP00 **transformers**, which are not accessible when the **transformer** is mounted in an appliance or other equipment, are not subjected to the test.*

16.3 Portable transformers (except portable transformers with integral pins for introduction in socket-outlet in the fixed wiring)

Portable transformers except those **portable transformers** with integral pins for introduction in socket-outlets of the fixed wiring are held in their normal position of use, and are then allowed to fall from a height of 25 mm onto a smooth steel plate at least 5 mm thick, placed on a flat concrete support. One hundred falls are carried out at a rate not exceeding one fall per 5 s.

The height shall be measured from the part of the specimen nearest to the test surface when the specimen is suspended prior to letting it fall.

The method of releasing the specimen shall be such as to allow free fall from the position of suspension with a minimum of disturbance at the moment of release.

*If the **transformer** is provided with fixed **external flexible cable(s)** or **cord(s)**, they are cut to a length of 100 mm.*

16.4 Portable transformers provided with integral pins for introduction in socket-outlets of the fixed wiring

16.4.1 General requirements

Portable transformers with integral pins for introduction into fixed socket-outlets shall have adequate mechanical strength.

Plug in power supply units with integral main plug complying with IEC TR 60083, without plugs complying with EN 50075 (IEC plug type C) shall be tested according 16.4.1.

Plug in power supply units with integral main plug complying with EN 50075 (IEC plug type C), shall be tested according 16.4.2, if no additional national standard or regulation for a plug complying with IEC TR 60083 is required.

NOTE 1 The countries using this type of plug are mentioned under world plugs type C (available at <http://www.iec.ch/worldplugs/typeC.htm>).

Compliance is checked by carrying out the tests a), b) and c). The test a) is carried out on three specimens that all shall withstand the tests. Both the test of b) and c) shall be carried out on a new specimen.

- a) *The test is carried out in a tumbling barrel as described in ~~IEC 60068-2-32~~ IEC 60068-2-31. If the **transformer** is provided with fixed external cord(s) they are cut to a length of 100 mm. Each specimen is tested individually.*

The barrel is turned at a rate of five revolutions per minute, 10 falls per minute thus taking place, the number of falls being:

- 50 if the mass of the specimen does not exceed 250 g;
- 25 if the mass of the specimen exceeds 250 g.

After the test, the specimen shall show no damage within the meaning of this document, but it need not be operable.

Small pieces may brake off, provided that the protection against electric shock is not affected.

Distortion of pins and damage to the finish and small dents which do not reduce the **creepage distances** or **clearances** below the values specified in 27.1 of IEC 60884-1:2002, IEC 60884-1:2002/AMD1:2006 and IEC 60884-1:2002/AMD2:2013 are neglected.

- b) The pins shall not turn when a torque of 0,4 Nm is applied, first in one direction for 1 min and then in the opposite direction for 1 min.

NOTE 2 This test is not carried out when rotation of the pins does not impair the safety, in the sense of this document.

- c) A pull force as given in Table 7 is applied without jerks for 1 min on each pin, in turn, and in the direction of the longitudinal axis of the pin.

The pull force is applied within a heating cabinet at a temperature of $(70 \pm 2) ^\circ\text{C}$, 1 h after the device has been placed in the heating cabinet.

Table 7 – Pull force on pins

Rating of the equivalent plug type	Number of poles	Pull force N
Up to and including 10 A 130/250 V	2 3	40 50
Above 10 A up to and including 16 A 130/250 V	2 3	50 54
Above 10 A up to and including 16 A 440 V	3 More than 3	54 70

For the purpose of this test, protective earthing contacts, irrespective of their number, are considered as one pole.

After the test, and after the device has cooled down to ambient temperature, no pin shall be displaced in the body of the device by more than 1 mm.

16.4.2 Portable transformers provided with integral pins according to EN 50075 (IEC plug type C) for introduction in socket-outlets of the fixed wiring

Portable transformers with integral pins for introduction into fixed socket-outlets shall have adequate mechanical strength.

Compliance is checked by carrying out the tests a), and b). The test are carried out on three specimens that all shall withstand the tests.

- a) The test is carried in a tumbling barrel as described in IEC 60068-2-31. If the **transformer** is provided with fixed external cord(s) they are cut to a length of 100 mm. Each specimen is tested individually.

The barrel is turned at a rate of five revolutions per minute, 10 falls per minute thus taking place, the number of falls being:

- 1 000 if the mass of the specimen does not exceed 100 g;
- 500 if the mass of the specimen exceeds 100 g but does not exceed 200 g
- 100 if the mass of the specimen exceeds 200 g

After the test the following requirements shall be fulfilled:

- 1) The specimen shall show no damage within the meaning of this document, but it need not be operable.

- 2) *Small pieces may break off, provided that the protection against electric shock is not affected.*
- 3) *A pin of the plug shall not break*
- 4) *Distortion of pins and damage to the finish and small dents are neglected.*
- 5) *The pull test according to IEC 60884-1:2002, 24.10 shall be done with the same samples which have been in the tumbling barrel test. For the pull test, the pins, if distorted, shall be accurate into the vertical position. The pin shall not break.*

The pull force is applied within a heating cabinet at a temperature of $(70 \pm 2) ^\circ\text{C}$, 1 h after the device has been placed in the heating cabinet. After the test, and after the device has cooled down to ambient temperature, no pin shall be displaced in the body of the device by more than 1 mm.

- b) *The torque test shall be done with new samples. The pins shall not turn when a torque of 0,4 Nm is applied, first in one direction for 1 min and then in the opposite direction for 1 min.*

NOTE This test is not carried out when rotation of the pins does not impair the safety, in the sense of this document.

16.5 Additional requirements for transformers to be used in vehicles and railway applications

16.5.1 Transformers to be used in vehicles and railway applications

An additional test according IEC 61373 shall be performed with conditions of Table 8 and Table 9 and the frequency values depending on the weight of the specimen are defined in Table 10

Table 8 – Conditions for vibration testing (random)

Directions	Testing duration	RMS value m/s ²	Frequency range
X-Y-Z	5h per axis	5,72	Figure 7

Table 9 – Amplitude spectrum density ASD values for accelerated life testing

Directions	ASD value (m/s ²) ² /Hz
X-Y-Z	0,964

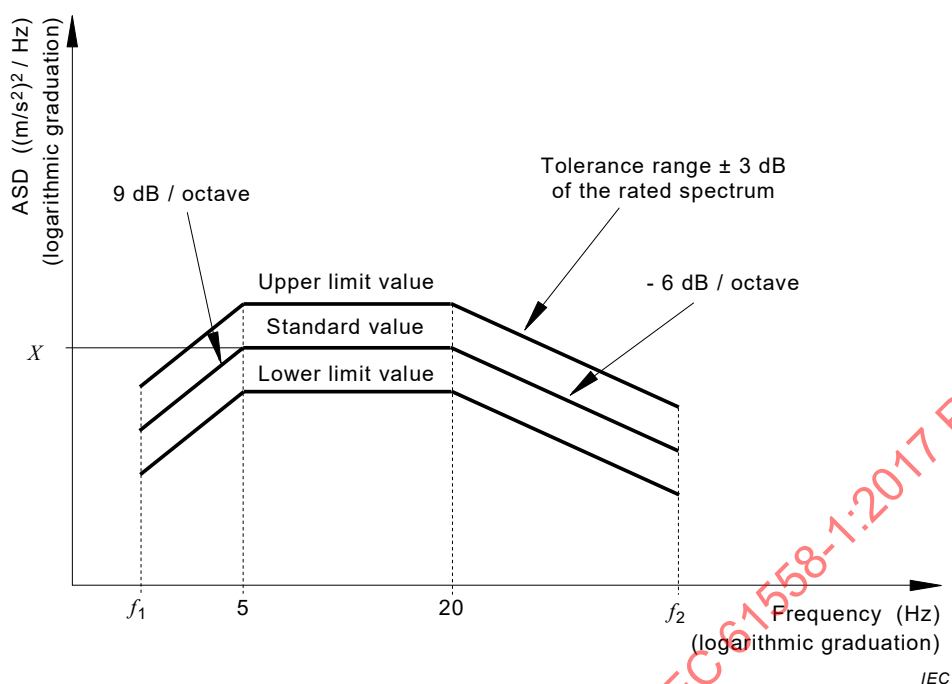


Figure 7 – Amplitude spectrum density for random testing

Table 10 – Frequency values depending on the weight of the specimen

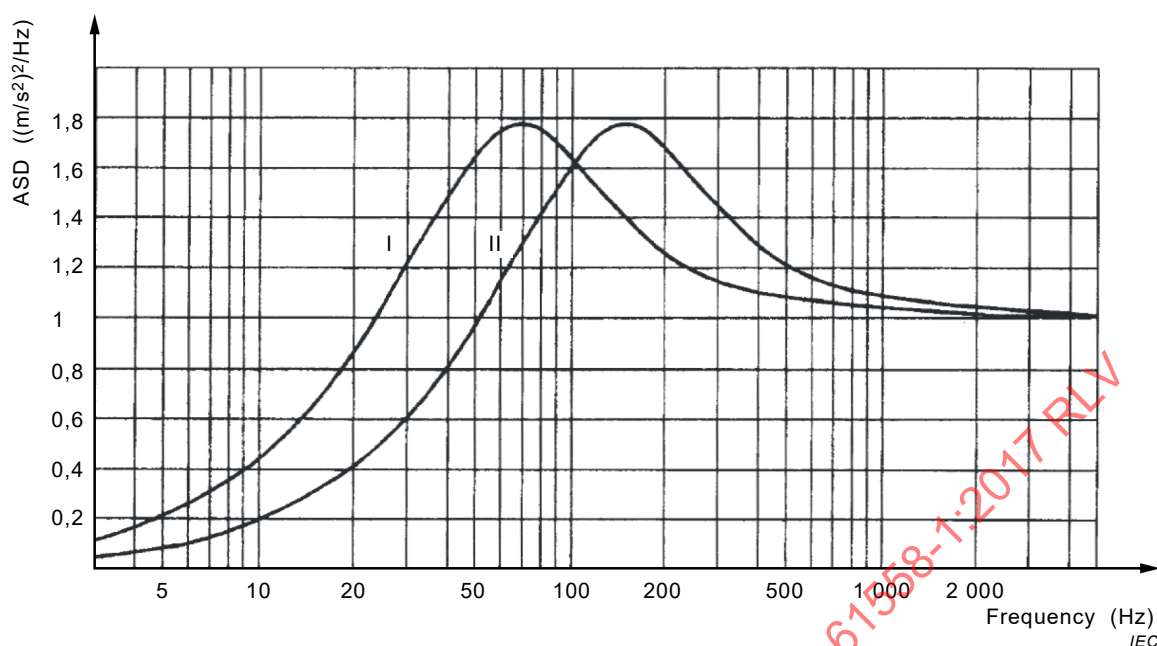
Frequency values		
For a mass ≤ 500 kg	$f_1 = 5$ Hz	$f_2 = 150$ Hz
For a mass > 500 kg and $\leq 1\,250$ kg	$f_1 = \frac{1\,250}{mass} \times 2$ Hz	$f_2 = \frac{1\,250}{mass} \times 60$ Hz
For a mass $> 1\,250$ kg	$f_1 = 2$ Hz	$f_2 = 60$ Hz

16.5.2 Test requirements for the transportation of transformers

Shock and vibration testing requirements for transformers subjected to while being transported per IEC 60721-3-2 with conditions according to Table 11 and Figure 8.

Table 11 – Excitation values for vibration testing

Type of vibration	Unit	Values		
Swept sine	mm	3,5		
	m/s ²		10	15
	Hz	2 to 9	9 to 200	200 to 500
Random	(m/s ²) ² /Hz	1		0,3
	Hz	10 to 200		200 to 2 000
Shock	Type I m/s ²	100		
	Type II m/s ²	300		



Example due to the duration of a half-sine impulse

Spectrum I

Duration 11 ms

Spectrum II

Duration 6 ms

Figure 8 – Normalised spectrum of shock

17 Protection against harmful ingress of dust, solid objects and moisture

17.1 Degrees of protection provided by enclosures (IP code)

17.1.1 General requirements

The **enclosure** of a **transformer** shall provide the degree of protection against ingress of dust, solid objects and moisture in accordance with the classification of the **transformer** and the IP number marked on the **transformer**, except IP1X which shall be marked and tested as IP00.

NOTE 1 An explanation of the IP code system is given in Annex Q.

NOTE 2 The degree of protection IP00 is not covered by Clause 17.

Compliance is checked by the appropriate test specified in 17.1.2, and for other IP ratings by the appropriate test specified in IEC 60529. If additional letters are used, the transformers shall comply with the relevant requirements of IEC 60529 where the test probe shall not touch hazardous-live-parts and hazardous moving parts.

Before the test of second characteristic numeral, with the exception of IPX8 and higher, the transformer shall be switched on under the rated output conditions and brought to a stable operating temperature at the rated voltage.

The water for the test shall be at a temperature of $(15 \pm 10) ^\circ\text{C}$.

Transformers shall be mounted and wired as in normal use with, where relevant, a suitable plug inserted in the **output circuit**.

Transformers not provided with an **external flexible cable or cord**, are fitted with external wiring, as specified in Clause 22, using the most unfavourable type and cross-sectional area.

For tests of 17.1.2 A to J, a **fixed transformer** intended for mounting with its **body** in contact with a surface shall be tested on a board equal in overall size to the projection of the **transformer**, if not otherwise specified.

Transformers with enclosure having provisions for draining water by means of drain holes shall be mounted with the lowest drain hole open unless otherwise specified in the manufacturer's installation instructions. Ventilation openings are left open during the test.

Portable transformers wired as in normal use, shall be placed in the most unfavourable position of normal use.

Glands, if any, shall be tightened with a torque equal to two-thirds of that applied to glands in the test of 25.6.

After completion of the tests, the **transformer** shall withstand the dielectric strength test specified in 18.3 and inspection shall show:

- a) no access with **hazardous-live-parts** or hazardous moving parts with the relevant test probe according to the test described in 17.1.2, items A 1), B 1) and C 1). The test finger may penetrate but the stop face ($\varnothing$ 50 x 20 mm) shall not pass through the openings for the number 2 of the first characteristic numeral
- b) no entry into the **transformer** enclosure by the relevant test probe for solid-object-proof **transformers** according to test described in 17.1.2, items A 2) and B 2). The protection is satisfactory if the full diameter of the probe does not pass through any openings;
- c) no deposit of talcum powder inside enclosures for dust-proof **transformers**, so that, if the powder were conductive, the insulation would fail to meet the requirements of this document (test described in 17.1.2, item C 2);
- d) no deposit of talcum powder inside **enclosures** for dust-tight **transformers** (test described in 17.1.2, item C 2);
- e) no trace of water on **live parts** except SELV parts below 15 V AC or 25 V DC or on insulation where it could become a hazard for the user or surroundings, for example where it could reduce the **creepage distances** below the values specified in Clause 26;
- f) no accumulation of water inside the enclosures of drip-proof, spray-proof, splash-proof and jet-proof **transformers**, which may impair safety;
- g) no water or trace of water entered inside the enclosure of a watertight **transformer**.

17.1.2 Tests on transformers with enclosure

A Solid-object-proof **transformers** (first characteristic IP numeral 2) shall be tested as follows:

- 1) with the standard test finger specified in IEC 60529 applied with a force of 10 N, with a relative tolerance of $\pm 10\%$ and the test pin specified in Figure 3 according to the requirements of Clause 9 and 26.2;
- 2) with a rigid sphere without handle or guard $12,5^{+0,2}_0$ mm diameter applied with a force of 30N, with a relative tolerance of $\pm 10\%$

B Solid-object-proof **transformers** (first characteristic IP numerals 3 and 4) shall be tested as follows:

- 1) at every possible point (~~excluding gaskets~~) with a probe according to test probe C or D of IEC 61032, applied with a force as given in Table 12:

Table 12 – Solid-object-proof transformer test

	Test probe according to IEC 61032	Probe wire diameter mm	Application force
First IP numeral 3	C	$2,5^{+0,05}_0$	$(3 \pm 0,3) \text{ N}$
First IP numeral 4	D	$1^{+0,05}_0$	$(1 \pm 0,1) \text{ N}$

The end of the probe wire shall be cut at right angles to its length and be free from burrs.

- 2) With a rigid steel rod with $2,5^{+0,05}_0$ mm diameter with edges free from burrs applied with a force of 3 N, with a relative tolerance of $\pm 10 \%$, for first characteristic IP numeral 3 and with a rigid steel wire with $1^{+0,05}_0$ mm diameter with edges free from burrs applied with a force of 1 N, with a relative tolerance of $\pm 10 \%$, for first characteristic IP numeral 4. The probes are intended to simulate foreign objects which may be spherical. Where an enclosure has an indirect or tortuous entry path and there is any doubt about ingress of a spherical object capable of motion, it may be necessary to examine drawings or to provide special access for the object probe to be applied with the specified force to the opening (s) where ingress has to be checked.

C Dust-proof **transformers** (first characteristic IP numeral 5) are tested as follows:

- 1) At every possible point with a probe according to test probe D of B 1).
- 2) In a dust chamber similar to that shown in Figure 2 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999, in which talcum powder is maintained in suspension by an air current; during the test the vacuum pump as shown is not connected. The chamber shall contain 2 kg of powder for every cubic metre of its volume. The talcum powder used shall pass through a square-meshed sieve whose nominal wire diameter is 50 μm , and whose nominal free distance between wire is 75 μm , ~~and shall have a range of particle size down to and including 1 μm with at least 50 % by weight less than 5 μm .~~ It should not be ~~have been~~ used for more than 20 tests.

The test shall be carried out as follows:

- a) the **transformer** is suspended outside the dust chamber and operated at **rated output** until operating temperature is achieved;
- b) the **transformer**, while still operating, is placed with the minimum disturbance in the dust chamber;
- c) the door of the dust chamber is closed;
- d) the fan/blower causing the talcum powder to be in suspension is switched on;
- e) after 1 min the **transformer** is switched off and allowed to cool for 3 h while the talcum powder remains in suspension.

NOTE 1 The 1 min interval between the switching on of the fan/blower and the switching off of the **transformer** is to ensure that the talcum powder is properly in suspension around the **transformer** during initial cooling, which is most important with smaller **transformers**. The **transformer** is operated initially as in item a) to ensure that the test chamber is not overheated.

NOTE 2 This treatment of test condition correspond to category 1 of IEC 60529.

D Dust-tight **transformers** (first characteristic IP numeral 6) are tested in accordance with C.

E Drip-proof **transformers** (second characteristic IP numeral 1) are subjected for 10 min to an artificial rainfall of ~~3 mm/min~~ $1^{+0,05}_0$ mm/min by means of a device as shown in Figure 3 of IEC 60529:1989, falling vertically from a height of 200 mm above the top of the **transformer**.

F Drip-proof **transformers** (second characteristic IP numeral 2) are tilted in any angle up to 15° and subjected for 10 min (2,5 min in each of the four fixed position of tilt) to a artificial rainfall of ~~3 mm/min~~ $3_0^{+0,5}$ mm/min by means of a device as shown in Figure 3 of IEC 60529:1989, falling vertically from a height of 200 mm above the top of the **transformer**.

G Spray-proof **transformers** (second characteristic IP numeral 3) are sprayed with water for 10 min by means of a spray apparatus as shown in Figure 4 of IEC 60529:1989. The radius of the semi-circular tube shall be as small as possible and compatible with the size and position of the **transformer**.

The tube shall be perforated so that jets of water are directed towards the centre of the circle, and a water ~~pressure at the inlet of the apparatus~~ flow rate shall be 0,07 l/min, with a relative tolerance of ±5 %, per hole, multiplied by number of holes (approximately 80 kN/m²).

The tube shall be caused to oscillate through an angle of 120°, 60° on either side of the vertical, the time for one complete oscillation (2 × 120°) being about 4 s.

The **transformer** shall be mounted above the pivot line of the tube so that the ends of the **transformer** receive adequate coverage from the jets. The **transformer** shall be turned about its vertical axis as stated in IEC 60529.

After this 10 min period, the **transformer** shall be switched off and allowed to cool naturally while the water spray is continued for a further 10 min.

H Splash-proof **transformers** (second characteristic IP numeral 4) are sprayed from every direction with water for 10 min by means of the spray apparatus shown in Figure 4 of IEC 60529:1989 and described in G. The **transformer** shall be mounted under the pivot line of the tube so that the ends of the **transformer** receive adequate coverage from the jets.

The tube shall be caused to oscillate through an angle of almost 360°, 180° on either side of the vertical, the time for one complete oscillation (2 × 360°) being about 12 s. The **transformer** shall be turned about its vertical axis as stated in IEC 60529.

The support for the equipment under test shall be grid shaped in order to avoid acting as a baffle. After this 10 min period, the **transformer** shall be switched off and allowed to cool naturally, while the water spray is continued for an additional 10 min.

I Jet-proof **transformers** (second characteristic IP numeral 5) are switched off and immediately afterwards are subjected to a water jet for 15 min from all directions by means of a hose, having a nozzle with the shape and dimensions shown in Figure 6 of IEC 60529:1989, the dimension D' being 6,3 mm. The nozzle shall be held 3 m away from the sample.

The rate of the water flow shall be 12,5 l/min, with a relative tolerance of ±5 %.

J Powerful jet-proof **transformers** (second characteristic IP numeral 6) are switched off and immediately afterwards are subjected to a water jet for 3 min from all directions by means of a hose, having a nozzle with the shape and dimensions shown in Figure 6 of IEC 60529:1989, the dimension D' being 12 mm. The nozzle shall be held 3 m away from the sample.

The rate of the water flow shall be 100 l/min, with a relative tolerance of ±5 %.

K Water-tight **transformers** (second characteristic IP numeral 7) are switched off and immediately immersed for 30 min in water, so that there is at least 150 mm of water above the top of the **transformer**, and the lowest portion is subjected to at least 1 m head of water. **Transformers** shall be held in position by their normal fixing means.

NOTE This treatment is not sufficiently severe for **transformers** intended for operation under water.

L Pressure watertight **transformers** (second characteristic IP numeral 8) are heated either by operating or by other suitable means, so that the temperature of the **transformer enclosure** exceeds that of the water in the test tank by between 5 °C and 10 °C.

The **transformer** shall then be switched off and subjected to a water pressure of 1,3 times that pressure which corresponds to the rated maximum immersion depth for a period of 30 min.

17.2 Humidity treatment

Transformers shall be proof against humid conditions which may occur in normal use.

Compliance is checked by the humidity treatment described in this subclause, followed immediately by the tests of Clause 18.

Transformers intended for fixed connection to the supply are tested with the cable fitted but with cable entries open. If several knock-outs are provided and positioned on different parts of the enclosure, the knock-out which produces the most unfavourable condition will be opened. **Transformers** intended to be used with an **external flexible cable or cord** are tested with the cord and cord entries correctly fitted.

*Electrical components, covers and other parts which can be removed without the aid of a **tool** are removed and subjected to the humidity treatment with the main part, if necessary.*

The humidity treatment is carried out in a humidity cabinet containing air with a relative humidity maintained between 91 % and 95 %. The temperature of the air at all places where specimens can be located, is maintained to within 1 °C of any convenient value t between 20 °C and 30 °C.

Before being placed in the humidity cabinet, the specimen is brought to a temperature between t and $(t + 4)$ °C.

The specimen is kept in the cabinet for:

- two days (48 h) for **transformers** with protection index IP20, or lower;
- seven days (168 h) for **transformers** with other protection index.

In most cases, the specimens may be brought to the specified temperature by keeping them at this temperature for at least 4 h before the humidity treatment.

NOTE A relative humidity between 91 % and 95 % can be obtained by placing a saturated solution of sodium sulphate (Na_2SO_4) or potassium nitrate (KNO_3) in water, the solution having a sufficiently large contact surface with the air in the humidity cabinet. In order to achieve the specified conditions within the cabinet, it is necessary to ensure constant circulation of the air and, in general, to use a cabinet which is thermally insulated.

*After this treatment and the tests of Clause 18, the **transformer** shall show no damage within the meaning of this document.*

18 Insulation resistance, dielectric strength and leakage current

18.1 General

The insulation resistance, the dielectric strength and the leakage current of **transformers** shall be adequate.

Compliance is checked by the tests of 18.2 to 18.5 which are carried out immediately after the test of 17.2, in the humidity cabinet or in the room where the specimen was brought to the prescribed temperature, after reassembling those parts which may have been removed.

Reducing the overvoltage category classification by about one category lower after the secondary side of the transformer is allowed, except for auto-transformers, under the following conditions:

- an earthed screen shall be between the primary and secondary winding or the secondary circuits have to be connected to functional earthing.

18.2 Insulation resistance

The insulation resistance shall not be less than that shown in Table 13.

The insulation resistance is measured with a DC voltage of approximately 500 V applied, the measurement being made 1 min after application of the voltage.

Table 13 – Values of insulation resistance

Insulation to be tested	Insulation resistance MΩ
Between hazardous-live-parts and the body :	
– for basic insulation	2
– for reinforced insulation	7
Between input circuits and output circuits (basic insulation)	2
Between input circuits and output circuits (double or reinforced insulation)	5
Between each input circuit and all other input circuits connected together	2
Between each output circuit and all other output circuits connected together	2
Between hazardous-live-parts and conductive parts of class II transformers which are separated from hazardous-live-parts by basic insulation only	2
Between conductive parts of class II transformers which are separated from hazardous-live-parts by basic insulation only, and the body	5
Between two metal foils in contact with the inner and outer surfaces of enclosures of insulating material of class II transformers	7

18.3 Dielectric strength test

Immediately after the test of 18.2, the insulation is subjected for 1 min to a dielectric strength voltage of substantially sinusoidal-wave form at 50/60 Hz. The value of the dielectric strength test voltage ~~and the points of application are~~ is given in Table 14.

Resistors, capacitors and other components are disconnected before carrying out the test.

Table 14 – Table of dielectric strength test voltages

Application of dielectric strength test voltage ^a	Working voltage V ^b				
	<50	150	300	600	1 000
1) Between ~~live parts~~ of input circuits and ~~live parts~~ of output circuits (~~basic insulation~~)	250	1 400	2 100	2 500	2 750
2) Between ~~live parts~~ of input circuits and ~~live parts~~ of output circuits (~~double or reinforced insulation~~)	500	2 800	4 200	5 000	5 500
3) Over ~~basic or supplementary insulation~~ between: a) ~~live parts~~ of different polarity: — inside the same winding: no test (~~functional insulation only~~); — other than winding: test applies; b) ~~live parts~~ and the ~~body~~ if intended to be connected to protective earth; c) accessible ~~conductive parts~~ and a metal rod of the same diameter as the flexible cable or cord (or metallic foil wrapped round the cord) inserted inside inlet bushing, cord guards and anchorage, and the like; d) ~~live parts~~ and an intermediate ~~conductive part~~ ; e) intermediate ~~conductive parts~~ and the ~~body~~ ; f) each ~~input circuit~~ and all other ~~input circuits connected together~~ .	250	1 400	2 100	2 500	2 750
4) Over ~~reinforced insulation~~ between the ~~body~~ and ~~live parts~~	500	2 800	4 200	5 000	5 500
^a For the construction according to 19.12.3 b) and 26.2.4.1, test b) the voltage is multiplied by the factor 1,25. For the construction according to 26.2.4.2 the voltage is multiplied by the factor 1,35. ^b Values of dielectric strength test voltage for intermediate values of ~~working voltage~~ are found by interpolation between tabulated values.					

Overvoltage category	Type of insulation	Working voltage V					
		<50	100	150	300	600	1 000
OVC I	Functional insulation	250	350	Working voltage + 500			
	Basic insulation	250	350	700	1 100	1 500	2 250
	Supplementary insulation						
	Double or reinforced insulation	500	700	1 400	2 200	3 000	4 500
OVC II	Functional insulation	250	350	Working voltage + 500			
	Basic insulation	250	500	1 250	1 500	2 100	2 500
	Supplementary insulation						
	Double or reinforced insulation	500	1 000	2 500	3 000	4 200	5 000
OVC III	Functional insulation	250	350	Working voltage + 500			
	Basic insulation	250	700	1 400	2 100	2 500	2 750
	Supplementary insulation						
	Double or reinforced insulation	500	1 400	2 800	4 200	5 000	5 500
OVC IV	Functional insulation	250	350	Working voltage + 500			
	Basic insulation	250	850	1 700	2 500	2 800	3 000
	Supplementary insulation						
	Double or reinforced insulation	500	1 700	3 400	5 000	5 600	6 000

NOTE 1 For the construction according to 19.12.3 b) and 26.2.5.1, test B the voltage is multiplied by the factor 1,25. For the construction according to 26.2.5.2 the voltage is multiplied by the factor 1,35. This increase does not apply to routine dielectric strength tests according to L4.

NOTE 2 Values of test voltage for intermediate values of working voltage are found by linear interpolation between the tabulated values.

No flashover or breakdown of the insulating materials and/or system shall occur during the test, corona effects and similar phenomena being disregarded. Diagrams showing examples of the application of test voltages are shown in Annex N.

Details of the test method to be used are given in IEC 61180-1 and IEC 61180-2.

The high-voltage transformer used for the test shall be capable of supplying a current of at least 200 mA when the output terminals are short-circuited.

Care shall be taken that the dielectric voltage applied between **input** and **output circuits** does not overstress other insulation. If it is stated by the manufacturer that a **double insulation** system exists between **input** and **output circuits**, such as from **input circuit** to core and from core to **output circuit**, each insulation is then tested separately according to the dielectric test voltage of item 3 of 19.1 and Table 14. The same applies to a **double insulation** between input and the **body**.

For class II situations incorporating both **reinforced insulation** and **double insulation**, care shall be taken that the dielectric test voltage applied to the **reinforced insulation** does not over-stress the **basic** or **supplementary insulation**.

18.3.1 A partial discharge test according to IEC 60664-1, (see test description below) shall be performed, if FIW wires or TIW wires are used and if the recurring peak working voltage U_t across the insulation is greater than 750 V. The relevant recurring peak voltage is the maximum measured voltage between the input and the output circuit, if the secondary side is earthed. The measuring shall be done at 1,0 of the maximum rated input voltage.

A partial discharge test shall be done at the transformer with the measured recurring peak voltage U_t , greater than 750 V peak.

where

U_t is the maximum peak working voltage (V);

t_1 is a duration of 5 s;

t_2 is a duration of 15 s;

Partial discharge shall be less than or equal to 10 pC at time t_2 . The test shall be done according to the Figure 9. For other applications higher values may be required (e.g. IEC 61800-5-1).

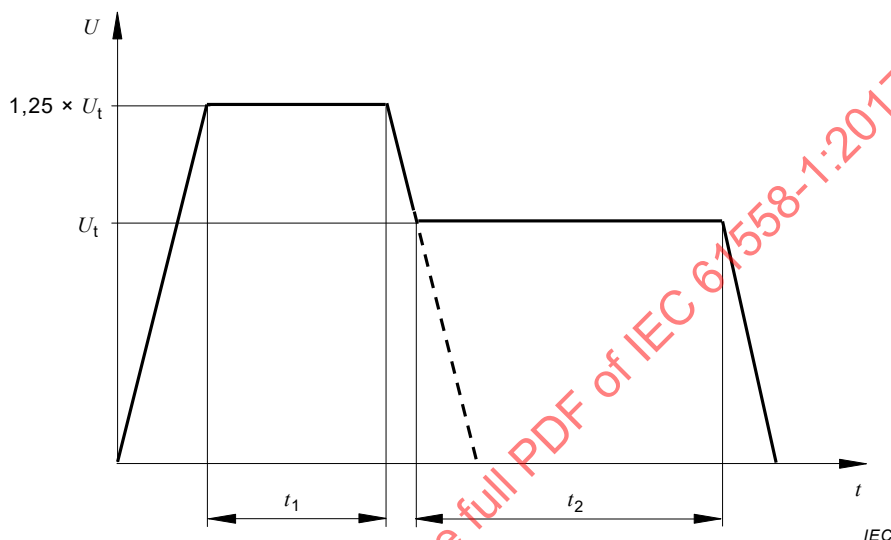


Figure 9 – Test voltage sequence

18.4 Insulation between and within windings

After the test of 18.3, one **input circuit** is connected to a voltage equal to double the **rated supply voltage**, at double the **rated supply frequency** for 5 min. No load is connected to the **transformer**. During the test polyfilar windings, if any, are connected in series. This test is only applicable for **transformers** with **rated supply frequency** lower than 500 Hz.

A higher test frequency than the double supply frequency may be used; the duration of the period of connection, in minutes, then being equal to 10 times the **rated supply frequency** divided by the test frequency, but not less than 2 min.

During the test, there shall be no breakdown of the insulation between turns of a winding, between **input** and **output circuits**, between adjacent **input** or **output circuits**, or between the windings and any conductive core.

18.5 Touch current and protective earthing conductor current

18.5.1 General

The **touch** and **protective earthing conductor current** are measured as described under 18.5.2 and 18.5.3 below.

For variable **transformers** or **transformers** with tapping, the most unfavourable setting shall be chosen. For **transformers** with more than one **input** or **output winding**, the most unfavourable combination shall be chosen.

The method of measurement described here is based on the assumption that the **transformer** is used in a star TN or TT system, i.e. the **transformer** is connected between line (L) and Neutral (N). For other systems, see relevant subclauses of the IEC 60990.

In case of multi phase connections the same procedure is used, but the measurement(s) are made on one phase at the time. The same limits apply for each phase.

The **touch current** and **protective earthing conductor current** are measured with the **transformer** loaded as described in Clause 14 and the measurements are made at steady-state condition.

NOTE To avoid unnecessary testing it is recommended that this measurement be carried out in connection with the heating test in Clause 14.

18.5.2 Touch current

In case of **enclosures** fabricated of insulating material, a metal foil 10 cm × 20 cm in size is placed in contact with the accessible surfaces and the measurement is made to this foil. In case of class II insulated parts on a **class I transformer** the **touch current** shall be measured simultaneously on the two parts.

*During the measurements, a test circuit according to Figure 10 shall be used. The test circuit shall include an **isolating transformer** and the "neutral" conductor connected to the measuring network shall be reliably earthed for safety reasons. For **class II transformers** the protective earthing conductor is ignored. The measuring network indicated is the network described in Figure J.1. However, if frequencies above 30 kHz are involved, measurement of **touch current** shall include measurement with regard to electric burn effects in addition to the measurements of Figure J.1. For the burn effects, the unweighted RMS value of the **touch current** is relevant. Unweighted **touch current** is calculated from the RMS voltage U_1 , measured across the 500 Ω resistor of Figure J.1.*

The terminal A electrode shall be applied to each accessible part in turn.

*For each application of the terminal A electrode, the terminal B electrode shall be applied to **protective earthing**, then applied to each of the other accessible part in turn.*

Measurements:

The **touch-current** is measured with the switch p in both position and the following combination of switches e and n :

- switches n and e in the on position;
- switch n in the off position and switch e in the on position;
- switch n in the on position and switch e in the off position.

For each application of the terminal A and B electrodes and for each combination of the switches p , e and n , the **touch current** measured shall be equal to or less than in Table 15.

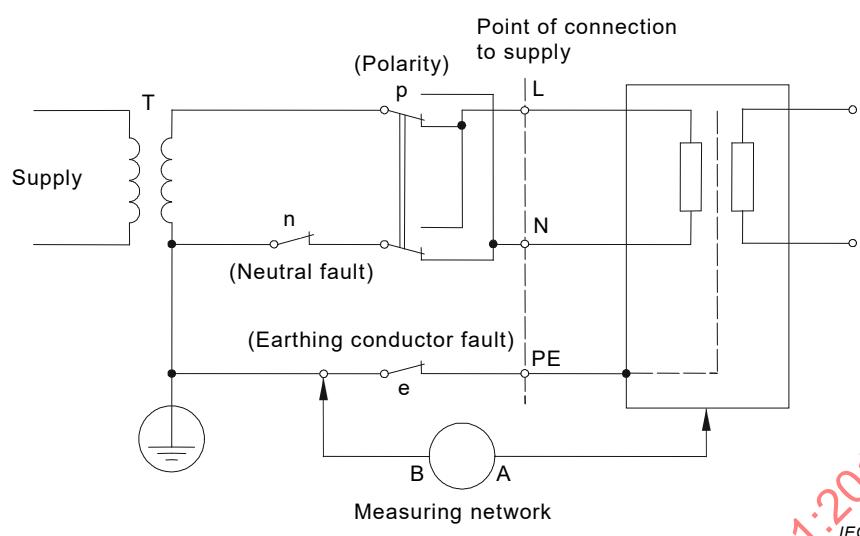


Figure 10 – Test configuration: single-phase equipment on star TN or TT system

18.5.3 Protective earthing conductor current

The **protective earthing conductor current** is measured with the **transformer** connected as described in Clause 14. In addition an ammeter of negligible impedance (less than $0,5\ \Omega$) is connected between the earthing terminal of the **transformer** and the protective earthing conductor.

The **protective earthing conductor current** (s) shall not exceed the values of Table 15.

Table 15 – Limits for currents

Type of leakage current	Rated current	Max limit (RMS)
Touch current: All class I and class II transformers equipped with a plug according to IEC TR 60083	–	0,5 mA
Protective conductor current:		
– Class I transformers fitted with a single or multiphase plug rated up to and including 32 A	< 4 A > 4 A but < 10 A > 10 A	2 mA 0,5 mA/A 5 mA
– Class I transformers intended for permanent connection	< 7 A > 7 A but < 20 A > 20 A	3,5 mA 0,5 mA/A 10 mA

The value to be observed during the measurement is a peak value. The peak value can be transformed into true RMS using a good quality oscilloscope.

NOTE Further explanations regarding the measurement of **touch current** and **protective conductor current** can be found in IEC 60990 and IEC 61140:2016 (7.6).

19 Construction

19.1 General construction

19.1.1 General

The **input** and **output circuits** shall be electrically separated from each other as specified in the relevant part of IEC 61558-2. The construction shall be such that there is no possibility of any connection between these circuits, either directly or indirectly, through other **conductive parts**, except by deliberate action.

NOTE To reflect different basic **transformer** types, this subclause is separated into the following three parts:

19.1.2 Auto-transformers

19.1.3 Separating transformers

19.1.4 Isolating and safety isolating transformers

19.1.2 Auto-transformers

19.1.2.1 Plug connected **auto-transformers** where the **rated input voltage** is higher than the **rated output voltage**, shall not have any potential to protective earthing at the output socket higher than the **rated output voltage**.

This requirement shall be fulfilled by using one of the following methods:

19.1.2.2 Polarized input and output plug and socket-outlet system

In this case, an instruction shall be given for not using such a **transformer** with a non-polarised plug and socket-outlet system.

19.1.2.3 Polarity detecting device (for non polarised input and output plug and socket-outlet system)

A polarity detecting device shall only energise the **output circuit** when the potential to protective earthing at the poles of the output socket does not exceed the **rated output voltage**. The contact separation of the breaking device shall be at least of 3 mm in each pole.

NOTE A magnetic relay is an example of a polarity detecting device.

Compliance is checked by the following test:

*The **auto-transformer** is connected to the mains at 1,1 times the **rated input voltage** under the most unfavourable condition of **load** and **output voltage**. The test is repeated with the polarity of the input reversed. During the test, the measured potential to protective earthing of each pole shall not exceed the maximum **output voltage** under load (1,1 times the **rated output voltage** taking into account the permissible deviations of Clause 11).*

Compliance is checked by measurement.

If the polarity detecting device uses a current flowing to the protective earthing for the detection, this current shall not exceed 0,75 mA and shall only be flowing for the period of measurement until the polarity is reversed.

Compliance is checked by measurement.

All the tests are repeated under the fault conditions of H.3.3. In this case, the potential to protective earthing of each pole shall not exceed 1,1 times the maximum output voltage under load for more than 5 s.

Compliance is checked by measurement.

In addition, the following requirements apply:

- for **class I transformers**, the insulation between the **input / output winding** and the **body** shall consist of at least **basic insulation** (rated for the **working voltage**);
- for **class II transformers**, the insulation between the **input / output winding** and the **body** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**).

Compliance is checked by inspection.

19.1.3 Separating transformers

19.1.3.1 The **input** and **output circuits** shall be electrically separated from each other and the construction shall be such that there is no possibility of any connection between these circuits, either directly or indirectly, via other **conductive parts**, except by deliberate action.

Compliance is checked by inspection and measurements, taking Clauses 18 and 26 into consideration.

19.1.3.2 The insulation between the **input** and **output winding(s)** shall consist of at least **basic insulation** (rated for the **working voltage**).

In addition, the following requirements apply:

- for **class I transformers**, the insulation between the **input windings** and the **body**, and between the **output windings** and the **body** shall consist of at least **basic insulation** (both **basic insulations** rated for the **working voltage**);
- for **class II transformers**, the insulation between the **input windings** and the **body**, and between the **output windings** and the **body** shall consist of **double** or **reinforced insulation** (both **double** or **reinforced insulations** rated for the **working voltage**).

19.1.3.3 For **transformers** with **intermediate conductive parts** (e.g. the iron core) not connected to the **body** and located between the **input** and **output windings**, the insulation between the **intermediate conductive parts** and the **input windings** or between the **intermediate conductive parts** and the **output windings** shall consist of at least **basic insulation** (rated for the **working voltage**).

NOTE An **intermediate conductive part** not separated from the **input** or **output windings** or the **body** by at least **basic insulation**, is considered to be connected to the relevant part(s).

If the core is not earthed and not intended to be earthed the values for **basic insulation** (**creepage distances** and **clearances**) between winding and core can be divided, but the summation of the divided distances shall not be less than the required **creepage distances** and **clearances** in Clause 26.

In addition, the following requirements apply:

- for **class I transformers**, the insulation between the **input** and **output windings** via the **intermediate conductive parts** shall consist of at least **basic insulation** (rated for the **working voltage**);
- for **class II transformers**, the insulation between the **input windings** and the **body**, and between the **output windings** and the **body**, via the **intermediate conductive parts** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**).

19.1.3.4 Parts of **output circuits** may be connected to the protective earthing.

19.1.3.5 There shall be no direct connection between the **output circuits** and the **body**, **unless** – for **associated transformers** – allowed by the relevant equipment standard.

Compliance is checked by inspection.

19.1.4 Isolating transformers and safety isolating transformers

19.1.4.1 The **input** and **output circuits** shall be electrically separated from each other and the construction shall be such that there is no possibility of any connection between these circuits, either directly or indirectly, via other **conductive parts**, except by deliberate action.

Compliance is checked by inspection and measurements taking Clauses 18 and 26 into consideration.

19.1.4.2 The insulation between **input** and **output winding(s)** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**), unless the requirements in 19.1.4.4 are complied with:

In addition, the following applies:

- for **class I transformers** not intended for connection to the mains supply by means of a plug, the insulation between the **input windings** and the **body** connected to protective earthing shall consist of at least **basic insulation** rated for the **input voltage**. The insulation between the **output windings** and the **body** connected to protective earthing, shall consist of at least **basic insulation** (rated for the **output voltage**);
- for **class I transformers** intended for connection to the mains supply by means of a plug, the insulation between the **input windings** and the **body** shall consist of at least **basic insulation**, and the insulation between the **output windings** and the **body** shall consist of at least **supplementary insulation** (both **basic** and **supplementary insulations** rated for the **working voltage**);
- for **class II transformers**, the insulation between the **input windings** and the **body** shall consist of **double** or **reinforced insulation** (rated for the **input voltage**). The insulation between the **output windings** and the **body** shall consist of **double** or **reinforced insulation** (rated for the **output voltage**).

19.1.4.3 For **transformers** with **intermediate conductive parts** (e.g. the iron core) not connected to the **body** and located between the **input** and **output windings**, the following requirements are applicable.

19.1.4.3.1 For **class I** and **class II transformers**, the insulation between the **input** and **output windings** via the **intermediate conductive parts** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**);

- for **class II transformers**, the insulation between the **input windings** and the **body**, and between the **output windings** and the **body** via the **intermediate conductive parts** shall consist of **double** or **reinforced insulation** (rated for the **input** and **output voltage**), for SELV circuits **basic insulation** only is required;
- for **transformers** other than independent (e.g. IP00), the insulation between the **input** and **output windings** via the **intermediate conductive parts** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**).

19.1.4.3.2 As an alternative to 19.1.4.3.1 for **class I transformer** not intended to be connected by means of a plug and for **transformer** different from independent (e.g. IP00), if the construction assures that all laminated plates of the iron core are connected to protective earthing (e.g. by soldering / welding) and if the data sheet or instruction sheet clearly state that the safety of the **transformer** depends on the earthing connection and that is not possible to use it in **class II** equipment, then the following apply:

- the insulation between the **input windings** and the **intermediate conductive part** connected to protective earthing, and between the **output windings** and the **intermediate conductive part** connected to protective earthing, shall consist of at least **basic insulation** (rated for the input and output voltage);

19.1.4.3.3 in addition to 19.1.4.3.1 and 19.1.4.3.2, the insulation between the **intermediate conductive parts** and the **input windings**, and between the **intermediate conductive parts** and the **output windings** shall consist of at least **basic insulation** (rated for the **input** and **output voltage**). An **intermediate conductive part** not separated from the **input** or **output**

windings or the **body** by at least **basic insulation** is considered to be connected to the relevant part(s).

NOTE An intermediate metal part which is isolated from one of the windings by **double** or **reinforced insulation** is considered as being connected to the other winding.

19.1.4.4 For **class I transformers**, not intended for connection to the mains supply by means of a plug, the insulation between the **input** and **output windings** may consist of **basic insulation** plus **protective screen** instead of **double** or **reinforced insulation** provided the following conditions are complied with:

- the insulation between the **input winding** and the **protective screen** shall comply with requirements for **basic insulation** (rated for the **input voltage**);
- the insulation between the **output winding** and the **protective screen** shall comply with requirements for **basic insulation** (rated for the **output voltage**);
- the **protective screen** shall, unless otherwise specified, consist of a metal foil or of a wire wound screen extending at least the full width of one of the **input winding** and shall have no gaps or holes;
- where the protective screen does not cover the entire width of the **input winding**, additional adhesive tapes or equivalent insulation shall be used to ensure **double insulation** in that area;
- if the **protective screen** is made of a foil, the turns shall be insulated from each other. In case of only one turn, it shall have an isolated overlap of at least 3 mm;
- the wire of a wire wound screen and the lead-out wire of the **protective screen** shall have a cross-sectional area at least corresponding to the **rated current** of the overload protective device to ensure that, if a breakdown of **insulation** should occur, the overload protective device opens the circuit before the lead-out wire is destroyed in the event of the breakdown of the **insulation system**;
- the lead-out wire shall be soldered to the **protective screen** or fixed in an equally reliable manner.

For **transformers** for connection to the mains by the means of a plug of any type (incorporating or not), the alternative with **basic insulation** plus **protective screening** is not allowed.

NOTE For the purpose of this subclause, the term “winding” does not include **internal circuits**.

Examples of construction of windings are given in Annex M.

19.1.4.5 There shall be no connection between the **output circuits** and the protective earthing, unless this is allowed for **associated transformers** by the relevant equipment standard, or when 19.8 is fulfilled.

19.1.4.6 There shall be no direct connection between the **output circuits** and the **body**, unless this is allowed for **associated transformers** by the relevant equipment standard, or when 19.8 is fulfilled.

Compliance is checked by inspection.

19.1.4.7 For **isolating transformers** and **safety isolating transformers**, the **input** and **output terminals** for the connection of external wiring shall be so located that the distance measured at the point of introduction of the conductors, into these terminals, is not less than 25 mm. If a barrier is used to obtain the distance, the measurement shall be made over and around the barrier which shall be of insulating material and permanently fixed to the transformer.

*Compliance is checked by inspection and by measurement disregarding **intermediate conductive parts**.*

19.1.4.8 Portable transformers having a **rated output** not exceeding 630 VA shall be class II.

19.1.4.9 There shall be no connection between the **output circuits** and the **body**, unless – for **associated transformers** – allowed by the relevant equipment standard.

19.1.4.10 For **transformers** for connection to the mains by means of a plug of many type (incorporated or not), the alternative with **basic insulation** plus **protective screening** is not allowed.

19.2 Flammability of materials

Materials known to be highly flammable, such as celluloid, shall not be used in the construction of **transformers**.

Cotton, silk, paper and similar fibrous material shall not be used as insulation, unless impregnated.

Wax and similar impregnators shall not be used, unless suitably restrained from migration.

Compliance is checked by inspection and, in case of doubt regarding fiercely burning materials, by the glow-wire test of 27.4 at 550 °C.

NOTE Insulating material is considered impregnated if the space between the fibres of the material are substantially filled with a suitable insulating coating (i.e., epoxy resin, varnish, etc.).

Wood, even if impregnated, shall not be used as **supplementary** or **reinforced insulation**.

19.3 Short-circuit characteristics of portable transformers

Portable transformers shall be either **short-circuit proof** or **fail-safe transformers**.

Compliance is checked by inspection.

19.4 Class II transformer contact prevention of accessible conductive parts

There shall be provisions to prevent contact between accessible **conductive parts** and conduits or metal sheaths of supply wiring for **class II transformers**.

Compliance is checked by inspection.

19.5 Class II transformer insulation reassembling after service

Parts of **class II transformers** serving as **supplementary insulation** or **reinforced insulation** which might be omitted during reassembly after servicing, shall either:

- be fixed in such a way that they cannot be removed without being seriously damaged; or
- be so designed that they cannot be replaced in an incorrect position and that, if they are omitted, the **transformer** is rendered inoperable or is manifestly incomplete.

Compliance is checked by inspection and by manual test.

NOTE Sleeving may, however, be used as **supplementary insulation** on internal wiring, if it is retained in position by positive means.

NOTE 1 A sleeve is considered to be fixed by positive means if it can be removed only by breaking or cutting, or if it is clamped at both ends.

NOTE 2 Servicing includes replacement of switches, protective devices and of **power supply cords** when the type of attachment allows this.

NOTE 3 Lining metal **enclosures** with a coating of lacquer or with material in the form of a coating which does not withstand the test of 19.10 is not considered to be adequate for the purpose of these requirements.

19.6 Loosening of wires, screws or similar parts

Class I and **class II transformers** shall be so constructed that, should any wire, screw, nut, washer, spring or similar part become loose or fall out of position, they cannot, in normal use, become so disposed that **creepage distances** or **clearances** over **supplementary insulation** or **reinforced insulation** or the distance between input and output terminals are reduced to less than 50 % of the value specified in Clause 26.

Compliance is checked by inspection, by measurement and by manual test.

NOTE For the purpose of this requirement:

- it is not expected that two independent fixings will become loose at the same time;
- parts fixed by means of screws or nuts provided with locking washers are regarded as not liable to become loose, provided these screws or nuts are not removed during the replacement of the supply flexible cable or cord, or other servicing;
- conductors connected by soldering are not considered to be adequately fixed unless they are held in place near to the termination by means such as hooking in, independent of the solder;
- screwless terminals complying with IEC 60998-2-2 are considered to provide adequate fixing of the conductor without any additional means;
- wires connected to terminals are not considered to be adequately secured, unless an additional fixing of an appropriate type is provided near to the terminal. In the case of stranded conductors, this additional fixing is to clamp the insulation and not the conductor only;
- short rigid wires are not regarded as liable to come away from a terminal if they remain in position when the terminal screw is loosened.

19.7 Resistor or capacitor connection with accessible conductive parts

Conductive parts connected to accessible conductive parts by resistors or capacitors shall be separated from the **hazardous-live-parts** by **double insulation** or **reinforced insulation**.

*Compliance is checked by all relevant requirements and tests for **double insulation** or **reinforced insulation**.*

19.8 Bridging of separated conductive parts by resistors or capacitors

Conductive parts separated by **double** or **reinforced insulation** e.g. **live parts** and the **body** or **primary** and **secondary circuits**, may be bridged (conductive bridge) by resistors or Y2 capacitors provided that they consist of at least two separate components whose impedance is unlikely to change significantly during the lifetime of the **transformer**.

If the resistors are used they shall comply with the requirements of test a) in 14.2 of IEC 60065:2014. If capacitors are used, they shall comply with the relevant requirements of IEC 60384-14:2013, including its Subclause 3.4.2.

Where two capacitors are used in series, they shall each be rated for the total working voltage across the pair and shall have the same nominal capacitance value. If any one of such two components is short-circuited or open-circuited, the values specified in Clause 9 shall not be exceeded.

In addition, if the **working voltage** does not exceed 250 V **AC**, **conductive parts** separated by **double** or **reinforced insulation** (e.g. live parts and the body or primary and secondary circuits) may be bridged by a single Y1 capacitor complying with the relevant requirements of

IEC 60384-14:2013, including its Subclause 3.4.2. These requirements are applicable up to overvoltage category III.

For a working voltage above 250 V AC and not exceeding 500 V AC and an overvoltage category III, two Y1 capacitors are required.

NOTE A Y1 capacitor is considered to have **reinforced insulation**.

Compliance is checked by inspection and by measurement.

19.9 Insulating material separating input and output windings

Insulating material separating **input** and **output windings**, and parts of natural or synthetic rubber used as **supplementary insulation** in **class II transformers**, shall be either resistant to ageing or so arranged and dimensioned that, if any cracks occur, **creepage distances** are not reduced below the values specified in Clause 26.

Compliance is checked by inspection, by measurement and, in case of doubt concerning the ageing properties of rubber, by the following test.

Rubber parts are aged in an atmosphere of oxygen under pressure. The specimens are suspended freely in an oxygen bomb, the effective capacity of the bomb being at least 10 times the volume of the specimens. The bomb is filled with commercial oxygen not less than 97 % pure, to a pressure of (210^{+7}) N/cm².

The specimens are kept in the bomb at a temperature of (70^{+1}) °C for four days (96 h). Immediately afterwards, they are taken out of the bomb and left at ambient temperature, avoiding direct daylight, for at least 16 h.

After the test, the specimens are examined and shall show no cracks with normal vision or corrected vision without magnification.

NOTE In case of doubt with regard to materials other than rubber, an alternative method has to be used (see 14.3 and 26.3).

The use of the oxygen bomb presents some danger, unless handled with care. All precautions should be taken to avoid the risk of explosion due to sudden oxidation.

19.10 Accidental contact protection against hazardous-live-parts provided by isolating coating

When protection of **hazardous-live-parts** against accidental contact is ensured by an insulating coating, this coating shall be capable of withstanding the following tests.

a) Ageing test

The coated part is subjected to the conditions described in section one (test ~~Ba~~ Na) of IEC ~~60068-2-2~~ 60068-2-14, at a temperature of (70 ± 2) °C for a period of seven days (168 h).

After this treatment, the part is allowed to cool to ambient temperature and inspection shall show that the coating has not loosened up or shrunk away from the base material.

b) Impact test

The part is then conditioned for a period of 4 h at a temperature of (-10 ± 2) °C. While still at this temperature, the coating is subjected to a blow applied to any point of the layer that is likely to be weak using a spring-operated impact hammer according to IEC 60068-2-75 with an energy of $(0,5 \pm 0,05)$ J.

After this test, the coating shall not be damaged. In particular, it shall show no cracks visible with normal vision, or corrected vision without magnification.

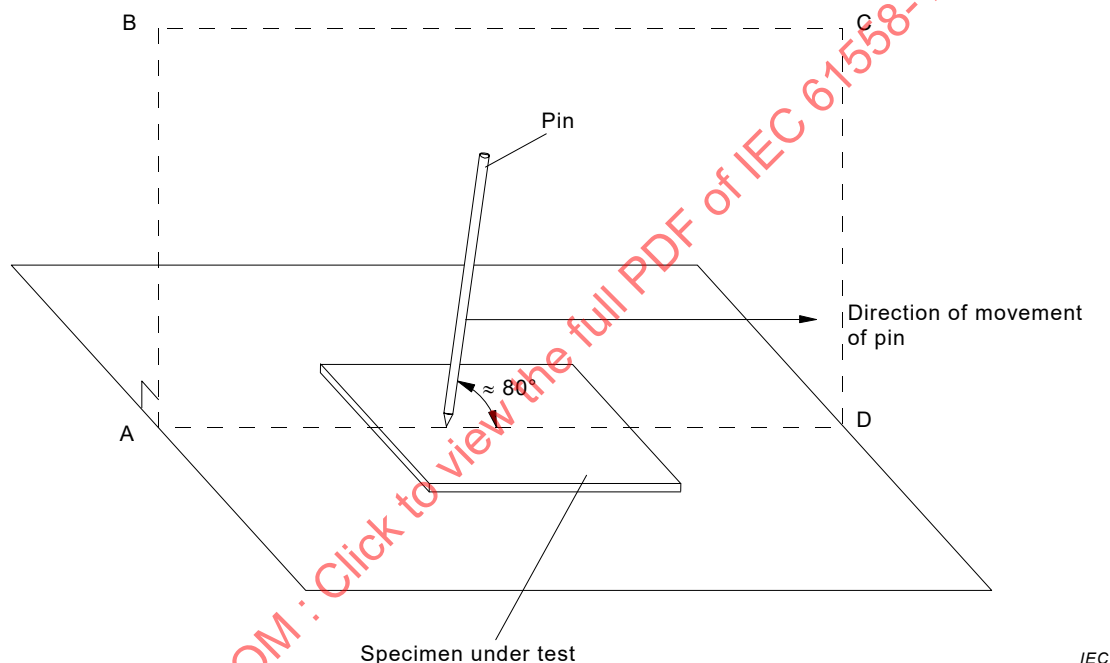
c) **Scratch test**

Finally, the part at the highest temperature attained under normal operating conditions is subjected to a scratch test. The scratches are made by means of a hardened steel pin, the end of which has the form of a cone having a top angle of 40° , its tip being rounded with a radius of $(0,25 \pm 0,02)$ mm.

Scratches are made by drawing the pin along the surface at a speed of about 20 mm/s as shown in Figure 11. The pin is so loaded that the force exerted along its axis is $(10 \pm 0,5)$ N. The scratches are at least 5 mm apart and at least 5 mm from the edge of the specimen.

After this test, the coating shall not loosen or be pierced, and it shall withstand a dielectric strength test as specified in 18.3, the test voltage being applied between the base material and a metal foil in contact with the coating.

NOTE The tests may be conducted on a separate specimen of the coated part.



NOTE The pin is in the plane ABCD which is perpendicular to the specimen under test.

Figure 11 – Abrasion resistance test for insulating coated layers

19.11 Insulating material of handles, operating levers, knobs and similar parts

Handles, operating levers, knobs and similar parts shall be of insulating material or be adequately covered by **supplementary insulation**, or separated from their shafts or fixing by such insulation in the event the shafts or fixing are likely to become live during an insulation breakdown.

*Compliance is checked by inspection and, if necessary, by the requirements specified for **supplementary insulation**.*

19.12 Winding construction

19.12.1 In all types of **transformers**, precautions shall be taken to prevent:

- undue displacement of **input** or **output windings** or the turns thereof;
- undue displacement of internal wiring or wires for external connections;

- undue displacement of parts of windings or of internal wiring, in the event of rupture of wires or loosening of connections.

Compliance is checked by inspection and by the tests of Clause 16.

The last turn of each winding shall be prevented from being displaced.

NOTE Means of prevention may be:

- positive means such as tape, suitable bonding agent, or anchoring the wire;
- or process technologies (e.g. manufacturing procedures).

NOTE A **protective screen**, if necessary, in order to prevent eddy current losses due to creation of a short turn, should be so arranged that both edges can neither simultaneously touch each other nor touch an iron core.

19.12.2 Where serrated tape is used as insulation, it is assumed that the serration of the different layers will coincide. For distance through insulation (DTI), the reduced values of Table 22 may be used if one additional layer of serrated tape and one additional layer without serration placed at the location of the serration are used.

NOTE An example is given in Figure M.3.

Where cheekless bobbins (bobbins without flange) are used, the end turns of each layer shall be prevented from being displaced.

NOTE Each layer can, for example, be interleaved with adequate insulation material projecting beyond the end turns of each layer and, moreover:

- either the winding(s) may be impregnated with hard-baking or cold-setting material, substantially filling the intervening spaces and effectively sealing-off the end turns;
- or the winding(s) may be held together by means of insulating material or by process technology.

Compliance is checked by inspection and by the tests of Clauses 16, 17, and 18.

19.12.3 Insulated winding wires, in an insulation system providing **basic**, **supplementary** or **reinforced insulation**, shall meet the following requirements.

Wire that has multi-layer extruded or spirally wrapped insulation (where only the finished wire can be tested) and passes the tests of Annex K.

The minimum number of constructional layers applied to the conductor shall be as follows:

- **basic insulation**: two wrapped layers or one extruded layer;
- **supplementary insulation**: two layers, wrapped or extruded;
- **reinforced insulation**: three layers wrapped or extruded.

For spirally wrapped insulation where the **creepage distances** between layers, as wrapped, are less than those given in Clause 26. For pollution degree 1, the path between layers shall be sealed as for a cemented joint in 26.2.4, Test A and the test voltages of the **type tests** in Clause K.2 are increased to 1,35 times their normal values.

One layer of material wound with more than 50 % overlap is considered to constitute two layers.

The finished component shall pass **routine test** for dielectric strength using the appropriate value of test voltages in 18.3.

Compliance is checked by inspection and measurement and, if applicable, as specified in Annex K.

- a) Where the insulation on the winding wire is used to provide **basic-** or **supplementary insulation** in a wound ~~component without additional interleaved insulation~~ part:

- the insulated wire (for example polyimide or insulation of equivalent quality) shall comply with Annex K;
- the insulation of one **insulated winding wire** shall consist of at least two layers for **supplementary insulation**;
- the insulation of one **insulated winding wire** shall consist of at least one layer for **basic insulation**;
- an insulation for mechanical separation which fulfil the dielectric strength test for **basic insulation** shall be provided between the insulated wires and the enamelled wires.

If for basic or supplementary insulation a triple insulated wire is used in combination with enamelled wire, an additional interleaved insulation (mechanical separation) is not required.

- b) Where the insulation on the winding wire is used to provide **reinforced insulation** in a wound part:

- the insulated wire (for example polyimide or insulation of equivalent quality) shall comply with Annex K;
- the insulation of one **insulated winding wire** shall consist of at least three layers;
- the insulation is subjected to the relevant dielectric strength test of 18.3 ~~which is conducted at a voltage multiplied by the factor 1.25.~~

Where the insulated winding wire is wound:

- upon metal or ferrite cores or
- upon enamelled wire or;
- under enamelled wire;

~~an additional insulation complying with dti in Table 13 for supplementary insulation for mechanical separation which fulfils the dielectric strength test for basic insulation~~ shall be provided between the insulated wires and the core or between the insulated wires and the enamelled wires. ~~These independent windings shall not be able to contact each other or the core.~~

NOTE 1 This requirement takes into consideration the mechanical production stress applied to the **insulated winding wires**.

The manufacturer of the **transformer** shall demonstrate that the winding wire has been subjected to 100 % routine dielectric strength test as in Clause K.3.

No requirements for **creepage distances** and **clearances** are applicable for the **insulated winding wires**.

~~For windings providing reinforced insulation, no value is required in box 2) c) of Table 13, Table C.1 and Table D.1,~~

Compliance is checked by inspection of the part and the declaration of the wire manufacturer.

- c) Toroidal cores used with **TIW** wires for **double or reinforced insulation** between the primary and secondary circuits shall comply with the following:

- 1) The toroidal core shall have a coating, which fulfils the requirements of **basic insulation** between a winding and the core
- 2) The primary winding consists of **TIW** wire with 3 layers (**reinforced insulation**) and the secondary winding consists of enamelled wire. These independent windings shall not

- be able to contact each other either by mechanical separation or a gap which fulfil the dielectric strength tests for **basic insulation**.
- 3) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding consists of **TIW** wire with 3 layers and the secondary winding consists of a **TIW** wire with 1 layer (requirements for primary and secondary windings can be changed). This construction also is allowed for use with EE-cores or similar.
- d) Toroidal cores used with **FIW** wires for **double or reinforced insulation** between the primary and secondary circuits shall comply with the following:
- 1) The toroidal core shall have a coating, which fulfil the requirements of **basic insulation**.
 - 2) The primary winding consists of **FIW** wire for **reinforced insulation** and the secondary winding consist of **FIW** wire – of **basic insulation**. These independent windings shall not be able to contact each other either by mechanical separation or a gap which fulfil the dielectric strength test for **basic insulation**.
 - 3) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding and the secondary winding consist of **FIW** wire for **reinforced insulation**. This construction also is allowed to use for EE-core of similar.
- e) Toroidal cores used with **TIW** in combination with **FIW** wire, for **double or reinforced insulation** between the primary and secondary circuits shall comply with the following:
- 1) The toroidal core shall have a coating, which fulfils the requirements of **basic insulation**.
 - 2) The primary winding consists of **FIW** wire for **reinforced insulation**, and the secondary winding consists of **TIW** wire for basic insulation (1 layer). These independent windings shall not be able to contact each other either by mechanical separation or a gap which fulfil the dielectric strength tests for **basic insulation**.
 - 3) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding consists of **TIW** wire for **reinforced insulation** (3 layer) and the secondary winding consists of **FIW** wire for **reinforced insulation**. This construction also is allowed for use with EE-cores or similar.
- f) Toroidal cores used with **TIW** in combination with **FIW** wire, for **basic insulation** between the primary and secondary circuits shall comply with the following:
- 1) The toroidal core shall have a coating, which fulfils the requirements of **basic insulation**
 - 2) The primary winding consists of **FIW** wire for **basic insulation**, and the secondary winding consists of **TIW** wire for **basic insulation** (1 layer). These independent windings shall not be able to contact each other either by mechanical separation or a gap which fulfils the dielectric strength tests for **basic insulation**.
- NOTE 2 Instead of **FIW** for **basic insulation**, enamelled wire is also accepted.
- 3) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding consists of **TIW** wire for **supplementary insulation** (2 layers) and the secondary winding consists of **FIW** wire for **basic insulation**. This construction also is allowed for use with EE-cores or similar.
 - 3.1) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding consists of **TIW** wire for **basic insulation** (1 layer) and the secondary winding consists of **TIW** wire for **basic insulation** (1 layer).
 - 4) Further polyfilar constructions with **FIW** and **TIW** wires in combination with enamelled wires for **basic insulation** only:
 - 4.1) Primary winding consists of enamelled wire, secondary winding consists of **FIW** wire for **reinforced insulation**
 - 4.2) Primary winding consists of enamelled wire, secondary winding consists of **TIW** wire for **reinforced insulation**

19.12.3.1 The transformer utilizing **fully insulated winding wires (FIW)** shall only be used up to and including insulation class F.

19.12.3.2 Fully insulated winding wires (FIW) shall comply with IEC 60851-5:2008, IEC 60317-0-7 and IEC 60317-56. If the wire has a nominal diameter other than defined in Table 24, the minimum high voltage strength value can be calculated according to Formula (6) in 26.3.5:

- **FIW** wires used for **basic** or **supplementary isolation** for **transformers** according to 19.1.3:
 - the test voltage required in Table 14 for **basic-/supplementary insulation** according to the **working voltage** of the **transformer**, shall comply with the minimum voltage strength of **basic insulation** for the **FIW**-wire according to Table 24;
 - between a basic insulated **FIW** wire and an enamelled wire an insulation for mechanical separation shall be used. The both windings shall not touch each other. The insulation for mechanical separation shall fulfil the high voltage test of basic insulation. **Creepage distances** and **clearances** for **FIW** wire are not required.
- **FIW** wires used for **double** or **reinforced insulation** for **transformers** according to 19.1.4:
 - the test voltage required in Table 14 for **basic-/supplementary insulation** according to the **working voltage** of the **transformer**, shall comply with the minimum voltage strength of **basic insulation** for the **FIW**-wires according to Table 24. For the primary and the secondary winding a basic insulated **FIW** wire shall be used;
 - between the two basic insulated **FIW** wires an insulation for mechanical separation shall be used. These independent windings shall not be able to contact each other. The insulation for mechanical separation shall fulfil the high voltage test of basic insulation. **Creepage distances** and **clearances** between the **FIW** wires are not required.
- Alternative construction with **FIW**-wires having reinforced insulation:
 - the test voltage required in Table 14 for **reinforced insulation** according to the **working voltage** of the transformer, shall comply with the minimum voltage strength for the **FIW** wire according to Table 24;
 - between a reinforced insulated **FIW** wire and an enamelled wire an insulation for mechanical separation shall be used. These independent windings shall not be able to contact each other. The insulation for mechanical separation shall fulfil the high voltage test of **basic insulation**. **Creepage distances** and **clearances** between the **FIW** wires are not required.
- Alternative construction with **FIW** wires, basic or supplementary insulated for **transformers** with **double** or **reinforced insulation**:
 - the test voltage required in Table 14 for **basic-/supplementary insulation** according to the **working voltage** of the **transformer**, shall comply with the minimum voltage strength of **basic insulation** for the **FIW**-wire according to Table 24. For either the primary or the secondary winding a basic insulated **FIW** wire shall be used. For the non **FIW** winding, enamelled wire can be used;
 - between the basic insulated **FIW** wire and the enamelled wire, a **supplementary insulation** according to the working voltage is required. **Creepage distances** and **clearances** between the **FIW** wire and the enamelled wire are required for **supplementary insulation**.
- Where the **FIW** wire is wound:
 - upon metal or ferrite cores, an insulation for mechanical separation which fulfil the dielectric strength test for **basic insulation** shall be provided between the **FIW** wires and the core. The **FIW** wire and enamelled wire (if used) shall not touch the metal or ferrite core.

19.13 Fixing of handles, operating levers and similar parts

Handles, operating levers and similar parts shall be fixed in a reliable manner so that they will not become loose as a result of heating, vibration, etc. which may occur in normal use.

Compliance is checked by inspection and by the tests of Clauses 14 and 16.

19.14 Fixing of covers providing protection against electric shock

Covers providing protection against electric shock shall be securely fixed. The fixing shall be achieved by at least two independent means, one of which at least requires the use of a **tool**.

Compliance is checked by inspection and by manual test.

NOTE The cover may incorporate a means, such as a notch or a rim, which forms one of the required fixing means.

NOTE Screws may be used as means requiring the use of a **tool**, but knurled nuts or screws, even if they have provision for sealing, are not suitable.

19.15 Strain on fixed socket-outlets caused by pin-transformers connection

Transformers provided with pins intended to be introduced into fixed socket-outlets shall not impose undue strain on these socket-outlets.

*Compliance is checked by inserting the **transformer**, as in normal use, into a fixed socket-outlet complying with IEC TR 60083, the socket-outlet being pivoted about the horizontal axis through the central lines of the contact tubes at a distance of 8 mm behind the engagement face of the socket-outlet.*

The additional torque which has to be applied to the socket-outlet to maintain the engagement face in the vertical plane shall not exceed 0,25 Nm.

19.16 Portable transformers for use in irregular or harsh conditions

~~Portable transformers with a rated output not exceeding 200 VA shall have a protection index IP20 or higher. For transformers having a protection index of IPX0, it shall be stated in the instructions for use that such transformers are only intended for indoor use.~~

~~Portable transformers having a rated output exceeding 200 VA but not exceeding 2,5 kVA for single phase transformers, or not exceeding 6,3 kVA for polyphase transformers, shall have a protection index IPX4 or higher.~~

~~Portable transformers having a rated output exceeding 2,5 kVA for single phase transformers, or exceeding 6,3 kVA for polyphase transformers, shall have a protection index IP24 or higher.~~

Portable transformers having a weight not exceeding 18 kg for use in irregular or harsh conditions, example indoor or outdoor heavy construction sites, exposure to high levels of dust, debris or moisture shall have a protection index IPX4 or higher.

NOTE IEC 61558-2-23 is extended to cover other kinds of rough handling.

19.17 Drain hole of transformers protected against ingress of water

Transformers having a protection index from IPX1 up to and including IPX6 shall have an effective drain hole at least 5 mm in diameter or 20 mm² in area, with a width of at least 3 mm.

The drain hole is not required if the **transformer**, including its windings and core and all uninsulated live parts, are completely embedded in an ~~appropriate~~ potting material.

19.18 Plug connected transformers protected against ingress of water

Transformers ~~having~~ classified for a protection index higher than IPX1 ~~shall be~~ and having a cord provided with a plug; it shall be a moulded-on plug, ~~if any~~.

19.19 Flexible cable or flexible cord connection for class I portable transformers

Class I portable transformers designed for connection by means of a flexible cable or cord, shall be provided with a **non-detachable** flexible cable or cord with protective earthing conductor and a plug with protective earthing contact.

If a **class I stationary transformer** is equipped with a **non-detachable** flexible cable or cord, the cable or cord shall have a protective earthing conductor and the plug shall have a protective earthing contact.

Compliance with the requirements of 19.16 to 19.19 is checked by inspection, by measurement, and by the tests of 17.1.

19.20 SELV- and PELV-circuit separation of live parts

Live parts of **SELV-** and **PELV-circuits** shall be electrically separated from each other and from other circuits. Taking the relevant **working voltage** into account the following requirements shall be met:

- **SELV output circuits** shall be electrically separated from all circuits other than **SELV** and **PELV** by **double** or **reinforced insulation**.
- **SELV output circuits** shall be electrically separated from other **SELV** and **PELV circuits** by **basic insulation**.

NOTE This requirement does not exclude the connection of **PELV circuits** to the protective earthing.

*Compliance is checked by compliance with 19.20.1 for **SELV-circuits** and 19.20.2 for **PELV-circuits***

19.20.1 Live parts of **SELV-circuits** shall not be connected to the protective earthing, to **live parts**, or protective earthing conductors forming part of other circuits.

Exposed **conductive parts** of **SELV-circuits** shall not be connected to:

- the protective earthing, or
- protective earthing conductors or exposed **conductive parts** of another circuit.

If the nominal voltage exceeds 25 V AC or 60 V ripple-free DC, protection against ~~direct~~ contact with **live parts** shall be provided by insulation capable of withstanding a test voltage for **double** or **reinforced insulation** according to Table 14.

If the nominal voltage does not exceed 25 V AC or 60 V ripple-free DC, protection against ~~direct~~ contact with **live parts** is generally unnecessary. However, it may be necessary under certain conditions of external influences (see relevant part of IEC 61558-2).

19.20.2 For **PELV-circuits**, the following requirements shall be fulfilled.

Protection against ~~direct~~ contact with **live parts** shall be ensured by insulation capable of withstanding a test voltage for **double** or **reinforced insulation** according to Table 14.

NOTE This requirement implies that **PELV-circuits** have to be insulated even for voltages below 25 V AC or 60 V ripple-free DC. Exempted are **live parts** directly connected to protective earthing.

19.21 Protection against contact for FELV-circuit

For **FELV-circuits**, the following requirements shall be fulfilled to ensure protection against both direct and indirect contact.

NOTE Such conditions may, for example, be ensured when the circuit contains equipment (such as **transformers**, relays, remote-control switches, contactors) insufficiently insulated with respect to circuits at higher voltages.

Protection against indirect contact shall be provided by insulation corresponding to the minimum test voltage required for the primary circuit.

19.22 Protective earthing regarding class II transformers

Class II transformers shall not be provided with means for protective earthing.

However, a **class II transformer** intended for looping-in may have an internal terminal for maintaining the electrical continuity of a protective earthing conductor not terminating in the **transformer**, provided that the terminal is insulated from the accessible **conductive parts** by class II insulation.

Compliance is checked by inspection.

19.23 Protective earthing regarding class III transformers

Class III transformers shall not be provided with means for protective earthing.

Compliance is checked by inspection.

20 Components

20.1 Components such as switches, plugs, fuses, lampholders, capacitors and flexible cables and cords shall comply with the relevant IEC standard as far as it reasonably applies.

Components incorporated in or supplied with the **transformers** are subjected to all tests of this document as part of the **transformer**.

Compliance with the IEC standard for the relevant component does not necessarily ensure compliance with the requirements of this document.

The testing of these components is, in general, carried out separately, according to the relevant standard, as follows:

- components marked with individual ratings are checked to establish that they suit the conditions which may occur in the **transformer**, including inrush current. The component is then tested in accordance with its marking, the number of specimens being that required by the relevant standard;
- components not marked with individual ratings are tested under the conditions occurring in the **transformer**, including inrush current, the number of specimens being, in general, that required by the relevant standard;
- where no IEC standard exists for the relevant component, or where the component is not marked, or where the component is not used in accordance with its marking, the

component is tested under the conditions occurring in the **transformer**; the number of specimens being, in general, that required by a similar specification.

20.2 Appliance couplers for mains supply shall comply with IEC 60320 (all parts) for IPX0 **transformers** and IEC 60320-2-3 or IEC 60309 (all parts) for other **transformers**.

20.3 Automatic controls shall comply with IEC 60730 (all parts) and the appropriate parts of IEC 61558-2 unless they are tested with the **transformer**.

20.4 Thermal-links shall comply with IEC 60691 as far as reasonable.

20.5 Switches forming part of the **transformer** assembly shall comply with Annex F.

In addition, switches intended to disconnect the **transformer** from the supply shall disconnect all poles and shall provide full disconnection under the relevant overvoltage category. The requirements with regard to all-pole disconnection and full disconnection do not apply to **transformers** intended to be connected to the supply by means of a flexible cable or cord and a plug, or to **transformers** accompanied by an instruction sheet stating that such means for disconnection shall be incorporated in the fixed wiring.

Compliance is checked by inspection.

20.6 There shall be no unsafe compatibility between the socket-outlets in the **output circuit** and a plug intended for direct connection to a socket-outlet which could be used for the **input circuit** in relation to installation rules, voltages, and frequencies.

Plugs and socket-outlets for **SELV** systems shall comply with the requirements of IEC 60906-3 and IEC 60884-2-4. However, plugs and socket-outlets for **SELV** systems with both a rated current ≤ 3 A and a maximum voltage of 24 V AC or 60 V DC with a power not exceeding 72 W are allowed to comply only with the following requirements:

- it shall not be possible for plugs to enter socket-outlets of other standardised voltage systems;
- socket-outlets shall not accommodate plugs for other standardised voltage;
- socket-outlets shall not have a protective earthing contact.

NOTE As IEC 60906-3 covers only 6 V, 12 V, 24 V and 48 V, **transformers** with intermediate supply voltage should be able to withstand the nearest upper voltage. Other plugs and socket-outlet systems are allowed for **associated transformers** only.

Plugs and socket-outlets for **PELV** systems shall comply with the following requirements:

- it shall not be possible for plugs to enter socket-outlets of other standardized voltage systems;
- socket-outlets shall not accommodate plugs of other standardized voltage systems;
- socket-outlets shall not have a protective earthing contact.

This does not preclude the use of socket-outlets incorporating functional bonding contact.

Plugs and socket-outlets for **FELV** systems shall comply with the following requirements:

- It shall not be possible for plugs to enter socket-outlets of other standardized voltage systems; and
- socket-outlets shall not accommodate plugs of other standardised voltage systems.

Compliance is checked by inspection and by manual test.

20.7 Thermal cut-outs, thermal links, **overload relays**, fuses and other overload protective devices shall have adequate breaking capacity.

*Compliance of the breaking capacity of **thermal cut-outs** is checked by the relevant tests of 20.8 and 20.9.*

*Compliance of the breaking capacity of **thermal links** is checked by the relevant test of 20.9*

The breaking capacity of the fuse shall be in accordance with the relevant fuse standard.

Fuses according to IEC 60127 (all parts) and IEC 60269 (all parts) are allowed to be continuously loaded by a current not exceeding 1,1 times the rated value.

20.8 Thermal cut-outs shall meet the requirements of 20.8.1.1 and 20.8.2, or 20.8.1.2 and 20.8.2.

20.8.1 Requirements according to IEC 60730-1.

20.8.1.1 Thermal cut-outs when tested as separate components shall comply with the appropriate requirements and tests of IEC 60730-1.

For the purpose of this document the following applies.

- a) **Thermal cut-outs** shall be of type 1 or type 2 (see 6.4 of IEC 60730-1:2013)
- b) **Thermal cut-outs** shall have at least micro-interruption (type 1.C or 2.C) (see 6.4.3.3 and 6.9.3 of IEC 60730-1:2013), or micro-disconnection (type 1.B or 2.B) (see 6.4.3.2 and 6.9.2 of IEC 60730-1:2013).
- c) **Thermal cut-outs** with manual reset shall have a trip free mechanism with contacts that cannot be prevented from opening against continuation of a fault (type 1.E and 2.E) (see 6.4.3.5 of IEC 60730-1:2013).
- d) The number of cycles of automatic action shall be:
 - 3 000 cycles for **self-resetting thermal cut-outs**,
 - 300 cycles for **non-self-resetting thermal cut-outs** which can be reset by hand without the use of a tool (see 6.11.10 of IEC 60730-1:2013),
 - 300 cycles for **non-self-resetting thermal cut-outs** which can be reset when the **transformer** is disconnected (see 6.11.10 of IEC 60730-1:2013),
 - 30 cycles for **non-self-resetting thermal cut-outs** which can only be reset by the use of a tool (see 6.11.11 of IEC 60730-1:2013).
- e) **Thermal cut-outs** shall be designed to withstand electrical stresses across their insulating parts for a long period of time and shall be tested accordingly (see 6.14.2 of IEC 60730-1:2013).
- f) The characteristics of **thermal cut-outs** with regard to:
 - their ratings (see Clause 5 of IEC 60730-1:2013);
 - their classification according to:
 - 1) nature of supply (see 6.1 of IEC 60730-1:2013),
 - 2) type of load to be controlled (see 6.2 of IEC 60730-1:2013),
 - 3) degree of protection provided by **enclosures** against ingress of solid objects and dust (see 6.5.1 of IEC 60730-1:2013),
 - 4) degree of protection provided by **enclosures** against harmful ingress of water (see 6.5.2 of IEC 60730-1:2013),
 - 5) **pollution degree** (see 6.5.3 of IEC 60730-1:2013),
 - 6) their comparative tracking index (see 6.13 of IEC 60730-1:2013), and

7) their maximum ambient temperature limit (see 6.7 of IEC 60730-1:2013), shall be appropriate for the application in the **transformer** under normal operating conditions and under fault conditions (e.g. short-circuit of the output terminals).

20.8.1.2 A thermal cut-out when tested as part of a **transformer** shall:

- have at least micro-interruption (type 1.C or type 2.C) or micro-disconnection (type 1.B or 2.B) according to IEC 60730-1:2013;
- be aged for 300 h at a temperature corresponding to the ambient temperature of the **thermal cut-out** when the **transformer** is operated under normal operating conditions at an ambient temperature of 35 °C or, where relevant, ($t_a + 10$) °C;
- be subjected to a number of cycles of automatic operation as specified under 20.8.1.1 for **thermal cut-outs** tested as a separate component, by establishing the relevant fault condition(s).

The tests are carried out on three samples.

NOTE A sample consists of a **transformer** with an incorporated **thermal cut-out**.

Compliance is checked by inspection and by the specified tests.

During the tests, no sustained arcing shall occur, and there shall be no damage from other causes.

*After the tests, there shall be no damage to the **thermal cut-out** and the **transformer** in the sense of this document, in particular, the **enclosure** shall not deteriorate, there shall be no reduction of **clearances** and **creepage distances**, and no loosening of electrical connections or mechanical securing means.*

20.8.2 Thermal cut-outs shall have adequate breaking capacity.

20.8.2.1 A transformer with a non-self-resetting thermal cut-out is supplied at 1,1 times **rated input voltage** and the output terminals are short-circuited until the **thermal cut-out** operates. Then the supply voltage is switched off until the **transformer** cools down to approximately the room temperature. The supply voltage is then switched on (the output terminals still short-circuited).

This cycle of operation is carried out:

- 3 times at a room temperature of (25 ± 10) °C for **transformers** without a t_{amin} marking;
- 3 times at minimum ambient temperature t_{amin} for **transformers** with a t_{amin} marking.

*After the cycling test, the **transformer** is supplied at 1,1 times the **rated supply voltage** for 48 h with the output terminals short-circuited.*

20.8.2.2 A transformer with a self-resetting thermal cut-out is supplied at 1,1 times the **rated input voltage** with the output terminals short-circuited.

This operation is carried out:

- 48 h at an ambient temperature of (25 ± 10) °C for **transformers** without a t_{amin} marking;
- 24 h at an ambient temperature of (25 ± 10) °C and 24 h at minimum ambient temperature t_{amin} for **transformers** with a t_{amin} marking.

Compliance is checked by inspection and by the specified tests in the given order.

During these tests, no sustained arcing shall occur.

*After the test, the **transformer** shall:*

- *withstand the test of Clause 18,*
- *show no damage in the sense of this document, and*
- *be operational.*

20.8.3 A PTC resistor of indirect heating type is considered to be a **non-self-resetting thermal cut-out** by this document.

Compliance is checked by the following test:

*The **transformer** is supplied at 1,1 times the rated input voltage for 48 h (two days) with the output terminals short-circuited.*

- *After 48 h, the **transformer** shall be allowed to cool down to approximately ambient temperature; this test shall be repeated five times at the maximum ambient temperature declared by the **transformer manufacturer**.*
- *The same test cycles shall be repeated, except at 0,9 times the rated input voltage and the minimum ambient temperature declared by the **transformer manufacturer**.*

*During the part of the cycle where the **transformer** is under load, the PTC shall operate and stay in high impedance position until the supply is switched off. At the end of the test, the **transformer** shall withstand the test of Clause 18, shall show no damage, and shall be operational.*

20.9 Thermal-links shall be tested in one of the following two ways.

20.9.1 The **thermal-links**, when tested as separate components, shall comply with the requirements and tests of IEC 60691.

When a **thermal link** is tested according to IEC 60691, the following applies:

- the electrical conditions (see 6.1 of IEC 60691:2015);
- the thermal conditions (see 6.2 of IEC 60691:2015);
- the ratings of the **thermal-link** (see 8 b) of IEC 60691:2015); and
- suitability of the sealing compounds, and impregnating fluids or cleaning solvents (see 8 c) of IEC 60691:2015)

shall be appropriate for the application under normal operating conditions, and short-circuit and overload conditions.

Compliance is checked according to the test specifications of IEC 60691, by inspection, and measurement.

20.9.2 The **thermal-links** when tested as part of a **transformer**,:

- shall be aged for 300 h at a temperature corresponding to the ambient temperature of the **thermal-link** when the **transformer** is operated under normal operating conditions at an ambient temperature of 35 °C or, when relevant, ($t_a + 10$) °C;
- shall be subjected to the **transformer** fault conditions which cause the **thermal-link** to operate. There shall be no sustained arcing during the tests, and no damage in the sense of this document; and
- shall be capable of withstanding 2 times the rated voltage across the disconnection, and have an insulation resistance of at least 0,2 MΩ when measured with a DC voltage equal to 2 times the rated voltage across the disconnection.

The test is conducted 3 times; no failure is allowed. This test is not applicable to **fail-safe transformers**.

The **thermal-link** is replaced, partially or completely, after each test.

Where the **thermal-link** is not replaceable, the test is conducted on three new specimens.

Compliance is checked by inspection and by specified tests in the given order.

20.10 Self-resetting thermal protective devices shall not be used unless no mechanical, electrical, or other hazards occur from their operation during and after the tests of this document.

Compliance is checked by inspection.

20.11 Thermal cut-outs intended to be reset by soldering operation shall not be used for overload protection.

Compliance is checked by inspection.

20.12 Overload protective devices shall not operate when the supply voltage is switched on.

*Compliance is checked by **carrying out** the following test.*

*The **transformer**, with no load, is supplied from a voltage source equal to 1,1 times the **rated supply voltage**. The supply voltage is then switched on and off 20 times at intervals of approximately 10 s or at a point on the voltage wave such that the inrush current is maximized.*

NOTE The switching -on and -off may be carried out only twice if a device is used to switch on at the most unfavourable electrical angle of the supply voltage.

The supply source shall be such that the voltage drop does not exceed 2 % as a result of the inrush current.

NOTE This is not required for associated transformers.

21 Internal wiring

21.1 Internal wiring and electrical connections between different parts of the **transformer** shall be adequately protected or enclosed.

Wire-ways shall be smooth and free from sharp edges, burrs, flashes, etc. which may damage the insulation of conductors.

21.2 Openings in sheet metal through which insulated wires pass shall have rounded edges with a radius not less than 1,5 mm, or the openings shall be provided with bushing of insulating material.

21.3 Uninsulated conductors shall be so fixed that their distance from one another and from the **enclosure** is adequately maintained.

Compliance with the requirements of 21.1 to 21.3 is checked by inspection.

21.4 Internal wiring shall not loosen up when external wires are connected to the input or output terminals.

*Compliance is checked by inspection and by **carrying out** the test of 23.3.*

21.5 Insulated conductors subject to temperatures exceeding the limitations in 14.1 under normal use shall be provided with heat-resistant and non-hygroscopic insulating materials.

Compliance is checked by inspection and, if necessary, by carrying out additional tests; the temperature is determined during the test described in 14.1.

22 Supply connection and other external flexible cables or cords

22.1 All cables, flexible cords and connecting means referred to in this clause shall have appropriate current and voltage ratings suitable for the ratings of the **transformers** to which they are connected.

Compliance is checked by inspection.

22.2 Separate entries shall be provided for the input and output wiring.

Inlet and outlet openings for external wiring shall be so designed that the protective covering of the cord can be introduced without risk of damage.

Inlet and outlet openings for flexible cables or cords shall be of insulating material, or be provided with bushing of insulating material which is substantially free from ageing effects under conditions expected in service. The openings of bushings shall be so shaped as to prevent damage to the cord.

Bushings for external wiring shall be reliably fixed, and shall be such that they are unlikely to be damaged by the material in which they are mounted.

Bushings shall not be of natural rubber unless they form part of a cord guard (see 22.9).

NOTE These requirements do not preclude the use of removable bushings.

Compliance is checked by inspection.

22.3 Fixed transformers shall be so designed that, after the **transformer** has been fixed to its support in the normal way, it shall be possible to connect the rigid or flexible conductors of the external wiring.

Transformers other than those intended to be permanently connected to the fixed wiring may be provided with an appliance inlet on the input side.

The space for the wires inside the **transformer** shall be adequate to allow the conductors to be easily introduced and connected, and the cover, if any, fitted without risk of damage to the conductors or their insulation.

It shall be possible to connect the external supply wires to terminals without their insulation coming into contact with **hazardous-live-parts** of a different polarity, including **live parts** of the **output circuits**.

Compliance is checked by inspection and by an installation test with conductors of the largest cross-sectional area corresponding to the rated connecting capacity of the terminals.

22.4 For **portable transformers** provided with **power supply cords**, the length of the cord shall:

- not exceed 2 m for cross-sectional area of 0,5 mm²;
- exceed 2 m for cross-sectional areas greater than 0,5 mm².

Compliance is checked by inspection.

22.5 Power supply cords ~~of both incorporated into transformers with both having a protection index of IPX0~~ IP20 or higher and **transformers** for “indoor use only” with protection index ~~higher than IPX0~~ of IP20 or higher, shall be as follows:

- for **transformers** with a mass not exceeding 3 kg, ~~not lighter than light polyvinyl chloride sheathed flexible cable or cords (60227 IEC 52) or ordinary tough rubber sheathed flexible cable or cords (60245 IEC 53)~~ the cable or cord shall be at least light polyvinyl chloride sheathed flexible cable or cords according to IEC 60227-5:2011 – type 60227 IEC 52 or ordinary tough rubber sheathed flexible cable or cords according to IEC 60245-4:2011 – type 60245 IEC 53;
- for **transformers** with a mass exceeding 3 kg, ~~not lighter than ordinary polyvinyl chloride sheathed flexible cable or cords (60227 IEC 53) or ordinary tough rubber sheathed flexible cable or cords (60245 IEC 53)~~ the cable or cord shall be at least ordinary polyvinyl chloride sheathed flexible cable or cords according to IEC 60227-5:2011 – type 60227 IEC 53 or ordinary tough rubber sheathed flexible cable or cords according to IEC 60245-4:2011 – type 60245 IEC 53;

Power supply cords of **transformers** with protection index higher than IPX0, except for **transformers** for “indoor use only”, shall be polychloroprene sheathed cord and shall ~~not~~ be ~~lighter than~~ at least ordinary polychloroprene sheathed cord ~~(60245 IEC 57)~~ according to IEC 60245-4:2011 – type 60245 IEC 57.

22.6 Power supply cords may be cord sets fitted with appliance couplers in accordance with IEC 60320 (all parts), provided the **transformers** are single-phase **portable transformers** with input current not exceeding 16 A at the **rated output**.

22.7 The nominal cross-sectional area of **external flexible cables** or **cords** shall not be less than shown in Table 16.

Table 16 – Nominal cross-sectional areas of external flexible cables or cords

Input or output current at rated output A	Nominal cross-sectional areas mm ²
Up to and including 3 ^a	0,5
Over 3 up to and including 6	0,75
Over 6 up to and including 10	1
Over 10 up to and including 16	1,5
Over 16 up to and including 25	2,5
Over 25 up to and including 32	4
Over 32 up to and including 40	6
Over 40 up to and including 63	10
NOTE In Japan, cords having a nominal cross-sectional area of 0,5 mm ² are not allowed for external power supply cords .	
^a These cords may be used as power supply cords if their length does not exceed 2 m between the point where the cord or cord guard enters the transformer and the entry to the plug.	

Compliance is checked by inspection and by measurement.

22.8 Each **power supply cord** of **class I transformers** shall have a green/yellow coloured cord connected to the protective earthing terminal of the **transformer** and to the protective earthing contact of the plug, if any.

Power supply cords of single-phase **portable transformers** having an input current at **rated output** not exceeding 16 A shall be provided with plugs complying with IEC TR 60083 or IEC 60906-1. Other **portable transformers** may be provided with plugs complying with IEC 60309 (all parts).

Compliance is checked by inspection.

22.9 External flexible cables or cords shall be attached to the **transformer** by **type X, Y** or **Z attachments** unless otherwise specified in the relevant part of IEC 61558-2.

Compliance is checked by inspection and, if necessary, by manual test.

22.9.1 For **type Z attachments**, moulding the **enclosure** of the **transformer** and the **external flexible cable or cord** together shall not affect the insulation of the cord.

Compliance is checked by inspection.

22.9.2 Inlet openings shall be designed and shaped, or be provided with an inlet bushing such that the protective covering of the **external flexible cable or cord** can be introduced without risk of damage.

The insulation between the conductor and the **enclosure** shall consist of the insulation of the conductor and, in addition:

- for **class I transformers**, at least **basic insulation**; and
- for **class II transformers**, at least **double** or **reinforced insulation**.

NOTE The sheath of an **external flexible cable or cord** equivalent to at least that of a cord complying with IEC 60227 (all parts) or IEC 60245 (all parts) is regarded as **basic insulation**.

NOTE A lining or a bushing of insulating material in a metallic enclosure is only regarded as **supplementary insulation** if it complies with the relevant requirements.

NOTE An **enclosure** of insulating material is regarded as **reinforced insulation**, in which case, two separate insulations are not necessary.

Compliance is checked by inspection and by carrying out a manual test.

22.9.3 Inlet bushings shall:

- be so shaped as to prevent damage to the **external flexible cable or cord**;
- be reliably fixed;
- not be removable without the aid of a **tool**; and
- not be of natural rubber, except if it is an integral part of the rubber sheath of the **external flexible cable or cord** for **type X** with a special cord, **type Y** and **type Z attachments** for **class I transformers**.

Compliance is checked by inspection and by carrying out a manual test.

22.9.4 Transformers provided with cords which are moved while in operation shall be constructed so that the cord is adequately protected against excessive flexing where it enters

the **transformer**. Cord guards, if any, shall be of insulating material and be fixed in a reliable manner.

Compliance is checked by *carrying out* the following test, which is conducted on an apparatus having an oscillating member as shown in Figure 12.

The part of the **transformer** comprising the cord entry, the cord guard, if any, and the **external flexible cable or cord** is fixed to the oscillating member so that when the latter is at the middle of its travel, the axis of the cord where it enters the cord guard or inlet is vertical and passes through the axis of oscillation. The major axis of the section of flat cords shall be parallel to the axis of oscillation.

The cord is loaded so that the force applied is:

- 10 N for cords having a cross-sectional area exceeding 0,75 mm²; and
- 5 N for other cords.

The distance A shown in Figure 12, between the axis of oscillation and the point where the cord guard enters the **transformer**, is adjusted so that when the oscillating member moves over its full range, the cord and load make the minimum lateral movement.

The oscillating member is moved through an angle of 90° (45° on either side of the vertical), the number of flexings for **type Z attachments** shall be 20 000, and for other attachments 10 000. The rate of flexing shall be 60 / min.

NOTE 1 A flexing is one movement of 90°.

The cord and its associated parts are turned through an angle of 90° after half the number of flexings, unless a flat cord is fitted.

During the test, the conductors are loaded with the maximum rated current of the circuit under test, and at the rated voltage.

NOTE 2 Current is not passed through the protective earthing conductor.

The test shall not result in:

- a short circuit between the conductors;
- breakage of more than 10 % of the strands of any conductor;
- separation of the conductor from the terminal;
- loosening of any cord guard;
- damage, within the meaning of this document, to the cord or cord guard; and
- broken strands piercing the insulation and becoming accessible.

NOTE 3 Conductors include protective earthing conductors.

NOTE 4 A short circuit between conductors of the cord is considered to occur if the current exceeds a value equal to twice the rated maximum current of the circuit in question.

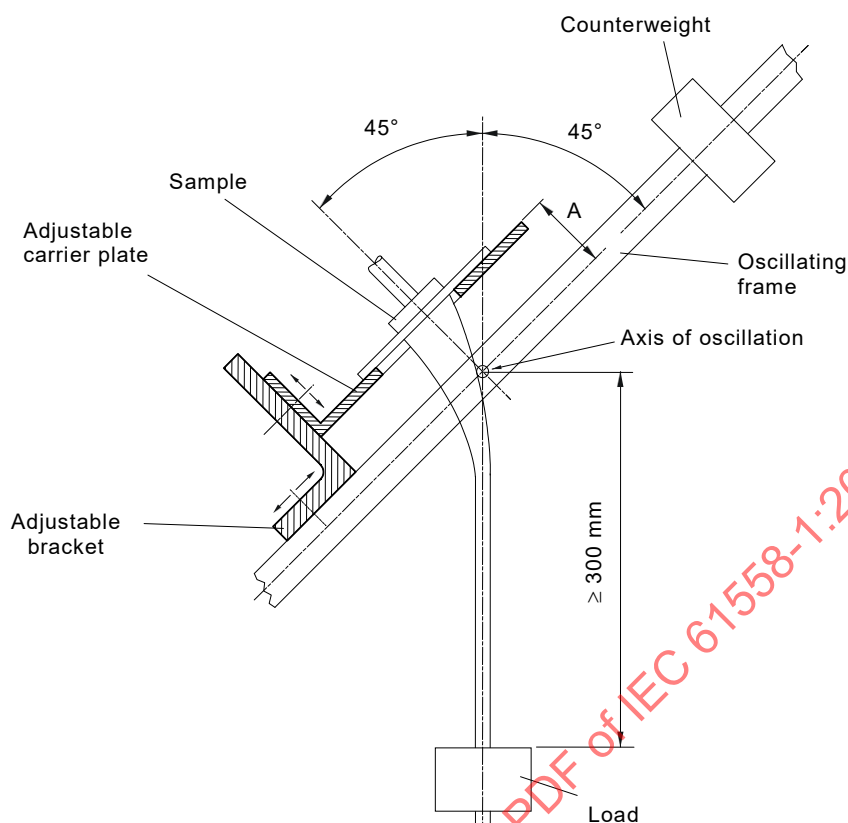


Figure 12 – Flexing test apparatus

22.9.5 Stationary transformers intended for use with **external flexible cables or cords** and **portable transformers** shall be provided with cord anchorages for strain relief including twisting where they are connected within the **transformer**, and for protection of the insulation of the conductors against abrasion.

For **type X attachments**, glands shall not be used as cord anchorages in **portable transformers** unless they have provisions for clamping all types and sizes of cables and cords which might be used as **external flexible cables or cords**. Production methods, such as, moulded-on designs, tying the cord into a knot or tying the ends with string, are not allowed; labyrinths or similar means are permitted, provided it is clear how the **external flexible cable or cord** is to be assembled.

For **type X attachments**, the cord anchorage shall be so designed or located that:

- replacement of the cord is easily possible;
- it is clear how strain relief and prevention of twisting are to be obtained;
- it is suitable for connection of different types of cords, unless the **transformer** is designed to accommodate only a specific type of cord;
- the entire flexible cable or cord with its covering, if any, is capable of being mounted into the cord anchorage;
- it does not damage the cord and is unlikely to be damaged when it is tightened or loosened in normal use; and
- the cord cannot touch the clamping screws of the cord anchorage if these screws are accessible or in contact with accessible **conductive parts**.

For **type X** with a special cord, and **type Y** and **Z attachments**, the cores of the **external flexible cable or cord** shall be insulated from accessible **conductive parts** by insulation

complying with the requirements for **basic insulation** for **class I transformers**, and the requirements for **supplementary insulation** for **class II transformers**.

This insulation may consist of:

- a separate insulating barrier fixed to the cord anchorage;
- a special lining fixed to the cord; or
- for **class I transformers**, the sheath of a sheathed cord.

For **type X** with a special cord, and **type Y attachments**, the cord anchorage shall be so designed that:

- the replacement of the **external flexible cable or cord** does not impair compliance with this document;
- the entire flexible cable or cord with its covering, if any, is capable of being mounted into the cord anchorage;
- it does not damage the cord and is unlikely to be damaged when it is tightened or loosened in normal use; and
- the cord cannot touch the clamping screws of the cord anchorage if these screws are accessible or in contact with accessible conductive parts;

Compliance is checked by inspection and by the following tests.

*For **type X attachments**, except with a special cord, the **transformer** shall be fitted with a suitable **external flexible cable or cord**. The conductors shall be introduced into the terminals, and the terminal screws, if any, shall be tightened sufficiently to prevent the conductors from shifting position. The cord anchorage shall be used in the normal way, its clamping screws tightened with a torque equal to two-thirds of that specified in Table 18.*

*The tests are first conducted with the lightest permissible type of cord of the smallest cross-sectional area specified in Table 16 and then with the next heavier type of cord of the largest cross-sectional area specified, unless the **transformer** is designed to accommodate only a specific type of cord.*

*For **type X** with a special cord, and **type Y** and **Z attachments**, the **transformer** is tested with the cord in place.*

*It shall not be possible to push the cord into the **transformer** to the extent that the cord or internal parts of the **transformer**, could be damaged.*

The cord shall then be subjected 25 times to a pull force of the value shown in Table 17. The pull force shall be applied in the most unfavourable direction without a jerking motion, each time for 1 s.

Immediately after the pull tests, the cord is subjected for 1 min to a torque of the value shown in Table 17.

Table 17 – Pull and torque to be applied to external flexible cables or cords fixed to stationary and portable transformers

Mass of transformer kg	Pull N	Torque Nm
Up to and including 1	30	0,1
Over 1 up to and including 4	60	0,25
Over 4	100	0,35

The cord shall not be damaged during the tests.

After the tests, the cord shall not be longitudinally displaced by more than 2 mm, and the conductors shall not shift over a distance of more than 1 mm in the terminals, nor shall there be appreciable strain at the connection.

Creepage distances and clearances shall not be reduced below the values specified in Clause 26.

For the measurement of the longitudinal displacement, a mark is made on the cord at a distance of approximately 20 mm from the cord anchorage or other suitable point before starting the tests.

After the tests, the displacement of the mark on the cord in relation to the cord anchorage or other point is measured, while the cord is still under the pull force.

22.9.6 The space for the supply cables or the **external flexible cable or cord** provided inside for the connection

- a) to fixed wiring and for **type X** and **Y attachments** shall be designed to:
- permit checking the proper connection and positioning of the conductors prior to fitting of cover, if any;
 - ensure the covers, if any, can be fitted without risk of damage to the conductors or their insulation;
 - prevent, for **portable transformers**, the un-insulated end of the conductor, should it pull free from the terminal, from coming into contact with accessible **conductive parts**, unless, for **type X** and **Y attachments**, the cord is provided with terminations that are unlikely to pull free from the conductor; and
- b) to fixed wiring and for **type X attachments**, in addition shall be:
- adequate to allow the conductors to be easily introduced and connected; and
 - designed such that covers, if any, giving access to terminals for external conductors can only be removed with the aid of a **tool**.

Compliance is checked by inspection and by manual tests.

23 Terminals for external conductors

23.1 Transformers intended to be permanently connected to fixed wiring, and **transformers** other than those provided with external flexible cords with **type Y** or **Z attachments** shall be provided with terminals in which connection is made by means of screws, nuts or equally effective devices.

*Terminals that are an integral part of the **transformer** shall comply with IEC 60999-1 under the conditions prevailing in the **transformer**.*

Other terminals shall be:

- *either separately checked according to IEC 60998-2-1, IEC 60998-2-2 or IEC 60947-7-1, and used in accordance with their marking, or*
- *checked according to IEC 60999-1 under the conditions prevailing in the **transformer**.*

For **transformers** with **type X attachment**, soldered connections may be used for external conductors, provided that the conductor is so positioned or fixed that reliance is not placed upon soldering alone to maintain the conductor in position, unless barriers are provided so that **creepage distances** and **clearances** between **hazardous-live-parts** and other conductive parts cannot be reduced to less than 50 % of the values specified in Clause 26, should the conductor break away at the soldered joint.

For **transformers** with **type Y** and **Z attachments**, soldered, welded, crimped and similar connections may be used for external conductors.

For **class II transformers**, the conductor shall be so positioned or fixed that reliance is not placed upon soldering, crimping, or welding alone to maintain the conductor in position, unless barriers are provided so that **creepage distances** and **clearances** between **hazardous-live-parts** and other **conductive parts** cannot be reduced to less than 50 % of the values specified in Clause 26, should the conductor break away at the soldered or welded joint, or slip out of the crimped connections.

NOTE In general, hooking-in before soldering is considered to be a suitable method for retaining the conductor of a flexible cable or cord in position, provided the hole through which the conductor is passed is not unduly large.

23.2 Terminals for **type X** attachment with a special cord, and **types Y** and **Z attachments** shall be suitable for their purpose.

*Compliance with the requirements of 23.1 and 23.2 is checked by inspection and by applying a pull force of 5 N to the connection immediately before **carrying out** the test of 14.1.*

23.3 Terminals, other than those with **type Y** or **Z attachments**, shall be so fixed that when the clamping means is tightened or loosened, the terminal does not loosen up, internal wiring is not subjected to stress, and **creepage distances** and **clearances** are not reduced below the values specified in Clause 26.

23.4 Terminals, other than those with **type Y** or **Z attachments**, shall be so designed that they clamp the conductor between metallic surfaces with sufficient contact pressure, and without damage to the conductor.

Compliance with the requirements of 23.3 and 23.4 is checked by inspection and by measurement after fastening and loosening 10 times a conductor of the largest cross-sectional area corresponding to the rated connecting capacity of the terminal, and the torque applied shall be equal to two-thirds of the torque specified in Clause 25.

NOTE Securing with sealing compounds without other means of clamping is not considered sufficient. However, self-hardening resins may be used to secure terminals that are not subject to torsion in normal use.

23.5 Terminals provided for connection to fixed wiring, and terminals with **type X attachment** shall be located near their associated terminals of different polarities and the protective earthing terminal, if any.

Compliance is checked by inspection.

23.6 Terminal blocks and similar devices shall not be accessible without the aid of a **tool**, even if their **hazardous-live-parts** are not accessible.

Compliance is checked by inspection and by carrying out a manual test.

23.7 Terminals or terminations of **transformers** with **type X attachment** shall be so located or shielded that, should a strand of wire from a stranded conductor pull out when the conductors are fitted, there shall be no risk of accidental connection between **live parts** and accessible **conductive parts**, and in case of **class II transformers**, between **live parts** and **conductive parts** separated from accessible **conductive parts** by **supplementary insulation** only.

Compliance is checked by inspection and by carrying out the following test.

An 8-mm length of insulation is removed from the end of a flexible conductor having a nominal cross-sectional area as specified in Clause 22. One strand of wire from the stranded conductor is left free, and the other strands are fully inserted into the terminal and clamped in.

*The free strand of wire is bent in every possible direction without making sharp bends round barriers and without tearing the insulation back. The free strand of wire connected to a live terminal shall not touch any accessible conductive parts. For **class II transformers**, it shall also not touch any conductive part separated from accessible conductive parts by **basic** or **supplementary insulation** only. The free strand of wire from a conductor connected to an earthing terminal shall not touch any **hazardous-live-part**.*

23.8 Terminals without pressure plate shall be provided with at least two clamping screws if the current exceeds 25 A.

Compliance is checked by inspection.

23.9 Terminal screws, other than screws of terminals for the connection of protective earthing conductors shall not come into contact with any accessible **conductive parts**. For **class II transformers**, they shall also not touch any conductive parts separated from accessible conductive parts only by **basic** or **supplementary insulation** when the screws are loosened up as far as possible.

Compliance is checked by inspection during the test of 23.2.

24 Provisions for protective earthing

24.1 Accessible conductive parts of **class I transformers** which may become live in the event of an insulation ~~break-down~~ **fault** shall be permanently and reliably connected to a protective earthing terminal within the **transformer**.

Class II transformers shall have no provisions for protective earthing the **transformer** except for functional purposes.

Compliance is checked by inspection.

NOTE If accessible **conductive parts** are separated from **hazardous-live-parts** by a conductive screen connected to the protective earthing terminal, or if they are separated from **hazardous-live-parts** by **double insulation** or **reinforced insulation**, they are not, for the purpose of this requirement, regarded as likely to become live in the event of an insulation ~~break-down~~ **fault**.

24.2 Protective earthing terminals for connection to fixed wiring, and protective earthing terminals with **type X attachment** shall comply with the requirements of Clause 23. Their clamping means shall be adequately locked against accidental loosening, and it shall not be possible to loosen them without the aid of a **tool**.

Compliance is checked by inspection, by manual test and by the tests of Clause 23.

NOTE Some terminals, especially, the pillar types, ~~may~~ can require special provisions, such as an adequately resilient part not likely to be removed inadvertently.

24.3 All parts of the protective earthing terminal shall be such that there is no risk of corrosion resulting from contact between these parts and the copper of the protective earthing conductor, or any other metal that is in contact with these parts.

If the **body** of the protective earthing terminal is part of a frame or **enclosure** of aluminium or aluminium alloy, precautions shall be taken to avoid the risk of corrosion resulting from contact between copper and aluminium or its alloys.

Compliance is checked by inspection.

The **body** of the protective earthing terminal shall be of brass or other metal not less resistant to corrosion, unless it is a part of the metal frame or **enclosure**, in which case, the screw or nut shall be of brass or other metal equally resistant to corrosion.

24.4 The connection between the protective earthing terminal and parts required to be connected thereto shall be of low resistance.

Compliance is checked by the following test.

A current derived from an AC source, having a no-load voltage not exceeding 12 V and equal to 1,5 times the rated input current or to 25 A, whichever is greater, is passed for 1 min between the protective earthing terminal and each of the **accessible conductive parts** in turn.

NOTE 1 Rated input current is determined as the quotient of the **rated output** by the **rated supply voltage**, or for polyphase **transformers**, by $\sqrt{n}$ times the **rated supply voltage**, n being the number of phases.

*The voltage drop between the protective earthing terminal and the **accessible conductive part** is measured and the resistance calculated from the current and this voltage drop.*

In no case shall the resistance exceed 0,1 Ω .

In case of doubt, after 1 min, the test shall be conducted until steady-state conditions are established.

NOTE 2 Care is taken to **ensure** that the contact resistance between the tip of the measuring probe and the conductive part under test does not affect the test results.

NOTE 3 The resistance of the supply's flexible cable or cord, if used for convenience in the test, is not included in the resistance measurement.

NOTE 4 The cores of IP00 **transformers** are considered to be not accessible.

24.5 For **class I transformers** with **external flexible cables or cords**, the arrangement of the terminals, or the length of the conductors between the cord anchorage and the terminals, shall be such that the current-carrying conductors are stretched before the protective earthing conductor if the cord pulls out of the cord anchorage.

25 Screws and connections

25.1 Screwed connections, electrical or otherwise, shall withstand the mechanical stresses occurring in normal use.

Screws transmitting contact pressure, and screws which are likely to be tightened by the user and have a nominal diameter less than 2,8 mm, shall screw into metal.

Screws shall not be of soft metal liable to creep, such as, zinc or aluminium.

Screws of insulating material shall not be used for any electrical connection.

Screws shall not be of insulating material if their replacement by a metal screw could impair **basic insulation** between **input** and **output circuit**, **supplementary insulation**, or **reinforced insulation**, and the screws which may be removed when replacing a **power supply cord** shall not be of insulating material if their replacement by a metal screw could impair **basic insulation**.

Compliance is checked by inspection and, for screws and nuts transmitting contact pressure or which are likely to be tightened by the user, by the following test.

The screws or nuts are tightened and loosened:

- 10 times for a screw in engagement with the threads of insulating material, and
- 5 times for nuts and other screws.

Screws in engagement with the threads of insulating material are completely removed and re-inserted each time.

When testing terminal screws and nuts, a flexible cable or cord of the largest cross-sectional area specified in Table 16 is placed in the terminal and it is repositioned before each tightening.

The test is conducted by means of a suitable test screwdriver, spanner or key, applying a torque as shown in Table 18, the appropriate column shall be:

- a) *for metal screws without heads, if the tightened screw does not protrude from the hole I*
- b) *for other metal screws and for nuts II*
- c) *for screws of insulating material:*
 - *having a hexagonal head with the dimension across flats exceeding the overall thread diameter, or*
 - *with a cylindrical head and a socket for a key, the socket having a dimension across flats not less than 0,83 times the overall thread diameter, or*
 - *with a head having a slot or cross slots, the length of which exceeds 1,5 times the overall thread diameter II*
- d) *for other screws of insulating material III*

Table 18 – Torque to be applied to screws and connections

Nominal diameter of screw mm	Torque Nm		
	I	II	III
Up to and including 2,8	0,2	0,4	0,4
Over 2,8 up to and including 3,0	0,25	0,5	0,5
Over 3,0 up to and including 3,2	0,3	0,6	0,6
Over 3,2 up to and including 3,6	0,4	0,8	0,6
Over 3,6 up to and including 4,1	0,7	1,2	0,6
Over 4,1 up to and including 4,7	0,8	1,8	0,9
Over 4,7 up to and including 5,3	0,8	2,0	1,0
Over 5,3 up to and including 6,0	–	2,5	1,25

The conductor is ~~moved~~ withdrawn and inserted each time the ~~screw or nut~~ fastener is loosened.

During the test, no damage impairing further use of the screwed connections shall occur.

NOTE Screws or nuts likely to be tightened by the user include screws intended to be operated when replacing power supply cords with type X attachment.

NOTE The blade of the test screwdriver shall fit the head of the screw to be tested. The screws and nuts should be tightened without jerking motion.

25.2 Screws in engagement with a thread of insulating material shall have a length of engagement of at least 3 mm plus one-third of the nominal screw diameter or 8 mm, whichever is shorter.

Proper introduction of the screw into the screw hole or nut shall be ensured.

Compliance is checked by inspection and by carrying out the test of 25.1, and the torque applied shall be increased to 1,2 times the torque specified.

NOTE The requirement for the proper introduction is met if introduction of the screw in a slanting manner is prevented (e.g., by guiding the screw using the part to be fixed, by a recess in the female thread, or by the use of a screw with the leading thread removed).

25.3 Electrical connections shall be designed so that contact pressure is not transmitted through insulating material other than ceramic or pure mica, except if the insulation material fulfills the tests according to 14.3, unless there is sufficient resiliency in the metallic parts to compensate for any possible shrinkage or distortion of the insulating material.

25.4 Thread-forming screws (sheet metal screws) shall not be used for the connection of current-carrying parts, unless they clamp these parts directly in contact with each other, and are provided with suitable locking means.

Thread-cutting (self-tapping) screws shall not be used for the connection of current-carrying parts unless they generate a full form standard machine screw thread. Such screws shall not, however, be used if they are likely to be operated by the user or installer unless the thread is formed in a length of material previously obtained by a swaging action.

Thread-cutting and thread-forming screws, when used to provide **protective** earthing continuity, shall be such that it is not necessary to disturb the connection in normal use, and at least two screws are used for each connection.

Compliance with the requirements of 25.3 and 25.4 is checked by inspection.

25.5 Screws making mechanical connections between different parts of the **transformer** shall be locked against loosening if the connection carries current or forms part of the protective earthing circuit.

Rivets used for current-carrying connections shall be locked against loosening if these connections are subject to torsion in normal use.

*Compliance is checked by inspection and by **carrying out a manual test**.*

NOTE 1 Spring washers and the like ~~may~~ **can** provide satisfactory locking.

NOTE 2 For rivets, a non-circular shank or an appropriate notch ~~may~~ **can** be sufficient.

NOTE 3 Sealing compounds softening due to heat provide satisfactory locking ~~only~~ for screw connections not subjected to torsion in normal use.

25.6 *Screwed glands shall comply with the following test:*

Screwed glands shall be fitted with a cylindrical metal rod having a diameter equal to the nearest whole number of millimetres below the internal diameter of the packing. The glands shall then be tightened by means of a suitable spanner, and the force shown in Table 19 shall be applied to the spanner for 1 min at a point 250 mm from the axis of the gland.

Table 19 – Torque test on glands

Diameter of test rod mm	Force	
	Metal glands N	Glands of moulded material N
Up to and including 14	25	15
Over 14 up to and including 20	30	20
Over 20	40	30

*After the test, the **transformer** and the glands shall show no damage.*

26 Creepage distances, clearances and distances through insulation

26.1 General

Creepage distances (CR), clearances (CL) and distances through insulation shall not be less than the values shown in the **relevant** Table 20, Table 21 and Table 22 for the **relevant** insulating ~~materials of group IIIa~~ **material** (see IEC 60664-1).

Compliance is checked by measurements under the provisions of 26.2 and 26.3.

~~NOTE For materials of groups I and II, see Annexes C and D.~~

NOTE 1 Table 20, Table 21 and Table 22 are only applicable for frequencies up to and including 30 kHz.

Creepage distances and **clearances** are measured, using the supply cable and cords for connection to fixed wiring and those for **type X attachment** with maximum and minimum size

conductors corresponding to the rated connecting capacity of the terminal. For **type X** with a special cord, **Y** or **Z attachments**, the supply cable and cords as delivered are used.

Where layers of serrated tapes are used, the value for **creepage distances** and **clearances** are determined as if the layers of serration coincided with one another.

NOTE 2 Diagrams showing some examples of the methods of measurement of **creepage distances** and **clearances** are found in Annex A.

NOTE 3 Diagrams showing some examples of points of measurement of **creepage distances** and **clearances** are given in Annex P.

NOTE 4 Details of the tests necessary to determine the separation of material groups are given in Annex G.

~~NOTE Table 13, Table C.1 and Table D.1 take into consideration over voltage category II for basic insulation and over voltage category III for double or reinforced insulation.~~

Values for printed wiring boards where failure may cause a hazard in the sense of this document, shall be the same as unreduced values for **live parts** as in Table 20 and Table 21, except if the printed wiring board complies with the requirements of IEC 60664-3.

If the **pollution** results in high and persistent conductivity caused, for instance, by conductive dust, rain or snow, the **creepage distances** and **clearances**, as given for **pollution degree 3**, shall be further increased with a minimum **clearance** of 1,6 mm and a value of **X** in Annex A of 4,0 mm.

26.2 Creepage distances and clearances ~~(or)~~

26.2.1 General

The **creepage distance** and **clearance** values are shown in Table 20 and Table 21.

26.2.2 Windings covered with adhesive tape

For windings covered with an adhesive bonding tape adhering to the flanges of a coil former, the values of creepage path are considered along the bonded surface of the adhesive bonding tape. Reduced values are those stated for **pollution degree 1** (P1), provided:

- all insulating materials are classified according to IEC 60085 and IEC 60216 (**all parts**);
- the impulse voltage dielectric test of 6.1.2.2.1 of IEC 60664-1:2007 is fulfilled; and
- the test A of 26.2.4 is fulfilled.

NOTE An explanation of the application of 6.1.2.2.1 of IEC 60664-1:2007 can be found in Annex R.

Clearance values are not required.

26.2.3 Uncemented insulating parts

Where an insulation barrier consisting of an uncemented snap-on partition wall is used, **creepage distances** and **clearance** are measured through the joint. If the joint is covered by adhesive bonding tape in accordance with IEC 60454 (**all parts**), one layer of adhesive bonding tape is required on each side of the wall in order to reduce the risk of tape folding over during production.

The materials used shall be classified according to IEC 60085 and IEC 60216 (**all parts**).

The values stated for **pollution degree 1** (P1) do not apply.

26.2.4 Cemented insulating parts

For **transformers** with cemented parts or parts adhered together, no minimum **creepage distance** and **clearance** are required through the joint. Only the values for distance through insulation (DTI) apply. In this case, the impulse voltage dielectric test of 6.1.2.2.1 of IEC 60664-1:2007 shall also be fulfilled.

NOTE An explanation of the application of 6.1.2.2.1 of IEC 60664-1:2007 can be found in Annex R.

The materials used shall be classified according to IEC 60085 and IEC 60216 (all parts).

In order to check whether the parts are adequately cemented or adhered, the following tests are performed as appropriate:

- **Test A**

*Three specially prepared specimens with winding wires replaced by uninsulated wires without any impregnation or potting are required. The windings shall be constructed such that there is no possible flashover between **input** and **output windings** anywhere other than in the cemented joint to be tested.*

The specimens shall be subjected 10 times to the following sequence of temperature cycles:

68 h at the highest winding temperature ± 2 °C measured in normal use plus 10 K with a minimum of 85 °C;

1 h at (25 ± 2) °C;

2 h at (0 ± 2) °C;

1 h at (25 ± 2) °C.

Two of the three specimens shall then be subjected to the humidity treatment of 17.2 (48 h treatment) and the relevant dielectric strength test of 18.3, except the test voltage is multiplied by 1,35.

One of the three specimens shall be subjected to the relevant dielectric strength test of 18.3 immediately after the last period at the highest temperature during the thermal cycling test, but with a test voltage multiplied by 1,35.

NOTE The test voltage applied to the specimens for cemented parts is higher than the normal test voltage in order to ensure that a breakdown occurs if the surfaces are not cemented together.

26.2.5 Enclosed parts (e.g. by impregnation or potting)

26.2.5.1 For **transformers** with parts enclosed or hermetically sealed against ingress of dust and moisture, and satisfying the following tests, the minimum required **creepage distances** may be the reduced values as stated for **pollution degree 1** (P1). In this case, the impulse voltage dielectric test of 6.1.2.2.1 of IEC 60664-1:2007 shall also be fulfilled.

NOTE An explanation of the application of 6.1.2.2.1 of IEC 60664-1:2007 can be found in Annex R.

No clearance values are required.

The materials used shall be classified according to IEC 60085 and IEC 60216 (all parts).

In order to check whether the parts are adequately potted or impregnated, the following tests are performed as appropriate:

- **Test B**

To test the potting or the impregnation, three prepared specimens shall be used as follows. For components where potting or impregnation is used, the reliability of the joint is checked by subjecting the samples to the dielectric strength test applied only directly to the joint.

The specimens shall be subjected 10 times to the following sequence of temperature cycles:

68 h at the highest winding temperature ± 2 °C measured in normal use plus 10 K with a minimum of 85 °C;

1 h at (25 ± 2) °C;

2 h at (0 ± 2) °C;

1 h at (25 ± 2) °C.

During each thermal cycling test, a test voltage of ~~twice the value of 500 V~~ or the working voltage, whichever is the higher value, at 50 Hz or 60 Hz shall be applied to the specimens between the windings where the reduced values apply.

Two of the three specimens shall then be subjected to the humidity treatment of 17.2 (48 h treatment) and the relevant dielectric strength test of 18.3 conducted at a voltage multiplied by 1,25.

One of the three specimens shall be subjected to the relevant dielectric strength test of 18.3 immediately at the end of the last period at the highest temperature during the thermal cycling test conducted at a voltage multiplied by 1,25.

26.2.5.2 For **transformers** with parts enclosed or hermetically sealed against ingress of dust and moisture, and satisfying the following tests, no minimum creepage distances and clearances are required. Only the values for distance through insulation (DTI) apply. In this case, the impulse voltage dielectric test of 6.1.2.2.1 of IEC 60664-1:2007 shall also be fulfilled.

NOTE An explanation of the application of 6.1.2.2.1 of IEC 60664-1:2007 can be found in Annex R.

In order to check whether the parts are adequately potted or impregnated, the following tests shall be performed as appropriate:

- **Test C**

To test the potting or the impregnation three specimens shall be used.

For components where insulating compound forms solid insulation between **conductive parts**, finished components shall be tested. There shall be neither cracks nor voids in the insulating compounds.

The specimens shall be subjected 10 times to the following sequence of temperature cycles:

68 h at the highest winding temperature ± 2 °C measured in normal use plus 10 K with a minimum of 85 °C;

1 h at (25 ± 2) °C;

2 h at (0 ± 2) °C;

1 h at (25 ± 2) °C.

During each thermal cycling test, a test voltage of ~~twice the value of 500 V~~ or the working voltage, whichever is the higher value, at 50 Hz or 60 Hz shall be applied to the specimens between the windings where the reduced values apply.

Two of the three specimens are then subjected to the humidity treatment of 17.2 (48 h treatment) and the relevant dielectric strength test of 18.3 conducted at a voltage multiplied by 1,35.

One of the three specimens shall be subjected to the relevant dielectric strength test of 18.3 immediately at the end of the last period at highest temperature during the thermal cycling test conducted at a voltage multiplied by 1,35.

26.3 Distance through insulation ~~(DTI)~~

26.3.1 The distances through insulation (DTI) are required for **supplementary, double or reinforced** insulation only as shown in Table 22.

The insulation shall fulfil either the material classification as given in IEC 60085 and IEC 60216 (all parts) or the test of 14.3.

NOTE The material is considered as having adequate mechanical strength and resistance to ageing if it fulfils the test of 14.3.

The requirements concerning distance through insulation (DTI) do not imply that the prescribed distance shall be through solid or thin sheet insulation only. It may consist of the thickness of solid or thin sheet insulation plus a specified clearance distance.

26.3.2 In case of solid insulation, the required values are specified in the Table 22. For classified materials in accordance to IEC 60085 and IEC 60216 (all parts), distances through insulation multiplied by 0,4 with a minimum of 0,2 mm for **reinforced insulation** and of 0,1 mm for **supplementary insulation** for **working voltage** above 25 V may be used if the test of 14.3 is fulfilled.

26.3.3 In the case of insulation constructed of thin sheets of insulated material, the insulation shall be such that at every place, there is at least the required number of layers and the DTI as follows:

- if the layers are non separable (glued together):
 - 3 layers are required;
 - the entire composite sheet shall fulfil the mandrel test of 26.3.4 with a pull force of (150 ± 10) N;
 - the required values for DTI of thin layers in Table 22;
- if the layers are separated:
 - 2 layers are required; for separated serrated layers, one additional layer is required (serrated tape) plus one layer without serration fixed (e.g. adhesive);
 - each layer shall fulfil the mandrel test of 26.3.4 with a pull force of (50 ± 5) N;
 - the required values for DTI of thin layers in Table 22;
- if the layers are separated (alternative):
 - at least 3 layers are required; for separated serrated layers, one additional layer is required (serrated tape) plus one layer without serration fixed (e.g. adhesive);
 - two-thirds of the number of layers shall fulfil the mandrel test of 26.3.4 with a pull force of (100 ± 5) N;
 - the required values for DTI of thin layers in Table 22.

NOTE Additional layers are required in case of use of serrated layers because it is assumed that different layers of serration can coincide with one another.

For classified materials in accordance to IEC 60085 and IEC 60216, (all parts), no requirements for distances through insulation are required if the test of 14.3 is fulfilled.

The required values of Table 22 for thin layers shall be used as follows:

- for **transformers** having a **rated output** greater than 100 VA, the values for thin layers apply;
- for **transformers** having a **rated output** of 25 VA up to and including 100 VA, the values for thin layers may be reduced to two-thirds of their value;

- for **transformers** having a **rated output** of less than 25 VA, the figures in values for thin layers may be reduced to one-third of their value.

26.3.4 For the mandrel test, three separate test specimens of thin sheets ($70 \pm 0,5$) mm in width shall be supplied by the manufacturer.

The test shall be performed by fixing the specimens of thin sheets on a mandrel made of nickel plated steel or brass with smooth surface finish as shown in Figure 13.

A metal foil (aluminium or copper) $0,035 \text{ mm} \pm 0,005 \text{ mm}$ thick shall be placed closely to the surface of the specimen and subjected to a pull force of $(1 \pm 0,1) \text{ N}$. The metal foil shall be so positioned that its borders are 20 mm away from the borders of the specimen, and when the mandrel is in its final position, it covers the edges upon which the specimen is lying by at least 10 mm.

The specimen is held in place at its free end by an appropriate clamping device and subjected to:

- a pull force of $(150 \pm 10) \text{ N}$ for a specimen consisting of several non separable layers;
- a pull force of $(100 \pm 5) \text{ N}$ for a specimen consisting of $2/3$ the number of separated layers (serrated or not); and
- a pull force of $(50 \pm 5) \text{ N}$ for a specimen consisting of a single layer (serrated or not).

The mandrel shall be slowly rotated forwards and backwards 3 times for 230° without jerking motion. If the specimen breaks at the clamping device during the rotation, the test shall be repeated. If one or more specimens break at any other place, the test is not fulfilled. While the mandrel is in its final position, within a minute following the final positioning, a dielectric strength test voltage shall be applied for 1 min as described in 18.3 between the mandrel and the metal foil as follows:

- a test voltage of at least 5 kV or the applicable test voltage of 18.3 multiplied by 1,35 for a specimen consisting of several non separable layers (at least 3 layers), whichever is greater;
- a test voltage of at least 5 kV or the applicable test voltage of 18.3 multiplied by 1,25 for a specimen consisting of $2/3$ of the number of at least 3 separated layers, whichever is greater;
- a test voltage of at least 5 kV or the applicable test voltage of 18.3 multiplied by 1,25 for a specimen consisting of one layer of the number of 2 separated layers, whichever is greater.

No flashover or breakdown shall occur during the test, and corona effects and similar phenomena shall be disregarded.

**Table 13 — Creepage distances (cr), clearances (cl) and distances through insulation (dti) —
—Material group IIIa (175 ≤ CTI < 400)**

NOTE—The following table extends over several pages. For notes and footnotes, please see the final page of the table.

Type of insulation		Measurement						Working voltages ^b V												Dimensions in millimetres			
		Through-winding-enamel ^a		Other than through-winding-enamel		≥25 ≤50		100		150		300		600		1 000							
		P2	P3	P2	P3	cl	cr	cl	cr	cl	cr	cl	cr	cl	cr	cl	cr	cl	cr				
1) Insulation between input and output circuits (basic insulation)	a) Creepage distances and clearances between live parts of input circuits and live parts of output circuits	X	X	X	X	0,2	1,2	0,5	1,4	1,5	1,6	3,0	3,0	5,5	6,0	8,0	10,0	10,0	16,0				
						0,8	1,9	0,8	2,2	1,5	2,5	3,0	4,7	5,5	9,5	8,0	16,0	10,0	10,0	16,0			
	- Reduced values, see 26.2 (P1)					0,8	1,9	0,8	2,2	1,5	2,5	3,0	4,7	5,5	9,5	8,0	16,0	10,0	16,0				
						0,2	1,2	0,5	1,4	1,5	1,6	3,0	3,0	5,5	6,0	8,0	10,0	10,0	16,0				
	b) Distances through insulation between input or output circuits and an earthed metal screen	X	X	X	X	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti				
	c) Distances through insulation between input and output circuits	X	X	X	X	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti				
2) Insulation between input and output circuits (double or reinforced insulation)	a) Creepage distances and clearances between live parts of input circuits and live parts of output circuits	X	X	X	X	0,5	1,4	1,5	2,0	3,0	3,0	3,0	3,0	5,5	6,0	8,0	12,0	14,0	20,0				
						0,8	2,2	1,5	3,2	3,0	4,7	5,5	5,5	8,0	9,5	10,2	14,0	14,0	32,0	32,0			
	- Reduced values, see 26.2 (P1)					0,5	1,4	1,5	2,0	3,0	3,0	3,0	3,0	5,5	6,0	8,0	12,0	14,0	20,0				
	b) Distances through insulation between input or output circuits and an earthed metal screen, see 26.3.	X	X	X	X	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti				
	c) Distances through insulation between input and output circuits, see 26.3.	X	X	X	X	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti	dti				

~~Table 13 (continued)~~

Dimensions in millimetres

		Type of insulation	Measurement		Working voltages ^b V															
					Through-winding-enamel ^a		Other than through-winding-enamel		≥25 ≤50		100		150		300		600		1 000	
					P2	P3	P2	P3	cl	cf	cl	cf	cl	cf	cl	cf	cl	cf	cl	cf
6) Reinforced or double insulation		Between the body and live parts or where it is required by the standard (excluding insulation between input and output windings)			X		0,5	1,4	1,5	2,0	3,0	3,0	3,0	5,5	6,0	8,0	12,0	14,0	20,0	
			X			X	0,8	2,2	1,5	3,2	3,0	4,7	5,5	9,5	8,0	19,2	14,0	32,0		
				X			0,2	1,4	0,5	2,0	1,5	3,0	6,0	5,5	12,0	8,0	20,0			
		Between body and live parts of the output circuit if protected by additional provisions against transient voltages	X		X		0,2	1,4	0,2	2,0	0,5	3,0	1,5	6,0	3,0	12,0	5,5	20,0		
				X		X	0,8	2,2	0,8	3,2	0,8	4,7	9,5	3,0	19,2	5,5	32,0			
							-	0,4	-	0,4	-	0,7	-	1,7	-	4,0	-	7,5		
7) Distance through insulation		a) Basic insulation ^f	X	X	X															
			X			X														
		b) Supplementary insulation ^f	X	X	X															
		c) Reinforced insulation (excluding insulation between input and output circuits)	X	X	X															
NOTE 1 For Material Group II see Annex C and Material Group I see Annex D.																				
NOTE 2 P1 = pollution degree 1 P2 = pollution degree 2 P3 = pollution degree 3																				
NOTE 3 When a numeric figure is replaced by a dash in a column of the Table it means that no value is required																				
NOTE 4 The minimum values of clearance in this table are applicable in air up to 2000 m above sea level:																				
a) Measurement through winding wire enamel if at least one winding is constructed with wire complying with at least grade 1 of IEC 60317.																				
b) Values of creepage distances and clearances and distances through insulation may be found for intermediate values of working voltages by interpolation between the values in the table. No values are required for working voltages below 25 V as the voltage test of Table 8a is considered sufficient.																				
e) These values do not apply:																				
— inside each winding or between groups of windings intended to be permanently connected together, provided that the termination of windings to be connected together are at the same potential,																				
— where the working voltage does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317, if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 110/220 V);																				
d) For solid insulation																				
e) In case of insulation consisting of thin sheets																				
f) When double insulation is required between input and output windings , the total thickness through insulation shall be the same as shown in box 2 c) whether measured directly or via metals parts, with the exception of insulated wires (see 19.12).																				
g) For insulation between SELV circuits and adjacent circuits other than SELV or PELV , the values of this box shall be replaced by the values of boxes 6 and 7 (according to 19.1).																				
In case of a physical breakdown of the basic insulation or supplementary insulation , the thickness of the insulation is added to the clearance.																				

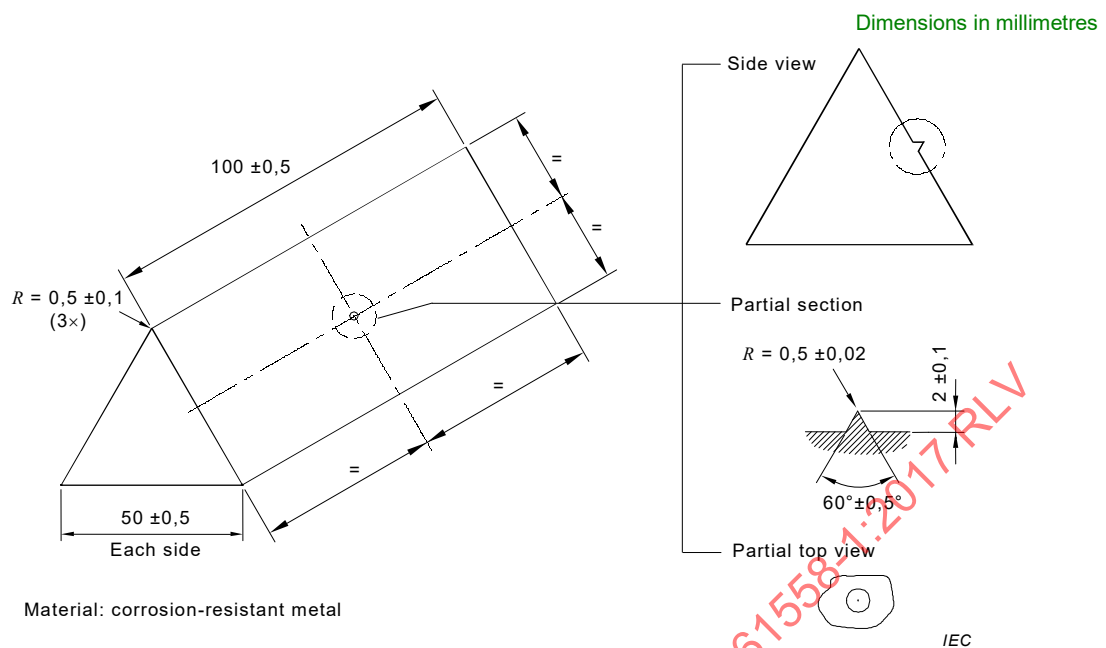


Figure 13a – Mandrel

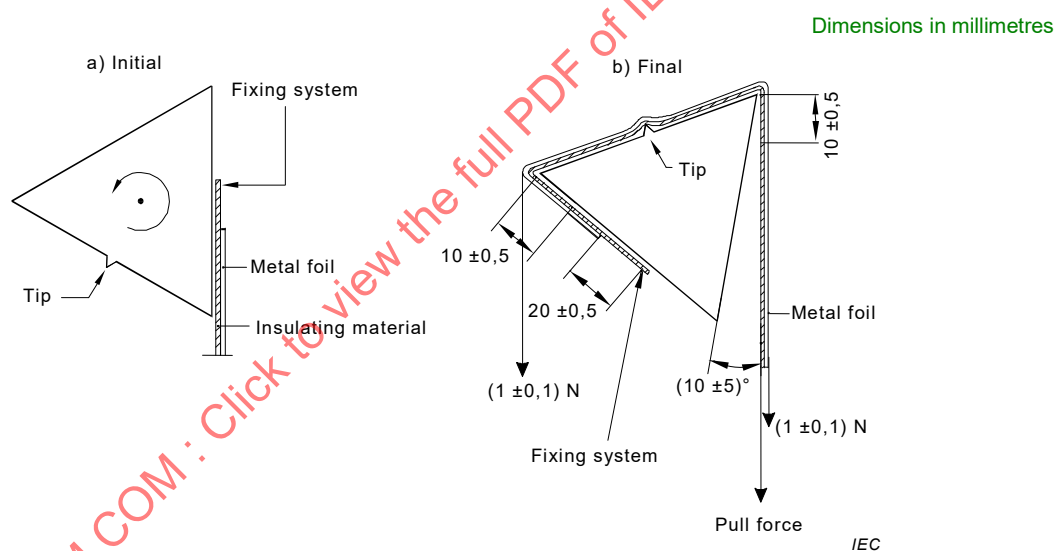


Figure 13b – Position of mandrel

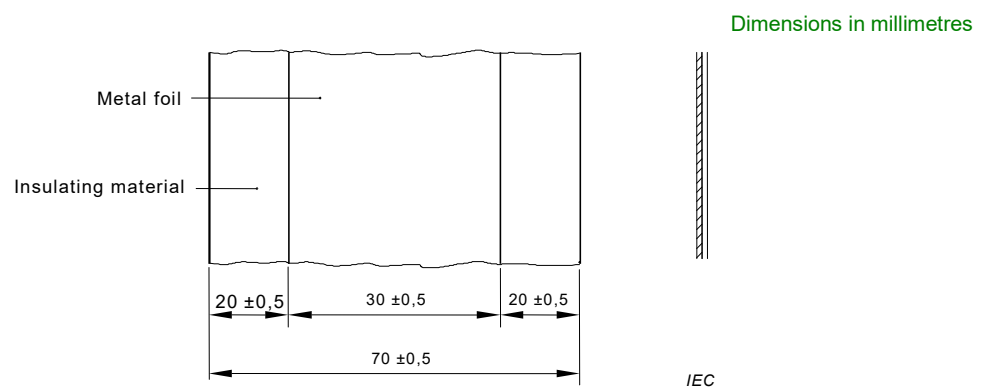


Figure 13c – Position of metal foil on paper

Figure 13 – Test arrangement for checking mechanical withstanding of insulating materials in thin sheet layers

Table 20 – Clearances in mm

Overvoltage category	Insulation of the conductive part	Pollution degree	Working voltage [V]					
			≥ 25 ≤ 50	100	150	300	600	1 000
OVC I	Basic insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,2	0,5	1,5	3,0
		P3	0,8	0,8	0,8	0,8	1,5	3,0
	Supplementary insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,2	0,5	1,5	3,0
		P3	0,8	0,8	0,8	0,8	1,5	3,0
	Double or reinforced insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,5	1,5	3,0	5,5
		P3	0,8	0,8	0,8	1,5	3,0	5,5
OVC II	Basic insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,5	1,5	3,0	5,5
		P3	0,8	0,8	0,8	1,5	3,0	5,5
	Supplementary insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,5	1,5	3,0	5,5
		P3	0,8	0,8	0,8	1,5	3,0	5,5
	Double or reinforced insulation	P1	-	-	-	-	-	-
		P2	0,2	0,5	1,5	3,0	5,5	8,0
		P3	0,8	0,8	1,5	3,0	5,5	8,0
OVC III	Basic insulation	P1	-	-	-	-	-	-
		P2	0,2	0,5	1,5	3,0	5,5	8,0
		P3	0,8	0,8	1,5	3,0	5,5	8,0
	Supplementary insulation	P1	-	-	-	-	-	-
		P2	0,2	0,5	1,5	3,0	5,5	8,0
		P3	0,8	0,8	1,5	3,0	5,5	8,0
	Double or reinforced insulation	P1	-	-	-	-	-	-
		P2	0,5	1,5	3,0	5,5	8,0	14,0
		P3	0,8	1,5	3,0	5,5	8,0	14,0
OVC IV	Basic insulation	P1	-	-	-	-	-	-
		P2	0,5	1,5	3,0	5,5	8,0	14,0
		P3	0,8	1,5	3,0	5,5	8,0	14,0
	Supplementary insulation	P1	-	-	-	-	-	-
		P2	0,5	1,5	3,0	5,5	8,0	14,0
		P3	0,8	1,5	3,0	5,5	8,0	14,0
	Double or reinforced insulation	P1	-	-	-	-	-	-
		P2	1,5	3,0	5,5	8,0	14,0	25,0
		P3	1,5	3,0	5,5	8,0	14,0	25,0

For **functional insulation** no **clearances** are required

Values of **clearances** may not be interpolated between the values in the table.

No values for **clearances** are required for **working voltages** below 25 V AC or 60 V DC as the dielectric strength test of Table 14 is considered sufficient.

These values do not apply:

- inside each winding or between groups of windings intended to be permanently connected together, provided that the termination of windings to be connected together are at the same potential,
- where the **working voltage** does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317 (all parts), if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 115 / 230 V).

For insulation between **SELV circuits** and adjacent **circuits** other than **SELV** or **PELV**, the insulation shall fulfil the requirements of **double or reinforced insulation** (according to 19.1).

NOTE 1 When a numeric figure is replaced by a dash in a column of the table it means that no value is required

NOTE 2 P1 = **pollution degree** 1; P2 = **pollution degree** 2; P3 = **pollution degree** 3.

NOTE 3 The minimum values for **clearances** in this table are applicable in air up to 2 000 m above sea level. For higher values use IEC 60664-1:2007 Table A.2

Table 21 – Creepage distances in mm

Material group (CTI-value)	Insulation of the conductive part	Pollution degree	Working voltage [V]					
			≥ 25 ≤ 50	100	150	300	600	1 000
I (CTI ≥ 600)	Basic insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	0,6	0,7	0,8	1,5	3,0	5,5
		P3	1,5	1,8	2,0	3,9	7,7	12,5
	Supplementary insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	0,6	0,7	0,8	1,5	3,0	5,5
		P3	1,5	1,8	2,0	3,9	7,7	12,5
	Double or reinforced insulation	P1	0,25	0,4	0,7	1,7	4,0	7,5
		P2	0,7	1,0	1,6	3,0	6,0	10,0
		P3	1,8	2,5	4,2	7,7	16,0	25,0
II ($400 \leq \text{CTI} < 600$)	Basic insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	0,9	1,0	1,1	2,1	4,3	7,1
		P3	1,7	2,0	2,2	4,2	8,6	14,0
	Supplementary insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	0,9	1,0	1,1	2,1	4,3	7,1
		P3	1,7	2,0	2,2	4,2	8,6	14,0
	Double or reinforced insulation	P1	0,25	0,4	0,7	1,7	4,0	7,5
		P2	1,0	1,4	2,0	4,3	8,6	14,0
		P3	2,0	2,8	4,2	8,6	17,2	28,0
IIIa ($175 \leq \text{CTI} < 400$)	Basic insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	1,2	1,4	1,6	3,0	6,0	10,0
		P3	1,9	2,2	2,5	4,7	9,5	16,0
	Supplementary insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	1,2	1,4	1,6	3,0	6,0	10,0
		P3	1,9	2,2	2,5	4,7	9,5	16,0
	Double or reinforced insulation	P1	0,25	0,4	0,7	1,7	4,0	7,5
		P2	1,4	2,0	3,0	6,0	12,0	20,0
		P3	2,2	3,0	4,7	9,5	19,2	32,0
IIIb ($100 \leq \text{CTI} < 175$)	Basic insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	1,2	1,4	1,6	3,0	6,0	10,0
		P3	1,9	2,2	2,5	4,7	9,5	16,0
	Supplementary insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	1,2	1,4	1,6	3,0	6,0	10,0
		P3	1,9	2,2	2,5	4,7	9,5	16,0
	Double or reinforced insulation	P1	0,36	0,5	0,7	1,7	4,0	7,5
		P2	2,4	2,8	3,2	6,0	12,0	20,0
		P3	3,8	4,4	5,0	9,5	19,2	32,0

For **functional insulation** no **creepage distance** values are required.

Values of **creepage distances** may be found for intermediate values of **working voltages** by linear interpolation between the values in the table.

No values for **creepage distances** are required for **working voltages** below 25 V AC or 60 V DC as the dielectric strength test of Table 14 is considered sufficient.

These values do not apply:

- inside each winding or between groups of windings intended to be permanently connected together, provided that the termination of windings to be connected together are at the same potential,
- where the **working voltage** does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317 (all parts), if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 115 / 230 V).

For insulation between **SELV circuits** and adjacent **circuits** other than **SELV** or **PELV**, the insulation shall fulfil the requirements of **double or reinforced insulation** (according to 19.1).

NOTE 1 When a numeric figure is replaced by a dash in a column of the table it means that no value is required.

NOTE 2 P1 = **pollution degree 1** P2 = **pollution degree 2** P3 = **pollution degree 3**.

Creepage distances shall not become less than the **clearances**.

Material group IIIb ($100 \leq \text{CTI} < 175$) is not recommended for application in **pollution degree 3** above 630 V

An explanation for the determination of the comparative tracking indices (CTI) defined in IEC 60112 is given in Annex G.

Table 22 – Distance through insulation in mm

Insulation of the conductive part		Working voltage [V]					
		≥ 25 ≤ 50	100	150	300	600	1 000
Basic insulation	solid	-	-	-	-	-	-
	thin layers	-	-	-	-	-	-
Supplementary insulation	solid	0,1	0,15	0,25	0,5	0,75	1,0
	thin layers	0,05	0,05	0,08	0,15	0,2	0,25
Double or reinforced insulation	solid	0,2	0,3	0,5	1,0	1,5	2,0
	thin layers	0,1	0,1	0,15	0,3	0,4	0,5

For **functional insulation** no distance through insulation (DTI) is required.

Values of distance through insulation (DTI) may be found for intermediate values of **working voltages** by linear interpolation between the values in the table.

No values for distances through insulation are required for **working voltages** below 25 V AC or 60 V DC as the dielectric strength test of Table 14 is considered sufficient.

These values do not apply:

- inside each winding or between groups of windings intended to be permanently connected together, provided that determination of windings to be connected together are at the same potential,
- where the **working voltage** does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317 (all parts), if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 115 / 230 V).

For insulation between **SELV circuits** and adjacent **circuits** other than **SELV** or **PELV**, the insulation shall fulfil the requirements of **double or reinforced insulation** (according to 19.1).

NOTE 1 When a numeric figure is replaced by a dash in a column of the table it means that no value is required

When **double insulation** is required between **input** and **output windings**, the total thickness through insulation shall be measured directly or via metals parts, with the exception of insulated wires (see 19.12).

NOTE 2 In case of a physical breakdown of the **basic insulation** or **supplementary insulation**, the thickness of the insulation is added to the **clearance**.

A reduction of these values is allowed in the case of different layers according to clause 26.3.3.

Table 23 – Creepage distances and clearance between terminals for external connection

	Current values [A]	Working voltage [V]					
		≥ 25 ≤ 50	100	150	300	600	1 000
Creepage distances and clearance between terminals or the connection of external cables and cords excluding those between screw terminals for input and for output	≤ 6	3,0	3,6	4,0	6,0	9,0	12,5
	> 6 and ≤ 16	5,0	6,0	7,0	10,0	13,0	16,0
	> 16	10,0	11,0	12,0	14,0	17,0	20,0
NOTE 1 Values of clearances and creepage distances may be found for intermediate values of working voltages by linear interpolation between the values in the table. NOTE 2 No values for clearances are required for working voltages below 25 V AC or 60 V DC as the dielectric strength test of Table 14 is considered sufficient. These values do not apply: – inside each winding or between groups of windings intended to be permanently connected together, provided that the termination of windings to be connected together are at the same potential; – where the working voltage does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317 (all parts), if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 115 / 230 V). For insulation between SELV circuits and adjacent circuits other than SELV or PELV, the insulation shall fulfil the requirements of double or reinforced insulation (according to 19.1).							

26.3.5 For transformers with FIW wires the following test is required:

To test the FIW-winding at the final transformer, three specimens shall be used. The specimens shall be subjected 10 times to the following sequence of temperature cycles:

68 h at the highest winding temperature ± 2 °C measured in normal use plus 10 K with a minimum of 85 °C;

1 h at (25 ± 2) °C;

2 h at (0 ± 2) °C;

1 h at (25 ± 2) °C.

During each thermal cycling test, a test voltage of 500 V or the working voltage, whichever is the higher value, at 50 Hz or 60 Hz shall be applied to the specimens between the windings where the reduced values apply.

Two of the three specimens are then subjected to the humidity treatment of 17.2 (48 h treatment) and the relevant dielectric strength test of 18.3.

One of the three specimens shall be subjected to the relevant dielectric strength test of 18.3 immediately at the end of the last period at highest temperature during the thermal cycling test.

The partial discharge test shall be done at the end of the cycling test at normal room temperature as performed in 18.3.1.

NOTE The minimal value depends on the of diameter increase at the temperature of 180°C. The voltage values are valid for all diameters of the FIW grade. The specimen has to withstand the dielectric strength test voltage for at least 60 s.

The values of allowed voltage strength for other **FIW** dimensions than defined in Table 24 are calculated according following formula:

$$U_s = (d_o - d_{Cu}) \times U_b \times 0,85 \times 10^3 \quad (6)$$

where

d_o is the minimum overall diameter [mm];

d_{Cu} is the nominal conductor diameter (copper diameter) [mm];

U_b is the minimum characteristic breakdown voltage [V/μm];

U_s is the allowed dielectric strength voltage for FIW [V] (duration of 60 s).

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Table 24 – Values of FIW wires with minimum overall diameter and minimum test voltages according to the total enamel increase

Nominal conductor diameter d_{Cu} [mm]	Minimum specific breakdown voltage ^a U_b [V/μm]	Minimum overall FIW diameter d_o [mm]								Minimum dielectric strength test voltage values per wire for basic or reinforced insulation at overall diameter U_s [V] (duration of 60 s)							
		Grade of FIW 3	Grade of FIW 4	Grade of FIW 5	Grade of FIW 6	Grade of FIW 7	Grade of FIW 8	Grade of FIW 9	Grade of FIW 3	Grade of FIW 4	Grade of FIW 5	Grade of FIW 6	Grade of FIW 7	Grade of FIW 8	Grade of FIW 9		
0,04	56	0,055	0,059	0,070	0,080	0,090	0,100		714	904	1 428	1 904	2 380	2 856			
0,045	56	0,062	0,067	0,079	0,090	0,101	0,112		809	1 047	1 618	2 142	2 666	3 189			
0,05	56	0,067	0,073	0,084	0,095	0,106	0,117		809	1 095	1 618	2 142	2 666	3 189			
0,056	56	0,075	0,082	0,093	0,105	0,117	0,129		904	1 238	1 761	2 332	2 904	3 475			
0,063	56	0,084	0,090	0,103	0,116	0,129	0,142		1 000	1 285	1 904	2 523	3 142	3 760			
0,071	56	0,092	0,098	0,111	0,124	0,137	0,150	0,163	1 000	1 285	1 904	2 523	3 142	3 760	4 379		
0,08	56	0,102	0,109	0,123	0,137	0,151	0,165	0,179	1 047	1 380	2 047	2 713	3 380	4 046	4 712		
0,09	56	0,114	0,121	0,135	0,149	0,163	0,177	0,191	1 142	1 476	2 142	2 808	3 475	4 141	4 808		
0,1	56	0,126	0,133	0,149	0,165	0,181	0,197	0,213	1 238	1 571	2 332	3 094	3 856	4 617	5 379		
0,112	53	0,140	0,148	0,165	0,182	0,199	0,216	0,233	1 261	1 622	2 388	3 154	3 919	4 685	5 451		
0,125	53	0,155	0,164	0,182	0,200	0,218	0,236	0,254	1 352	1 757	2 568	3 379	4 190	5 001	5 811		
0,14	53	0,172	0,182	0,202	0,222	0,242	0,262	0,282	1 442	1 892	2 793	3 694	4 595	5 496	6 397		
0,16	53	0,195	0,206	0,228	0,250	0,272	0,294	0,316	1 577	2 072	3 063	4 055	5 046	6 037	7 028		
0,18	53	0,218	0,230	0,254	0,278	0,302	0,326	0,350	1 712	2 253	3 334	4 415	5 496	6 577	7 659		
0,2	53	0,240	0,253	0,278	0,303	0,328	0,353	0,378	1 802	2 388	3 514	4 640	5 766	6 893	8 019		
0,224	53	0,267	0,281	0,308	0,335	0,362	0,389	0,416	1 937	2 568	3 784	5 001	6 217	7 433	8 650		
0,25	53	0,298	0,313	0,343	0,373	0,403	0,433	0,463	2 162	2 838	4 190	5 541	6 893	8 244	9 596		
0,28	53	0,330	0,346	0,377	0,408	0,439	0,470	0,501	2 253	2 973	4 370	5 766	7 163	8 560	9 956		
0,315	53	0,368	0,385	0,416	0,447	0,478	0,509	0,540	2 388	3 154	4 550	5 947	7 343	8 740	10 136		
0,355	53	0,412	0,429	0,460	0,491	0,522	0,553	0,584	2 568	3 334	4 730	6 127	7 523	8 920	10 316		
0,4	49	0,460	0,479	0,510	0,541	0,572	0,603		2 499	3 290	4 582	5 873	7 164	8 455			
0,45	49	0,514	0,534	0,565	0,596	0,627	0,658		2 666	3 499	4 790	6 081	7 372				
0,5	49	0,567	0,588	0,629	0,670	0,711			2 791	3 665	5 373	7 081	8 788				

^a Value according to Table 7 of IEC 60317-0-7:2012

27 Resistance to heat, fire and tracking

27.1 General

For components previously tested in accordance with their relevant IEC standards, the requirements and tests having the same level of severity as the requirements and tests of this document, the following tests may be omitted.

27.2 Resistance to heat

27.2.1 General

All parts of the **transformer** made of insulating material shall be resistant to heat.

The following tests do not apply to parts made of natural or synthetic rubber that shall be tested according to 19.9. Additionally the tests do not apply to parts made of ceramic material.

Compliance is checked by subjecting parts made of insulating materials to a ball-pressure test according to 27.2.2 and 27.2.3 as appropriate by means of the apparatus shown in Figure 14.

The test is not carried out for cables and small connectors with a rated current ≤ 3 A and a rated voltage ≤ 24 V AC or ≤ 60 V DC and a power not exceeding 72 W.

The test shall be performed in a heating cabinet at a temperature specified below.

NOTE Details of the ball pressure test procedure are described in IEC 60695-10-2.

The surface of the part to be tested shall be placed in a horizontal position and a steel ball of $(5 \pm 0,05)$ mm diameter shall be pressed against the surface with a force of $(20 \pm 0,2)$ N.

After 1 h, the ball is removed from the specimen, and the specimen is cooled down, within 10 s, to approximately ambient temperature by immersion in cold water. The diameter of the impression caused by the ball is measured and shall not exceed 2 mm.

Dimensions in millimetres

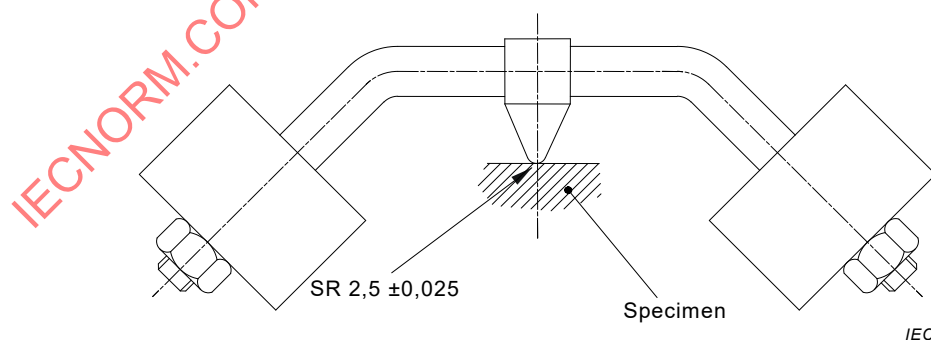


Figure 14 – Ball-pressure apparatus

27.2.2 External accessible parts

External accessible parts of insulating materials shall be resistant to heat.

Compliance is checked by the following test.

The test is carried out at a temperature of $(70 \pm 2) ^\circ\text{C}$, or at a temperature of $(T + 15 \pm 2) ^\circ\text{C}$ where T is the temperature of the relevant part during the test of 14.1, whichever is higher.

*The temperature of the relevant part shall be measured at the hottest point, normally, occurring inside the **enclosure**.*

NOTE The constant $15 ^\circ\text{C}$ is the safety margin.

27.2.3 Internal parts

Internal parts of insulating material retaining current carrying parts in position shall be resistant to heat.

Compliance is checked by the following test.

The test shall be performed at a temperature of $(125 \pm 2) ^\circ\text{C}$, or at a temperature of $(T + 15 \pm 2) ^\circ\text{C}$ where T is the temperature of the relevant part during the test of 14.1, whichever is higher.

NOTE 1 The constant $15 ^\circ\text{C}$ is the safety margin.

NOTE 2 The test is not conducted on parts of ceramic material, bobbins, or glass.

27.3 Resistance to abnormal heat under fault conditions

~~The insulation system of the transformers under fault conditions shall not act as a source of ignition, result in breakdown of the insulation between the windings, and for transformers with protection index IP 20 or higher, hazardous life parts shall not be accessible.~~

27.3.1 Transformers with protection index IP20 or higher, under fault conditions, shall not act as a source of ignition, and the insulation between the windings shall not result in breakdown; moreover, **hazardous-live-parts** shall not be accessible.

*Compliance is checked by the tests of 27.3.2 and 27.3.3. This test is not required on **fail-safe transformers** as they are covered by 15.5.*

For this test, one or two additional specially prepared specimens is (are) required. A short-circuit in the winding(s) shall either be built in, or made possible by short-circuiting the leads connected to the winding(s) provided by the manufacturer.

If the **transformer** is provided with a thermal protective device in the **input circuit**, the short-circuit shall be introduced in the **output winding** and vice versa.

If the **transformer** is provided with a thermal protective device in both the **input** and **output circuits**, the short-circuit shall be introduced in each winding in two separate specimens.

The short-circuit shall be made in the middle of the winding. In case of more than two windings, the short-circuit shall be introduced in the winding being thermally farthest away from the thermal control.

The percentage of turns to be short-circuited shall be approximately equal to the **short-circuit voltage** expressed as a percentage of the **rated supply voltage**. The specimen with the short-circuit shall then be checked as follows.

*The unloaded **transformer** shall be supplied at 1,1 times the **rated input voltage** at ambient temperature and the input power (W) measured shall be equal to the value of the **rated output** with a tolerance of $\pm 20\%$. During the measurement, no adjustments shall be made.*

27.3.2 Portable transformers shall be placed on a dull black painted plywood support as described in 14.1.1.

Stationary transformers, not designed to be built in, shall be mounted in the most unfavourable position under normal use to a dull black painted plywood support as described in 14.1.1. When the most unfavourable position of use is vertical or on the ceiling, the **stationary transformer** and the support are placed in this position (200 ± 5) mm above a piece of white pinewood board, approximately 10 mm thick, covered with a single layer of tissue paper.

For this test, the **input circuit** shall be protected by a fuse or circuit-breaker with a rated current 10 times the rated current of the **transformer**, but at least 16 A.

The **transformer**, with its protective devices when applicable, shall be tested as specified above for 15 days but without load. The result shall be a definitive interruption in the circuit. If no definitive interruption occurs after this period, the supply is switched off.

For **transformers** with self-resettable protective devices, all the protective devices are short-circuited.

If the non-self-resettable or replaceable protective device, if any, interrupts the circuit, the supply shall be switched off and the **transformer** shall be left to cool down for 2 h. Then the protective device shall be reset or replaced, and the supply shall be switched on until the device interrupts the circuit or an interruption in the **transformer** occurs. If no interruption in the **transformer** occurs, 30 cycles shall be conducted in the case of resettable protective devices, or 10 cycles in the case of replaceable devices. Each cycle consists of supplying the **transformer** until the protective device interrupts the circuit and the power remains switched off for 2 h.

During the test, no flames shall occur, and the **transformer** shall not act as a source of ignition for the surroundings. The temperature of the support shall not exceed 125 °C. If **stationary transformers** are placed in a vertical position or on the ceiling, burning drops, if any, shall not ignite the tissue paper or scorch the pinewood board.

27.3.3 After the test of 27.3.2 and after cooling down to ambient temperature, the following applies.

- a) **Transformers** where a definitive interruption in the **input circuit** has occurred shall withstand a dielectric strength test, the test voltage being 35 % of the values according to Table 14 of Clause 18.
- b) **Transformers** where no definitive interruption has occurred after the cycling test shall withstand the test voltages according to Table 14 of Clause 18.

Transformers with protection index IP20 and higher shall not allow the standard test finger to touch **hazardous-live-parts** without appreciable force. In case of doubt, contact with **hazardous-live-parts** is shown by means of an electrical contact indicator, the voltage being not less than 40 V. If one specimen does not pass the test, the complete test has failed.

27.4 Resistance to fire

27.4.1 General

All parts of the **transformer** made of insulating material shall be resistant to ignition and spread of fire.

This requirement does not apply to decorative trims, knobs and other parts not likely to be ignited or to propagate flames originating from inside the **transformer**.

Compliance is checked by subjecting parts made of insulating materials to the glow-wire test, specified in IEC 60695-2-10 and amended in Annex E of this document.

The test shall be performed on a complete **transformer**. If this is not possible, a suitable specimen of the part to be tested shall be used.

If necessary, parts of an **enclosure** can be removed or a suitable specimen can be cut off to perform the test. However, care shall be taken to ensure that the standard test conditions are not significantly different from those occurring in normal use, with regard to shape, ventilation, effects of thermal stresses and of possible flames, burning droplets or glowing particles falling in the vicinity of the specimen.

Any flame or glowing of the specimen shall extinguish within 30 s of withdrawing the glow-wire. Burning or molten drops, if any, shall not ignite the tissue paper, as specified in IEC 60695-2-10:2013 (ISO 4046-4:2016), spread out horizontally as a single layer (200 ± 5) mm below the specimen.

Only one specimen shall be tested. In case of inconclusive results, the test is repeated on two additional specimens and both shall pass the test.

27.4.2 External accessible parts

External parts of insulating materials shall be resistant to ignition and spread of fire.

Compliance is checked by subjecting **enclosures** and other external **accessible parts** to the glow-wire test with the temperature of the glow wire as follows:

- 650 °C for **enclosures**;
- 650 °C for parts retaining current carrying (keeping in position) parts in position and terminals for external conductors which carry a current up to 0,2 A during normal operation;
- 750 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors with fixed connection (e.g., soldering) which carry a current exceeding 0,2 A during normal operation;
- 850 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors with non-fixed connection which carry a current exceeding 0,2 A during normal operation.

No glow wire tests are required for foils in thin sheet form with a thickness of up to 0,2 mm.

27.4.3 Internal parts

Parts of insulating materials retaining (keeping in position) current carrying parts in position shall be resistant to ignition and spread of fire.

Compliance is checked by subjecting the parts of insulating materials to the glow-wire test with the temperature of the glow wire as follows:

- 550 °C for internal insulating material not retaining (not keeping in position) current carrying parts in position;
- 650 °C for coil formers (bobbins);
- 650 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors which carry a current up to 0,2 A during normal operation;
- 750 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors with fixed connection (e.g., soldering) which carry a current exceeding 0,2 A during normal operation;

- 850 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors with non fixed connection which carry a current exceeding 0,2 A during normal operation.

No glow wire tests are required for foils in thin sheet form with a thickness of up to 0,2 mm.

27.5 Resistance to tracking

For **transformers** with an IP rating other than IPX0, insulating parts retaining current carrying parts in position shall have resistance to tracking corresponding to at least material group IIIa if they are exposed to pollution degree 3.

Material group IIIb ($100 \leq \text{CTI} < 175$) is not recommended for application in pollution degree 3 above 630 V

For materials other than ceramics, compliance is checked by the tests of Annex G.

No flashover or breakdown between electrodes shall occur before a total of 50 drops has fallen.

28 Resistance to rusting

Ferrous parts, the rusting of which might cause the **transformer** to become unsafe, shall be adequately protected against rusting.

NOTE This requirement applies to the outer surfaces of iron cores, in which case, protection by a coating of varnish is deemed to be adequate.

Compliance is checked by inspection and, in case of doubt, by the following test.

All grease shall be removed from the parts to be tested by immersion in trichloroethane for 10 min. The parts shall then be immersed for 10 min in a 10 % solution of ammonium chloride in water at a temperature of $(20 \pm 5) ^\circ\text{C}$. Without drying, but after shaking off any drops, the parts shall be placed for 10 min in a box containing air saturated with moisture at a temperature of $(20 \pm 5) ^\circ\text{C}$.

After all the parts have been dried for 10 min in a heating cabinet at a temperature of $(100 \pm 5) ^\circ\text{C}$; their surfaces shall show no signs of rust.

NOTE Traces of rust on sharp edges and any yellowish film removable by rubbing are ignored.

Annex A (normative)

Measurement of creepage distances and clearances

The widths X of grooves specified in Figure A.1 to Figure A.8 apply to all examples as a function of the **pollution degree** as follows:

Table A.1 – Width of groove values depending on the pollution degree

Pollution degree	Width X of grooves' minimum values mm
1	0,25
2	1,0
3	1,5

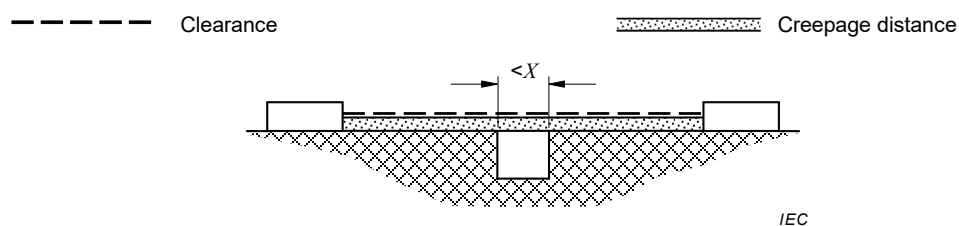
NOTE If the associated **clearance** is less than 3 mm, the minimum groove width ~~may~~ can be reduced to one-third of this distance.

The dimension X , specified in the examples A.1 to A.8 has a minimum value depending on the pollution degree according to Table A.1.

The methods of measuring **creepage distances** and **clearances** are indicated in Figure A.1 to Figure A.8. These cases do not differentiate between gaps and grooves or between types of insulation.

The following assumptions are made:

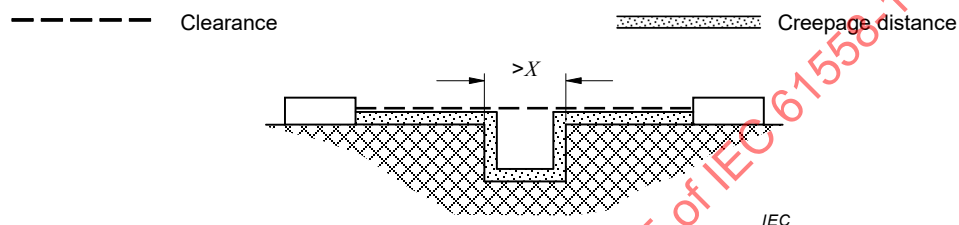
- any recess is assumed to be bridged with an insulating link having a length equal to the specified width X and being placed in the most unfavourable position (see Figure A.3);
- where the distance across a groove is equal to or larger than the specified width X , the **creepage distance** is measured along the contours of the groove (see Figure A.2);
- **creepage distances** and **clearances**, measured between parts which can assume different positions in relation to each other, are measured when these parts are in their most unfavourable position.



Condition: Path under consideration includes a parallel or converging sided groove of any depth with a width of less than X mm.

Rule: **Creepage distance** and **clearance** are measured directly across the groove as shown above.

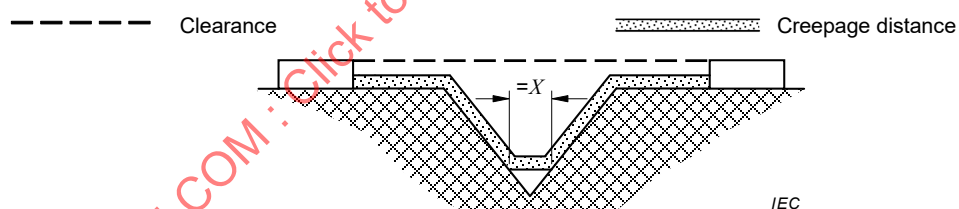
Figure A.1 – Example 1



Condition: Path under consideration includes a parallel sided groove of any depth and equal to or more than X mm wide.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove.

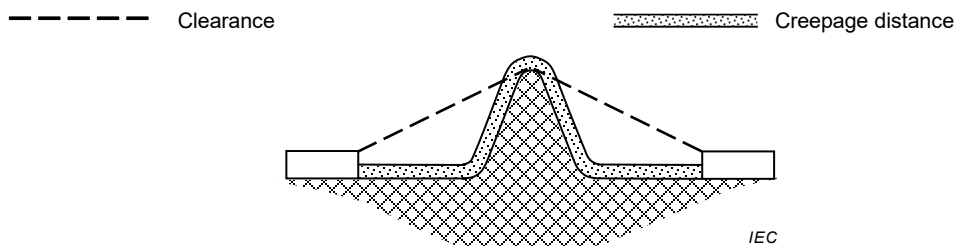
Figure A.2 – Example 2



Condition: Path under consideration includes a V-shaped groove with an internal angle of less than 80° and 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 a length of X mm.

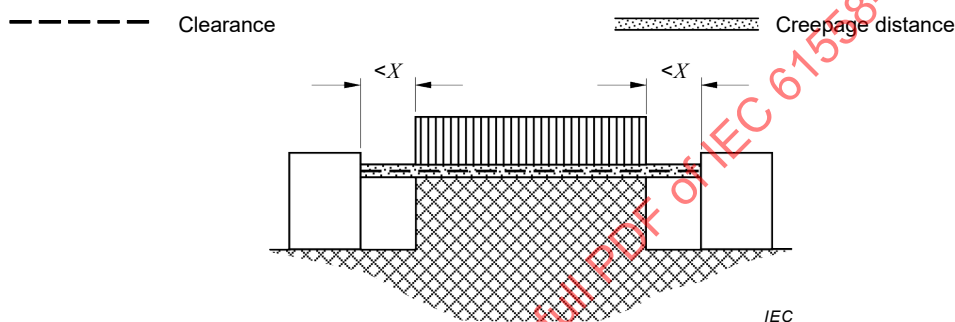
Figure A.3 – Example 3



Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib.

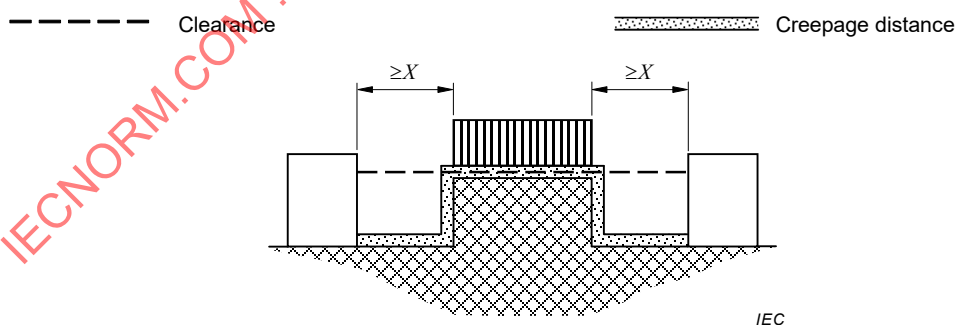
Figure A.4 – Example 4



Condition: Path under consideration includes an uncemented joint with grooves less than X mm wide on either side.

Rule: Creepage distance and clearance path is the "line of sight" distance shown.

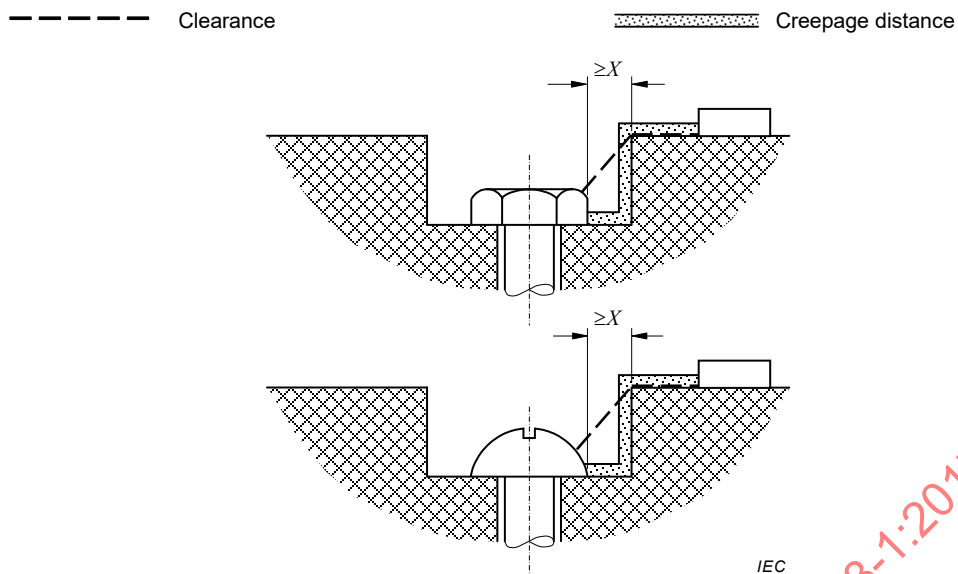
Figure A.5 – Example 5



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm wide on each side.

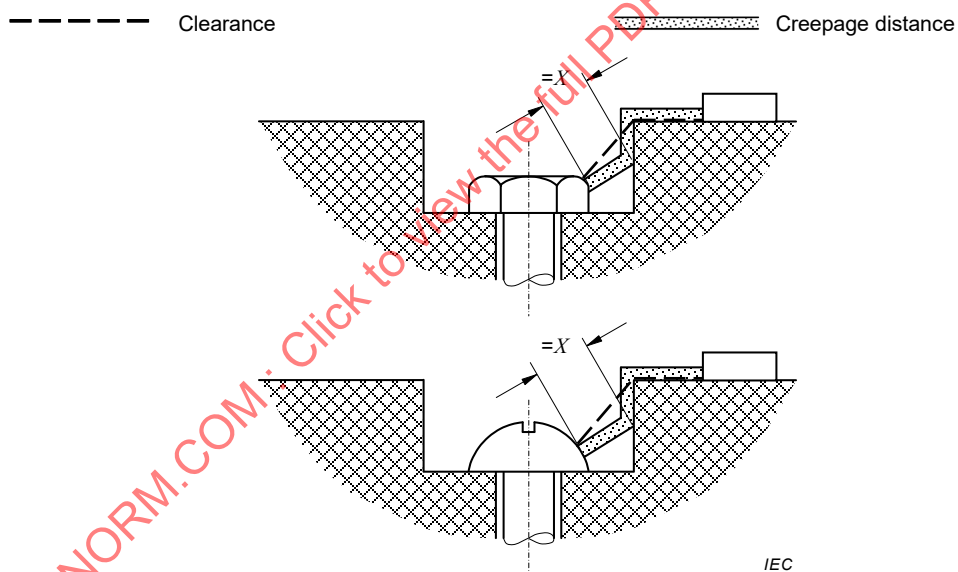
Rule: Clearance path is the "line of sight" distance. Creepage follows the contour of the groove.

Figure A.6 – Example 6



Gap between head of screw and wall of recess wide enough to be taken into account.

Figure A.7 – Example 7



Gap between head of screw and wall of recess too narrow to be taken into account.

Figure A.8 – Example 8

Annex B (normative)

Testing a series of transformers

B.1 General

The requirements of this annex are intended to facilitate the testing of a series of **transformers**.

If a series of **transformers** is to be tested, the number of samples to be tested may be reduced.

Transformers can be considered as a series if:

- a) they are of the same family, this meaning that they are covered by the same part of IEC 61558-2;
- b) they are of the same construction, implying that:
 - 1) they have lamination or core from the same pattern range and made of the same material,
 - 2) the same type of winding technology has been used (for example concentric or two chambers, same insulation system),
 - 3) the same assembling technology has been used (for example open type, enclosed type, encapsulated type, impregnated, potted, etc.),
 - 4) the same type of protection against overload has been used (for example fuses, **thermal cut-out**, etc.),
 - 5) they are of the same frequency range;
- c) they are designed for the same minimum and maximum ambient temperatures.

Variations in the following parameters are permitted, provided that the **transformers** comply in all other respects with the rules detailed above:

- input voltage range;
- output voltage range;
- number of tapping and/or windings;
- supply frequency in the declared frequency range;
- **rated output**.

B.2 Requirements

The number of samples needed in case of testing a series of **transformers** as defined above shall be:

- a) for parameters 1) 2) and 3): two samples minimum and not more than four, chosen in order to be sure that they represent the most unfavourable situation in the family to be tested;

NOTE The samples should be chosen according to the following rules:

- one of the lowest rated output, with the highest voltages and the lowest number of tappings;
- one of the highest rated output, with the lowest voltages and the lowest number of tappings;

- one of the lowest rated output, with the highest number of tapplings with the highest voltage difference between adjacent windings;
- one of the medium rated output, with medium voltages and medium number of tapplings;
- one of the highest rated output, with the lowest voltages and the highest number of windings.

When only two samples are chosen the first two alternatives should be used.

- b) for parameter 4): one sample of the lowest supply frequency and, in case of doubt, one sample of the highest supply frequency within the range;

NOTE If possible, the sample may be the second sample chosen for parameters 1), 2) and 3).

- c) for parameter 5): two samples minimum, taken from the extremities of the range.

NOTE The samples should be chosen according to the following rules:

- one of the lowest rated output, with the highest difference in percentage between the value of the current of the transformer and the value of the current of the relevant protective device, if any;
- one of the highest rated output, with the highest difference in percentage between the value of the current of the transformer and the value of the current of the relevant protective device, if any;
- one sample representing the most unfavourable condition of the temperature of winding and core;
- one sample representing the most unfavourable condition of the temperature rise of the enclosure.

To be sure that in any case the most unfavourable situation is covered, the manufacturer shall declare the type in the series having the maximum losses in normal condition; this type shall be chosen as one of the samples to be tested.

The conditions above may be covered by a minimum of two samples.

The number of specimens for each sample shall be in accordance with 5.2, except for:

- the test of 14.3 where only two samples of three specimens in total are needed for the series, the samples being the two first of parameter 5;
- the test of 15.5 where only two samples of three specimens in total are needed for the series, the samples being the two first of parameter 5;
- the test of 16.4 where only three specimens in total are needed for the series, the heaviest type being chosen.

B.3 Constructional inspection

At least one specimen of each lamination or core size shall be provided for constructional clearances, mechanical strength, etc.

NOTE The samples required in B.3 shall include the samples used in B.2.

Creepage distances (cr), clearances (cl) and distances through insulation (dti)
Material group II (400 ≤ CTI ≤ 600)

~~NOTE The following table extends over several pages. For notes and footnotes, please see the final page of the table.~~

Dimensions in millimetres

		Measurement		Working voltages ^{b)-} V													
	Type of insulation	Through winding enamel ^{a)}		Other than through-winding enamel		≥25		100		150		300		600		1-000	
		P2	P3	P2	P3	cl	cf	cl	cf	cl	cf	cl	cf	cl	cf	cl	cf
1) Insulation between input and output circuits-(basic insulation)	a) Creepage distances and clearances between live parts of input circuits and live parts of output circuits	X		X		0,2	0,85	0,5	1,0	1,5	3,0	3,0	5,5	5,5	8,0	8,0	8,0
						0,8	1,7	0,8	2,0	2,2	3,0	4,2	5,5	8,6	14,0	14,0	14,0
		X				0,2	0,85	0,2	1,0	1,1	1,5	2,1	3,0	4,3	5,5	7,1	7,1
			X			0,8	1,7	0,8	2,0	2,2	1,5	4,2	3,0	8,6	14,0	14,0	14,0
	Reduced values, 26.2 (P1)					-	0,18	-	0,25	0,3	-	0,7	-	1,7	-	3,2	3,2
						dti		dti		dti		dti		dti		dti	
	b) Distances through insulation between input or output circuits and an earthed metal screen	X	X	X	X												
	c) Distances through insulation between input and output circuits	X	X	X	X												
						No requirements of thickness											
						No requirements of thickness											
2) Insulation between input and output circuits (double or reinforced insulation)	a) Creepage distances and clearances between live parts of input circuits and live parts of output circuits	X		X	X	0,5	1,0	1,5	1,5	3,0	5,5	5,5	8,0	8,6	14,0	14,0	14,0
				X		0,8	2,0	1,5	2,8	4,2	8,6	8,6	8,0	17,2	14,0	28,0	28,0
		X				0,2	1,0	0,5	1,4	2,0	4,3	4,3	5,5	8,6	8,0	14,0	14,0
			X			0,8	2,0	0,8	2,8	4,2	3,0	8,6	5,5	17,2	8,0	28,0	28,0
	Reduced values, see 26.2 (P1)					-	0,25	-	0,4	0,7	-	1,7	-	4,0	-	7,5	7,5
						dti		dti		dti		dti		dti		dti	
	b) Distances through insulation between input or output circuits and an earthed metal screen, see 26.3	X	X	X	X	0,1 ^{d)}	-[0,05] ^{e)}	0,2 ^{d)}	-[0,07] ^{e)}	0,25 ^{d)}	-[0,08] ^{e)}	0,5 ^{d)}	-[0,19] ^{e)}	0,7 ^{d)}	1,0 ^{d)}	-[0,25] ^{e)}	-[0,25] ^{e)}
						-[0,05] ^{e)}		-[0,07] ^{e)}		-[0,08] ^{e)}		-[0,16] ^{e)}		-[0,19] ^{e)}		-[0,25] ^{e)}	-[0,25] ^{e)}
	c) Distances through insulation between input and output circuits, see 26.3	X	X	X	X	0,2 ^{d)}	-[0,1] ^{e)}	0,3 ^{d)}	-[0,1] ^{e)}	0,5 ^{d)}	1,0 ^{d)}	1,5 ^{d)}	4,5 ^{d)}	2,0 ^{d)}	2,0 ^{d)}	-[0,5] ^{e)}	-[0,5] ^{e)}
						-[0,1] ^{e)}		-[0,1] ^{e)}		-[0,15] ^{e)}		-[0,3] ^{e)}		-[0,4] ^{e)}		-[0,5] ^{e)}	-[0,5] ^{e)}

Table C.1 (continued)

	Type of insulation	Measurement				Working voltages ^b V											
		Through winding enamel ^a		Other than through winding enamel		≥25 ≤50		100		150		300		600		1 000	
		P2	P3	P2	P3	cl	cf	cl	cf	cl	cf	cl	cf	cl	cf	cl	cf
3) Insulation between adjacent input circuits or insulation between adjacent output circuits ^{c,g}	Creepage distances and clearances	X		X		0,2	0,85	0,2	1,0	0,2	1,1	0,5	2,1	1,5	4,3	3,0	7,1
			X		X	0,8	1,7	0,8	2,0	0,8	2,2	0,8	4,2	1,5	8,6	3,0	14,0
4) Creepage distances and clearances between terminals for the connection of external cables and cords excluding those between screw terminals	Reduced values see 26.2 (P1)					–	0,18	–	0,25	–	0,3	–	0,7	–	1,7	–	3,2
		X	X	X	X	3,0	3,0	3,6	3,6	4,0	4,0	6,0	6,0	9,0	9,0	12,5	12,5
5) Basic or supplementary insulation^h	a) Up to and including 6 A	X	X	X	X												
	b) Over 6 A up to and including 16 A	X	X	X	X			6,0		7,0		10,0		13,0		16,0	
	c) Over 16 A	X	X	X	X			11,0		12,0		14,0		17,0		20,0	
Between: a) live parts of different polarity b) live parts and the body if intended to be connected to protective earth c) accessible conductive parts and metal-rod of the same diameter as the flexible cable or cord (or metal foil wrapped around the cord) inserted inside inlet bushing, anchorage and the like d) live parts and an intermediate conductive part e) an intermediate conductive part and the body						0,2	0,9	0,5	1,0	1,5	1,5	3,0	3,0	5,5	5,5	8,0	8,0
						0,8	1,7	0,8	2,0	1,5	2,2	3,0	4,2	5,5	8,6	8,0	14,0
						0,2	0,9	0,2	1,0	0,5	1,1	1,5	2,1	3,0	4,3	5,5	7,1
						0,8	1,7	0,8	2,0	0,8	2,2	1,5	4,2	3,0	8,6	5,5	14,0
	Reduced values, see 26.2 (P1)					–	0,03	–	0,1	–	0,24	–	0,7	–	1,7	–	3,2

Annex D (void) (normative)

Creepage distances (cr), clearances (cl) and distances through insulation (dti) Material group I (CTI ≥ 600)

**Table D.1 – Creepage distances (cr), clearances (cl) and distances through insulation (dti) –
Material group I (CTI ≥ 600)**

NOTE – The following table extends over several pages. For notes and footnotes, please see the final page of the table.

		Working voltages ^b V														Dimensions in millimetres	
		Measurement															
		Through winding enamel ^a		Other than through winding enamel		≥25 ≤50		100		150		300		600		1 000	
		P2	P3	P2	P3	cl	cr	cl	cr	cl	cr	cl	cr	cl	cr	cl	cr
1) Insulation between input and output circuits (basic insulation)	a) Creepage distances and clearances between live parts of input circuits and live parts of output circuits			×		0,2	0,6	0,5	0,7	1,5	1,5	3,0	3,0	5,5	5,5	8,0	8,0
					×	0,8	1,5	0,8	1,8	2,0	2,0	3,0	3,9	5,5	7,7	8,0	12,5
		×				0,2	0,6	0,2	0,7	0,5	0,8	1,5	1,5	3,0	3,0	5,5	5,5
	Reduced values, 26.2 (P1)					0,8	1,5	0,8	1,8	2,0	2,0	1,5	3,9	3,0	7,7	5	12,5
						–	0,18	–	0,25	–	0,3	–	0,7	–	1,7	–	3,2
						dti		dti		dti		dti		dti		dti	
	b) Distances through insulation between input or output circuits and an earthed metal screen	×	×	×	×							No requirements of thickness					
	c) Distances through insulation between input and output circuits	×	×	×	×							No requirements of thickness					
2) Insulation between input and output circuits (double or reinforced insulation)	a) Creepage distances and clearances between live parts of input circuits and live parts of output circuits			×		0,5	0,7	1,5	1,5	3,0	3,0	5,5	5,5	8,0	8,0	14,0	14,0
					×	0,8	1,8	1,5	2,5	3,0	3,9	5,5	7,7	8,0	16,0	14,0	25,0
		×				0,2	0,7	0,5	1,0	1,5	1,5	3,0	3,0	5,5	6,0	8,0	10,0
			×			0,8	1,8	0,8	2,5	3,9	3,9	7,7	7,7	5,5	16,0	8,0	25,0
	Reduced values, see 26.2 (P1)					–	0,25	–	0,4	–	0,7	–	1,7	–	4,0	–	7,5
	b) Distances through insulation between input or output circuits and an earthed metal screen, see 26.3					dti		dti		dti		dti		dti		dti	
		×	×	×	×	0,1 ^d [0,05] ^e	0,2 ^d [0,07] ^e	0,25 ^d [0,08] ^e	0,25 ^d [0,08] ^e	0,25 ^d [0,08] ^e	0,25 ^d [0,08] ^e	0,5 ^d [0,16] ^e	0,5 ^d [0,16] ^e	0,7 ^d [0,19] ^e	0,7 ^d [0,19] ^e	1,0 ^d [0,25] ^e	1,0 ^d [0,25] ^e
	c) Distances through insulation between input and output circuits, see 26.3	×	×	×	×	0,1 ^d [0,05] ^e	0,2 ^d [0,07] ^e	0,25 ^d [0,08] ^e	0,25 ^d [0,08] ^e	0,25 ^d [0,08] ^e	0,25 ^d [0,08] ^e	0,5 ^d [0,16] ^e	0,5 ^d [0,16] ^e	0,7 ^d [0,19] ^e	0,7 ^d [0,19] ^e	1,0 ^d [0,25] ^e	1,0 ^d [0,25] ^e

Table D.1 (continued)

		Measurement	Working voltages ^b V															
	Type of insulation	Through winding enamel ^a	Other than through-winding enamel	≥25 ≤50		100		150		300		600		1 000				
		P2	P3	cl	cr	cl	cr	cl	cr	cl	cr	cl	cr	cl	cr			
3) Insulation between adjacent input circuits or insulation between adjacent output circuits ^{c, g}	Creepage distances and clearances	X		0,2	0,6	0,2	0,7	0,2	0,8	0,5	1,5	1,5	3,0	3,0	5,0			
			X	0,8	1,5	0,8	1,8	0,8	2,0	0,8	3,9	1,5	7,7	3,0	12,5			
	Reduced values see 26.2 (P1)			–	0,18	0,25	–	0,3	–	0,7	–	1,7	–	–	3,2			
4) Creepage distances and clearances between terminals for the connection of external cables and cords excluding those between screw terminals for input and for output circuits	a) Up to and including 6 A	X	X	3,0	3,6	3,6	4,0	4,0	6,0	6,0	9,0	9,0	12,5	12,5	16,0			
	b) Over 6 A up to and including 16 A	X	X	5,0	6,0	6,0	7,0	7,0	10,0	10,0	13,0	13,0	16,0	16,0	20,0			
	c) Over 16 A	X	X	10,0	11,0	11,0	12,0	12,0	14,0	14,0	17,0	17,0	20,0	20,0	24,0			
5) Basic or supplementary insulation ^h	Between:																	
	a) live parts of different polarity		X	0,2	0,6	0,5	0,7	1,5	1,5	3,0	3,0	5,5	8,0	8,0	12,5			
	b) live parts and the body if intended to be connected to protective earth			0,8	1,5	0,8	1,8	1,5	2,0	3,0	3,9	5,5	8,0	8,0	12,5			
	c) accessible conductive parts and metal rod of the same diameter as the flexible cable or cord (or metal foil wrapped around the cord) inserted inside inlet bushing, anchorage and the like	X		0,2	0,6	0,2	0,7	0,5	0,8	1,5	1,5	3,0	5,5	5,5	8,0			
	d) live parts and an intermediate conductive part			0,8	1,5	0,8	1,8	0,8	2,0	3,0	3,9	5,5	8,0	8,0	12,5			
	e) an intermediate conductive part and the body			0,8	1,5	0,8	1,8	0,8	2,0	3,0	3,9	5,5	8,0	8,0	12,5			
	Reduced values, see 26.2 (P1)			–	0,03	–	0,1	–	0,24	–	0,7	–	1,7	–	3,2			

~~Table D.1 (continued)~~

	Type of insulation	Measurement				Working voltages ^b V											
		Through winding enamel ^a		Other than through winding enamel		≥25 ≤50		100		150		300		600		1 000	
		P2	P3	P2	P3	cl	cf	cl	cf	cl	cf	cl	cf	cl	cf	cl	cf
6) Reinforced or double insulation	Between the body and live parts or where it is required by the standard (excluding insulation between input and output windings)	X		X		0,5	0,7	1,5	1,5	3,0	3,0	5,5	5,5	8,0	8,0	14,0	14,0
			X		X	0,8	1,8	1,5	1,5	3,0	3,0	5,5	5,5	8,0	16,0	25,0	25,0
		X				0,2	0,7	0,5	0,5	1,5	1,5	3,0	3,0	5,5	6,0	10,0	10,0
			X			0,8	1,8	0,8	0,8	3,0	3,0	7,7	7,7	16,0	16,0	25,0	25,0
	Between body and live parts of the output circuit if protected by additional provisions against transient voltages	X		X		0,2	0,7	0,2	1,0	1,5	1,5	3,0	3,0	6,0	6,0	10,0	10,0
	Reduced values, see 26.2 (P1)					0,8	1,8	0,8	2,5	0,5	0,5	1,5	1,5	3,0	16,0	25,0	25,0
						0,25	0,75	0,25	0,25	0,75	0,75	1,75	1,75	4,0	4,0	7,5	7,5
7) Distance through insulation	a) Basic insulation ^f	X	X	X	X												
	b) Supplementary insulation ^f	X	X	X	X												
	c) Reinforced insulation (excluding insulation between input and output circuit)	X	X	X	X												
NOTE 1 For Material Group IIIa, see Table 13, and for Material Group II, see Annex C.																	
NOTE 2 P1 = pollution degree 1, P2 = pollution degree 2, P3 = pollution degree 3.																	
NOTE 2 When a numeric figure is replaced by a dash in a column of the table it means that no value is required.																	
NOTE 4 The minimum values of clearance in this table are applicable in air up to 2000 m above sea level.																	
a. Measurement through winding wire enamel if at least one winding is constructed with wire complying with at least grade 1 of IEC 60317.																	
b. Values of creepage distances and clearances and distances through insulation may be found for intermediate values of working voltages by interpolation between the values in the table. No values are required for working voltages below 25 V as the voltage test of Table 8a is considered sufficient.																	
e. These values do not apply: — inside each winding or between groups of windings intended to be permanently connected together, provided that the termination of windings to be connected together are at the same potential; — where the working voltage does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317, if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 110/220 V).																	
d. For solid insulation																	
e. In case of insulation consisting of thin sheets																	
f. When double insulation is required between input and output windings , the total thickness through insulation shall be the same as shown in box 2 c) whether measured directly or via metals parts, with the exception of insulated wires (see 19.12).																	
g. For insulation between SELV circuits and adjacent circuits other than SELV or PELV , the values of this box shall be replaced by the values of boxes 6 and 7 (according to 19.1).																	
In case of a physical breakdown of the basic insulation or supplementary insulation , the thickness of the insulation is added to the clearance.																	

Annex E (normative)

Glow-wire test

E.1 General

The glow-wire test is carried out in accordance with IEC 60695-2-10 and IEC 60695-2-11.

For the purpose of this document, the following applies with reference to the relevant clauses and subclauses of IEC 60695-2-11.

E.2 Severity

The requirements of 8.2, “Test temperatures” of IEC 60695-2-11:2014 apply, except that the temperature of the tip of the glow-wire is that stated in 27.4 of this document.

E.3 Conditioning

The requirements of Clause 7, “Conditioning”, of IEC 60695-2-11:2014 apply, but preconditioning is required.

E.4 Test procedure

The requirements of Clause 8, “Test procedure”, of IEC 60695-2-11:2014 apply with the following addition to 8.1:

“If possible, the tip of the glow-wire is applied to flat surfaces and not to grooves, knock-outs, narrow recesses or sharp edges.”

Annex F (normative)

Requirements for manually operated switches which are parts of transformers assembly

F.1 General

The tests on switches being either integrated or incorporated in the **transformers** are carried out in accordance with IEC 61058-1 as stated in F.2 or F.3.

Manually operated mechanical switches shall comply with the requirements of F.2 or F.3.

F.2 Switches tested as a separate component

The switch, tested as a separate component, shall comply with the requirements and tests of IEC 61058-1:2016, modified as follows:

- 7.9: the switch shall be suitable for use in the relevant **pollution degree** situation;
- 7.11.3: the switch shall be ~~of category D~~ **resistant to 850 °C glow wire temperature** regarding the resistance to heat and fire.

In addition, the characteristics of the switches as described in IEC 61058-1:2016 shall be appropriate for the function of the switches under normal operating conditions with regard to:

- a) Clause 6: the rating of the switches;
- b) The classification of the switches according to:
 - 7.1: nature of supply;
 - 7.2: type of load to be controlled by the switches;
 - 7.3: ambient air temperature.

If the switch energises or de-energises the socket-outlet(s) in the **secondary circuit**, the rated output current and the rated peak surge current of the socket-outlet(s) of Table F.1 shall be taken into account as specified in F.3.3.

Compliance is checked by inspection and by measurements according to test specifications of IEC 61058-1.

F.3 Switches tested as part of the transformer

F.3.1 The switch, tested as part of the apparatus **transformer** working under normal operating conditions, shall meet the requirements of F.3.2, F.3.3 and F.3.4.

F.3.2 The switch shall withstand without excessive wear or other harmful effects the electrical, thermal and mechanical stresses that occur in normal use, and shall have a mechanism complying with Clause 13 of IEC 61058-1:2016 for switches.

Compliance is checked according to Clause 13 of IEC 61058-1:2016 and by the following endurance test:

The switch is subjected to 10 000 cycles of operation with a sequence according to 17.1.2 of IEC 61058-1-1:2016, except the increased voltage test at accelerated speed specified in 17.5.1 of IEC 61058-1-1:2016, and under electrical and thermal conditions given by the normal operating conditions of the apparatus.

The test is carried out on three specimens, no failure is allowed.

F.3.3 If the switch energises or de-energises the socket-outlet(s) in the **secondary circuit**, the endurance test is carried out with an additional load connected to the socket-outlet(s), consisting of the circuit shown in Figure 8 of IEC 61058-1:2016, taking into account Figure 10 of IEC 61058-1:2016.

The rated current I of the additional load shall correspond to the marking of the socket outlet(s) (see item d) of 8.1). The peak surge current of the additional load shall have a value as shown in Table F.1.

Table F.1 – Peak surge current of additional loads

Rated current I of the socket-outlet(s) A	Peak surge current A
$I \leq 0,5$	20
$0,5 < I \leq 1,0$	50
$1,0 < I$	100

If the socket-outlet(s) is/are marked with the current which may be drawn, this/these value(s) is/are chosen for the rated current I of the socket-outlet(s).

If the socket-outlet(s) is/are marked with the power which may be drawn, the rated current of the socket-outlet(s) is calculated from this/these value(s).

After the test, the switch shall show no damage in the sense of this document. In particular, it shall show no deterioration of its **enclosure**, no reduction of **clearances** and **creepage distances** and no loosening of electrical connections with mechanical fixing.

Compliance is checked by inspection and by the tests specified in F.3.4 and F.3.5, respectively, in the given order.

F.3.4 The switch shall be so constructed that it does not attain excessive temperatures in normal use. The materials used shall be such that the performance of the switch is (are) not adversely affected by the operation in normal use in the conditions given by the apparatus. In particular, the material and design of the contacts and terminals shall be such that the operation and the performance of the switch are not adversely affected by its oxidation or other deterioration.

Compliance is checked in the "ON" position under normal operating conditions and according to 16.4 e) and q) of IEC 61058-1:2016, taking into account the rated current of the socket-outlet(s), if any, including the peak surge current according to Clause F.3.

F.3.5 The switch shall have adequate dielectric strength.

Compliance is checked by the following tests:

The switch shall withstand a dielectric strength test as specified in 18.3, without being previously subjected to the humidity treatment, the test voltage being decreased to 75 % of the corresponding test voltage specified in that subclause, but not less than 500 V RMS (700 V peak).

- *The test voltage is applied in the "ON" position between **hazardous-live-parts** and accessible conductive parts, and, in addition, between the poles in case of a multipole switch.*

- *The test voltage is applied in the "OFF" position across each contact gap. During the test, resistors and capacitors in parallel to a contact gap may be disconnected.*

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Annex G (normative)

Tracking test

G.1 General

The tracking tests on the **transformers** are carried out in accordance with IEC 60112 as follows.

For the purpose of this document, materials are classified into ~~three~~ **four** groups by their comparative tracking index (CTI) values, as follows:

- material group I $600 \leq (\text{CTI})$;
- material group II $400 \leq (\text{CTI}) < 600$;
- material group IIIa $175 \leq (\text{CTI}) < 400$;
- **material group IIIb $100 \leq (\text{CTI}) < 175$.**

Separation of the material groups is (are) determined by compliance with the comparative tracking index test made in accordance with IEC 60112.

The test is made on three separate specimens or on three pieces cut from the relevant component, care being taken that the electrodes are clean, correctly shaped and correctly positioned before each test is started. In case of doubt, the test is repeated, if necessary, on a new specimen.

For the purpose of this document, the following applies with reference to the clauses and subclauses of IEC 60112.

G.2 Test specimen

*The requirements of Clause 5 “Test specimen”, of IEC 60112:2003 apply except ~~that the last sentence of the first paragraph does not apply~~ **the thickness requirement of at least 3 mm.***

G.3 Test apparatus

~~The requirements of Clause 5 “Test apparatus”, of IEC 60112 apply except that the:~~

- ~~— The note in 5.1 does not apply~~
- ~~— Note 4 in 5.3 does not apply~~
- ~~— Test solution A as described in 5.4 is used.~~

The requirements of Clause 7 “Test apparatus”, with the test solution A as described in 7.3 of IEC 60112:2003 shall be used.

G.4 Procedure

~~The requirements of Clause 6 “Procedure”, of IEC 60112 apply except that:~~

- ~~— for the CTI test of 6.2, notes 2 and 3 of Clause 3 also apply.~~
- ~~— subclause 6.3 does not apply.~~

The requirements of Clause 8 “Basic test procedure”, of IEC 60112:2003 applies except that:

- *for the CTI test of Clause 11, the Note 3 and last paragraph of Clause 5 also applies;*
- *Clause 10 does not apply.*

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Annex H (normative)

Electronic circuits

H.1 General

For **transformers** including **electronic circuits**, the following requirements apply additionally to Clauses 5, 15, 26.

This annex is not required for associated transformers.

H.2 General notes on tests (addition to Clause 5)

H.2.1 All clauses of this document, as modified in this annex, and in the Parts of IEC 61558-2 for the specific **transformers**, apply to electronic circuits.

H.2.2 The accumulation of stress resulting from successive tests is to be avoided. It may be necessary to replace components or to use additional samples.

NOTE The number of additional samples should be kept to a minimum by an evaluation of the relevant circuits.

H.3 Short circuit and overload protection (addition to Clause 15)

H.3.1 Electronic circuits shall be so designed and applied that a fault condition will not render the **transformer** unsafe with regard to electric shock, fire hazard or dangerous malfunction.

Compliance is checked by evaluation of the fault conditions specified in H.3.3 for all circuits or parts of circuits, unless they comply with the conditions specified in H.3.2.

*If the safety of the **transformer** under any of the fault conditions depends on the operation of a fuse-link, the test of H.3.4 is made.*

*During and after each test, the temperatures shall not exceed the values specified in Table 5 and the **transformer** shall comply with the conditions specified in 15.1.*

If a conductor of a printed circuit board becomes open-circuited, the **transformer** is considered to have withstood the particular test, provided that all six of the following conditions are met:

- the printed circuit board complies with the requirements of FV1;
- the interrupted conductors have not peeled by more than 2 mm on each side;
- the interruption is in a low-power circuit as described in H.3.2, and in addition the voltage over the interruption shall not exceed 50 V;
- the **transformer** complies with the requirements of this subclause with the interrupted conductors bridged;
- no other conductor has been loosened over a length of more than 5 mm;
- any peeled or loosened conductor does not reduce the **creepage distances** and **clearances** between **hazardous-live-parts** and **accessible parts** below the values specified in Clause 26.

NOTE Unless it is necessary to replace components after any of the tests, the dielectric strength test of 18.3 need only be carried out after the final test on the **electronic circuit**.

NOTE In general, examination of the **transformer** and its circuit diagram will reveal the fault conditions which have to be simulated, so that testing can be limited to those cases which may be expected to give the most unfavourable result.

H.3.2 Fault conditions a) to f) specified in H.3.3 are not applied to circuits or parts of circuits where both of the following conditions are met:

- the **electronic circuit** is a low-power circuit as described below;
- the protection against electric shock, fire hazard, mechanical hazards or dangerous malfunction in other parts of the **transformer** does not rely on the correct functioning of the **electronic circuit**.

A low-power circuit is determined as follows (an example is given in Figure H.1):

*The **transformer** is operated at rated voltage and a variable resistor, adjusted to its maximum resistance, is connected between the point to be investigated and the opposite pole of the supply source to the electronic circuit.*

The resistance is then decreased until the power consumed by the resistor reaches a maximum. Any point nearest to the supply at which the maximum power delivered to this resistor does not exceed 15 W at the end of 5 s is called a low-power point. The part of the circuit which is further from the supply source than a low-power point is considered to be a low-power circuit.

NOTE The measurements are made from only one pole of the supply source to the electronic circuit, preferably the one that gives the fewest low power points.

When determining the low power points, it is recommended to start with points close to the supply source.

NOTE The power consumed by the variable resistor is measured by a wattmeter.

H.3.3 The following fault conditions are considered and, if necessary, applied one at a time. Consequential faults are taken into consideration.

- a) Short circuit of **creepage distances** and **clearances** between **live parts** of different polarity, if these distances are less than those specified in Clause 26.
- b) Open circuit at the terminals of any component.
- c) Short circuit of capacitors, unless they comply with IEC 60384-14.
- d) Short circuit of any two terminals of an electronic component, other than integrated circuits. This fault condition is not applied between the two circuits of an optocoupler.
- e) Open circuit or short circuit inside an integrated circuit. In that case, the possible hazardous situations of the **transformer** are assessed to ensure that safety does not rely on the correct functioning of such a component.

All possible output signals of the integrated circuit are considered in the result. If it can be shown that a particular output signal is unlikely to occur, then the relevant fault is not considered.

NOTE Microprocessors are tested as integrated circuits.

NOTE Semiconductor components such as thyristors and triacs are subjected to fault conditions b) and d).

- f) In addition, each low-power circuit is short-circuited by connecting the low power point to the pole of the supply from which the measurements were taken.

For simulation of the fault conditions, the **transformer** is operated at any supply voltage between ~~0,94~~ 0,9 times and ~~1,06~~ 1,1 times the **rated supply voltage**.

Where any of the fault conditions are simulated, the test is continued until steady-state conditions are established.

In each case, the test is ended if interruption of the supply occurs within the **transformer**.

If the **transformer** incorporates an electronic circuit which operates to ensure compliance with Clause 15, the relevant test is repeated with a single fault simulated, as indicated in a) to e) above.

Fault condition e) is applied to encapsulated and similar components if the circuit cannot be assessed by other methods.

Positive temperature coefficient resistors (PTCs) and negative temperature coefficient resistors (NTCs) are not short-circuited if they are used within their manufacturer's declared specification.

H.3.4 If, for any of the fault conditions specified in H.3.3, the safety of the **transformer** depends on the operation of a fuse-link, the test is repeated but with the fuse-link replaced by an ammeter.

In case of doubt, the maximum resistance of the fuse-link has to be taken into account when determining the current.

For miniature fuse-links complying with IEC 60127-3 the following applies.

If the current measured does not exceed 2,1 times the rated current of the fuse-link, the circuit is not considered to be adequately protected, and the test is carried out with the fuse-link short-circuited.

If the current is at least 2,75 times the rated current of the fuse-link, the circuit is considered to be adequately protected.

If the current measured exceeds 2,1 times the rated current of the fuse-link, but ~~does not exceed~~ less than 2,75 times the rated current, the fuse-link is short-circuited and the test is carried out:

- for quick acting fuse-links for the relevant period, or for 30 min, whichever is the shorter;
- for time lag fuse-links, for the relevant period, or for 2 min, whichever is the shorter.

NOTE The verification whether the fuse-link acts as a protective device is based on the fusing characteristics specified in IEC 60127-3, which also gives the information necessary to calculate the maximum resistance of the fuse-link.

For fuses other than those complying with IEC 60127-3, the test is carried out as specified in 15.3.2 to 15.3.5.

H.4 Creepage distances, clearances and distances through insulation (addition to Clause 26)

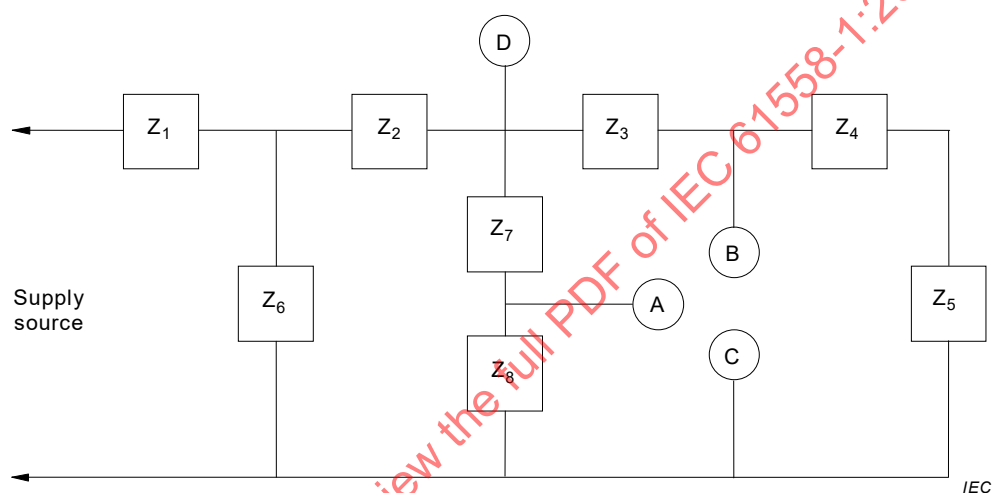
H.4.1 For live parts of different polarity separated by **basic insulation** only, **creepage distances** and **clearances** smaller than those specified in Clause 26 are allowed, provided the requirements of Clause H.3 are met if these **creepage distances** and **clearances** are short-circuited in turn.

Creepage distances and **clearances** within optocouplers are not measured if the individual insulation is adequately sealed, and if air is excluded between individual layers of the material.

If coatings are used on printed circuit boards to protect the micro-environment or to provide **basic insulation**, Annex W applies. Smaller distances as required in Clause 4 of IEC 60664-3:2016, are applicable (Type 1 protection: P1 value; Type 2 protection distances to insulation).

For cycling tests for potted **transformers** see 26.2.

H.4.2 For optocouplers, the conditioning procedure is carried out at a temperature of 50 K in excess of the maximum temperature measured on the surface of the optocoupler during the tests of Clause 14 or Clause 15, the optocoupler being operated under the most ~~onerous~~ unfavourable conditions which occur during these tests.



D is a point furthest from the supply source where the maximum power delivered to external load exceeds 15 W.

A and B are points closest to the supply source where the maximum power delivered to external load does not exceed 15 W. These are low-power points.

Points A and B are separately short-circuited to C.

The fault conditions a) to e) specified in H.3.3 are applied individually to Z₁, Z₂, Z₃, Z₆, and Z₇.

Figure H.1 – Example of an electronic circuit with low-power points

Annex I**(void)**

(informative)

**Dimensions for rectangular cross-section connectors
of transformers, basic dimensions and coordination**

If the dimension A in the Table I.1 is not higher than 400 mm, the size of the rectangular cut surface cross-section shall be at least 50 % of the cross-section value for the winding wire or foil.

When the size A in the Table I.1 is higher than 400 mm, the dimension parameters shall be according to DIN 43671 for copper rectangular cross-section connectors, DIN 43670 for aluminium rectangular cross-section connectors and DIN 43670 part 2 for copper cladding aluminium cross-section connectors or at least equal to the cross-section value for the winding wire or foil.

The current-density of the rectangular cross-section connector shall not exceed 4,0 A/mm². The dimensions and mounting holes of the attachment surface shall conform with the values stated in Table I.1.

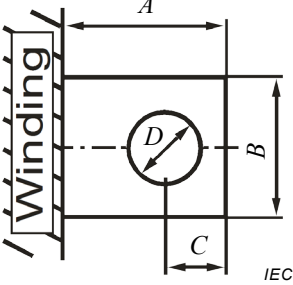
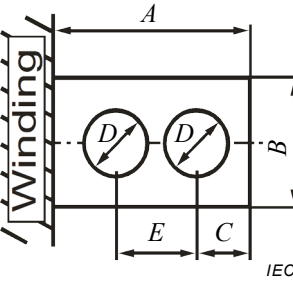
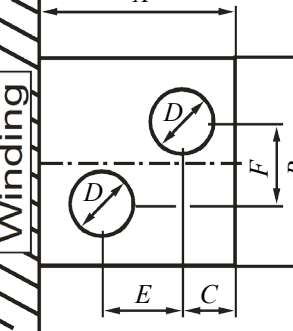
For higher current values or by constructional reasons, rectangular cross-section connectors can be used in parallel connection if the same value of the cross-section dimension is met.

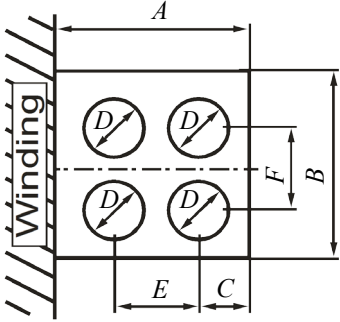
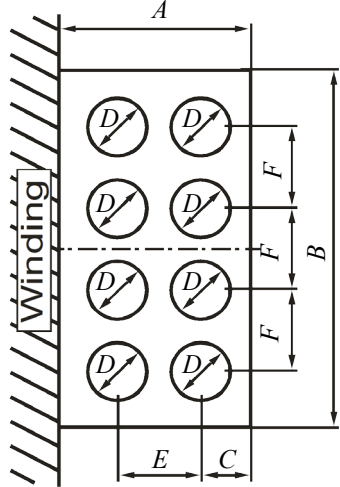
NOTE These values can be reduced when the rectangular cross-section connectors are cooled by additional methods and the attachment is ensured. Methods are for example liquid cooling.

The rectangular cross-section connectors shall have sufficient mechanical strength to avoid contortion or breaking away caused, for example, by high short-circuit currents and the connection with a bunched conductor.

Table I.1 is only necessary to ensure the connection with busbars.

Table I.1 – Dimensions of rectangular copper connectors

Dimensions	Current A	A mm	B mm	C mm	D mm	E mm	F mm	Mounting Screws
	≤ 145	15	12	6	5,5	/	/	M5
	≤ 215	18	15	7,5	6,6			M6
	≤ 365	23	20	10	9			M8
	≤ 430	28	25	12,5	11			M10
	≤ 760	35	30	15	11			M10
	≤ 950	45	40	20	13,5			M12
	≤ 1 130	85	50	20	13,5	40	/	M12
	≤ 1 305	65	60	17	13,5	26	26	M12

 IEC	$\leq 1\,645$	85	80	20	13,5	40	40	M12
	$\leq 1\,975$	85	100	20	13,5	40	50	M12
 IEC	$\leq 2\,305$	85	120	20	13,5	40	60	M12
	$\leq 2\,940$	85	160	20	13,5	40	40	M12
 IEC	$\leq 3\,565$	85	200	20	13,5	40	50	M12

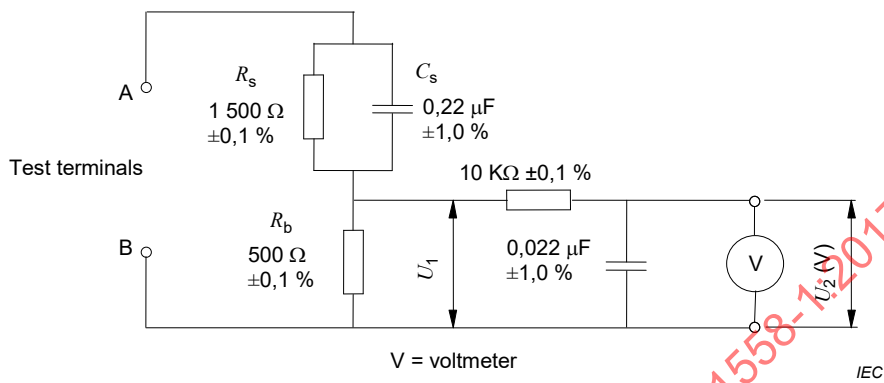
NOTE 1 For aluminium rectangular cross-section connectors, the value for the current can be reduced to 78 % of the specified value.

NOTE 2 For copper cladding aluminium rectangular cross-section connectors the value for the current can be reduced to 83 % of the specified value.

Annex J

(normative)

Measuring network for touch-currents



Source: Figure 4 of IEC 60990:2016.

True RMS reading		Input capacitance:	$\leq 200\,\text{pF}$
Uncertainty:	$\leq 2\,\%$	Supply frequency range:	15 Hz to 1 MHz
Input resistance:	$0,1\,\text{M}\Omega$		

Figure J.1 – Measuring network for touch-current

Annex K (normative)

Insulated winding wires ~~for use as multiple layer insulation~~

~~This annex specifies winding wire insulated with polyimide film or equivalent insulation, that may be used to provide basic, supplementary or reinforced insulation in wound parts without additional interleaved insulation.~~

NOTE Typical values of some properties of polyimide are given below for information. Adherence to these values is not part of this standard.

— Dielectric strength —————	180 kV/mm
— Dielectric constant —————	3,5
— Dissipation factor —————	0,003 at 1 kHz
— Insulation resistance —————	10^5 M Ω
— Surface resistivity —————	10^{16} Ω at 50 % relative humidity
— Folding endurance —————	10^4 cycles.

K.1 Wire construction

~~Winding wire shall be insulated with two or more layers. In case of spirally wrapped layers of tape, contra rotation layers shall be used. Overlap of these layers shall be adequate to ensure continued overlap during manufacture of the wound part.~~

~~Such layers of tape shall be sealed to eliminate creepage paths between layers.~~

K.2 Conformance tests

~~The wire shall pass the following five type tests K.2.1 to K.2.5.~~

K.2.1 Dielectric strength

~~Test 13 of IEC 60851-5, applied for the same duration as in 18.3, with a test voltage not less than the appropriate voltage in Table 8a of this standard, or 3 kV in case of two layers and 5,5 kV in case of three layers, whichever is the greater in each case.~~

K.2.2 Adherence and flexibility

~~Test 8 of 5.1 of IEC 60851-3, followed by the dielectric strength test of K.2.1, carried out at rated ambient temperature.~~

K.2.3 Heat shock

~~Test 9 of 3.1.1 and 3.2 of IEC 60851-6, followed by the dielectric strength test of K.2.1.~~

K.2.4 Retention of dielectric strength after bending

~~Test 13 of 4.1 to 4.5 of IEC 60851-5, followed by the dielectric strength test of K.2.1.~~

K.2.5 Resistance to abrasion

~~Test 11 of IEC 60851-3 is applicable.~~

~~K.3 Routine test (production tests)~~

~~The wire shall be subjected by the wire manufacturer to 100 % dielectric strength testing in accordance with IEC 60851-5, with a test voltage not less than the appropriate voltage in Table 8a of this standard, or 3 kV in the case of two layers and 5,5 kV in the case of three layers, whichever is the greater in each case.~~

K.1 General

This annex specifies the winding wires of the insulation that may be used to provide basic insulation, supplementary insulation, double insulation or reinforced insulation in wound components. For details of the construction, see 19.12.3.

This annex applies to solid circular winding wires and stranded winding wires having diameters between 0,05 mm and 5,0 mm and solid square and solid rectangular (flatwise bending) winding wires with equivalent cross-sectional areas (0,002 mm² to 19,6 mm²).

If the wire is insulated with two or more spirally wrapped layers of tape, the overlap of layers shall be adequate to ensure continued overlap during manufacture of the wound component. The layers of spirally wrapped wire insulation shall be sufficiently secured to maintain the amount of overlap.

K.2 Type tests

K.2.1 General

The winding wire shall pass the following type tests, carried out at a temperature between 15 °C and 35 °C and a relative humidity between 25 % and 75 %, unless otherwise specified.

K.2.2 Dielectric strength test

K.2.2.1 Solid circular winding wires and stranded winding wires

The test sample is prepared according to 4.4.1 of IEC 60851-5:2008 (twisted pair). The sample is then subjected to the dielectric strength test of 18.3 in this document with a test voltage standard, with a minimum of:

- 6 kV RMS for reinforced insulation, or
- 3 kV RMS for basic insulation or supplementary insulation.

K.2.2.2 Square or rectangular wires

The test sample is prepared according to 4.7.1 of IEC 60851-5:2008 (single conductor surrounded by metal shots). The sample is then subjected to the dielectric strength test of 18.3, with a minimum test voltage of:

- 5,5 kV RMS for reinforced insulation, or
- 2,75 kV RMS for basic insulation or supplementary insulation.

K.2.3 Flexibility and adherence

The mandrel winding test 5.1 (in Test 8) of IEC 60851-3:2009 shall be used, with the mandrel diameters of Table K.1. The test voltage is applied between the wire and the mandrel.

The test sample is then examined in accordance with 5.1.1.4 of IEC 60851-3:2009, followed by the dielectric strength test of 18.3, with minimum test voltage of:

- 5,5 kV RMS for reinforced insulation, or

- 2,75 kV RMS for basic insulation or supplementary insulation.

The test voltage is applied between the wire and the mandrel.

Table K.1 – Mandrel diameter

Nominal conductor diameter or thickness ^a mm	Mandrel diameter mm
< 0,35	4,0 ± 0,2
< 0,50	6,0 ± 0,2
< 0,75	8,0 ± 0,2
< 2,50	10,0 ± 0,2
< 5,00	4 times the conductor diameter or thickness ^b
^a Up to but excluding this value.	
^b In accordance with IEC 60317-43.	

The tension to be applied to the wire during winding on the mandrel is calculated from the wire diameter to be equivalent to 118 MPa, with a relative tolerance of ±10 %, (118 N/mm², with a relative tolerance of ±10 %).

Edgewise bending on the smaller dimension side (width) is not required for rectangular wire. For mandrel winding test of the square and rectangular wire, two adjacent turns do not need to contact each other.

K.2.4 Heat shock

The test sample shall be prepared in accordance with 3.2.1 (in Test 9) of IEC 60851-6:2012, followed by the dielectric strength test of 18.3, with a minimum test voltage of:

- 5,5 kV RMS or for reinforced insulation, or
- 2,75 kV RMS for basic insulation or supplementary insulation.

The test voltage is applied between the wire and the mandrel. The oven temperature is the relevant temperature of the thermal class of insulation in Table K.2. The mandrel diameter and tension applied to the wire during winding on the mandrel are as in Table K.1. The test voltage is applied between the wire and the mandrel.

The dielectric strength test is conducted at room temperature after removal from the oven.

Table K.2 – Oven temperature

Thermal class	Class 105 (A)	Class 120 (E)	Class 130 (B)	Class 155 (F)	Class 180 (H)
Oven temperature °C	200	215	225	250	275

Edgewise bending on the smaller dimension side (width) is not required for rectangular wire.

NOTE 3.2.2 in Test 9 of IEC 60851-6:2012 is not used for solid square and solid rectangular winding wires.

K.2.5 Retention of dielectric strength after bending

Five samples are prepared as in K.2.3 and tested as follows. Each sample is removed from the mandrel, placed in a container and positioned so that it can be surrounded by at least 5

mm of metal shot. The ends of the conductor in the sample shall be sufficiently long to avoid flash over. The shot shall be not more than 2 mm in diameter and shall consist of balls of stainless steel, nickel or nickel plated iron. The shot is gently poured into the container until the sample under test is covered by at least 5 mm of shot. The shot shall be cleaned periodically with a suitable solvent.

NOTE The above test procedure is reproduced from 4.6.1 c) of IEC 60851-5:1988 but is not included in the fourth edition (2008) of that standard.

The samples shall be subjected to the dielectric strength test of 18.3, with a minimum test voltage of:

- *5,5 kV RMS for reinforced insulation, or*
- *2,75 kV RMS for basic insulation or supplementary insulation.*

The mandrel diameter and tension applied to the wire during winding on the mandrel are as in Clause K.2.3.

K.3 Testing during manufacturing

K.3.1 General

The wire shall be subjected by the wire manufacturer to dielectric strength tests during manufacture as specified in K.3.2 and K.3.3.

K.3.2 Routine test

The test voltage for routine test shall be in accordance with the dielectric strength test of 18.3, with a minimum of:

- *4,2 kV RMS for reinforced insulation, or*
- *2,1 kV RMS for basic insulation or supplementary insulation.*

K.3.3 Sampling test

K.3.3.1 Solid circular winding wires and stranded winding wires

Twisted pair samples shall be tested in accordance with 4.4.1 of IEC 60851-5:2008. The test voltage shall be in accordance with the dielectric strength test of 18.3, with a minimum of:

- *6 kV RMS for reinforced insulation, or*
- *3 kV RMS for basic insulation or supplementary insulation.*

K.3.3.2 Square or rectangular wire

The test sample is prepared according to 4.7.1 of IEC 60851-5:2008. The sample is then subjected to the dielectric strength test of 18.3. The test voltage shall be in accordance with the dielectric strength test of 18.3, with a minimum of:

- *5,5 kV RMS for reinforced insulation, or*
- *3 kV RMS for basic insulation or supplementary insulation.*

Annex L (normative)

Routine tests (production tests)

L.1 General

The tests specified in this annex are intended to reveal, as far as safety is concerned, unacceptable variations in material or manufacture. These tests are intended not to impair the properties and the reliability of the **transformer**, and shall be made by the manufacturer on each **transformer** after production. The inspection is to check that the following is ascertained on 100 % of the products by the manufacturer production system.

These tests should be carried out at the temperature of the production line.

Further tests may have to be made to ensure that every **transformer** is conform with the specimens that withstood the tests of this document, depending on the experience gained by the manufacturer.

The routine tests shall in principle be carried out at the end of the production. However they may be carried out at an earlier stage if it can be shown that the procedure provides the same degree of safety.

L.2 Protective earthing continuity test

For **class I transformers**, a current of at least 10 A, derived from a source with a no-load voltage not exceeding 12 V, is passed in turn between the protective earthing terminal and each of accessible conductive parts which have to be earthed for safety reasons.

During this test, no interruption of the connections or substantial decrease of the current shall occur between the protective earthing terminal and the relevant accessible metal part conductive parts.

L.3 Checking of no-load output voltage

The **no-load output voltage** shall comply with the declared value and tolerance stated by the manufacturer and shall in addition not exceed the maximum **no-load output voltage** required by the relevant part of IEC 61558-2.

L.4 Dielectric strength test

The test is made in accordance with Table 14 at ambient temperature and without the ~~moisture test~~ humidity treatment of 17.2.

The specified test voltage is applied for 1 s.

The tests are made between:

- a) **live parts** of the **input circuits** and accessible conductive parts of the **transformer**;
- b) **input circuits** and **output circuits**.

No flashover or breakdown shall occur during the test.

Additional tests may be required for high insulation level **transformers** and **separating transformers** with **working voltage** above 1 000 V.

L.5 Checking of protective devices mounting

The operation of a protection device, if any, shall not be prevented by incorrect mounting of the device in the **transformer**.

Compliance is checked by inspection.

L.6 Visual inspection

Visual inspection shall ensure that all required and relevant markings are provided.

L.7 Repetition test after routine dielectric strength test

Any repetitions test for the dielectric strength test shall be 80 % according to Table 14 of the required test voltage value.

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Annex M (informative)

Examples to be used as a guide for 19.1

M.1 General

The examples of Figure M.1, Figure M.2, Figure M.3, Figure M.4 and Figure M.5 can be used as a guide for 19.1.

Key

R*	One piece of specified thickness or at least three layers of tape.	CR	creepage distance
R**	One piece of specified thickness plus an adhesive tape or an insulation insert or at least three layers of tape plus, for example, an adhesive tape or at least four layers of serrated tape	CL	clearance
1	A tube of a specified thickness for supplementary insulation or at least three layers of tape (see Clause 26).	B	basic insulation
2	Formed part of thickness as specified for supplementary insulation in Clause 26	S	supplementary insulation
3	Last turn of winding prevented from being displaced. For example, adhesive bonding tape or a bonding agent.	R	reinforced insulation or double insulation
		I	input or first winding
		O	output or second winding

M.2 Coil-former

M.2.1 Concentric type

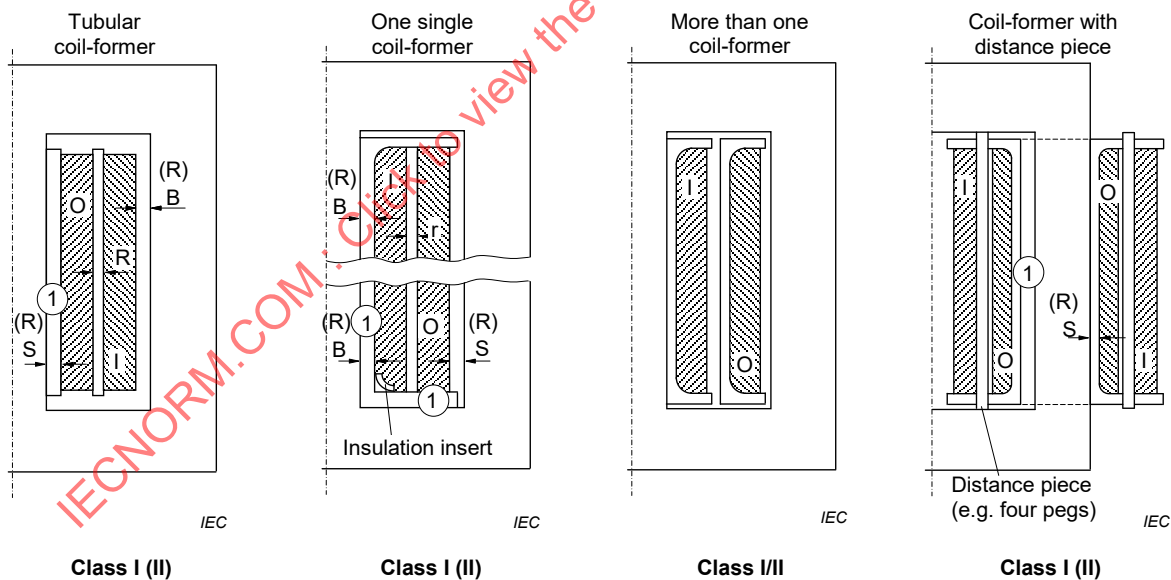


Figure M.1 – Examples for concentric type constructions

M.2.2 Side-by-side type

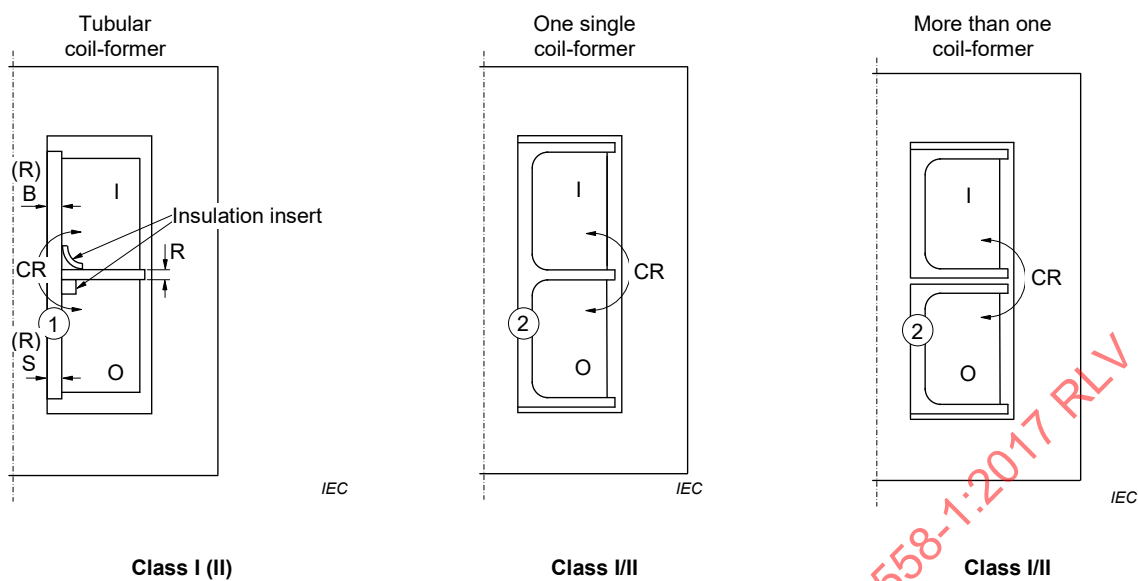


Figure M.2 – Examples for side-by-side type constructions

M.3 Windings

M.3.1 Without screen

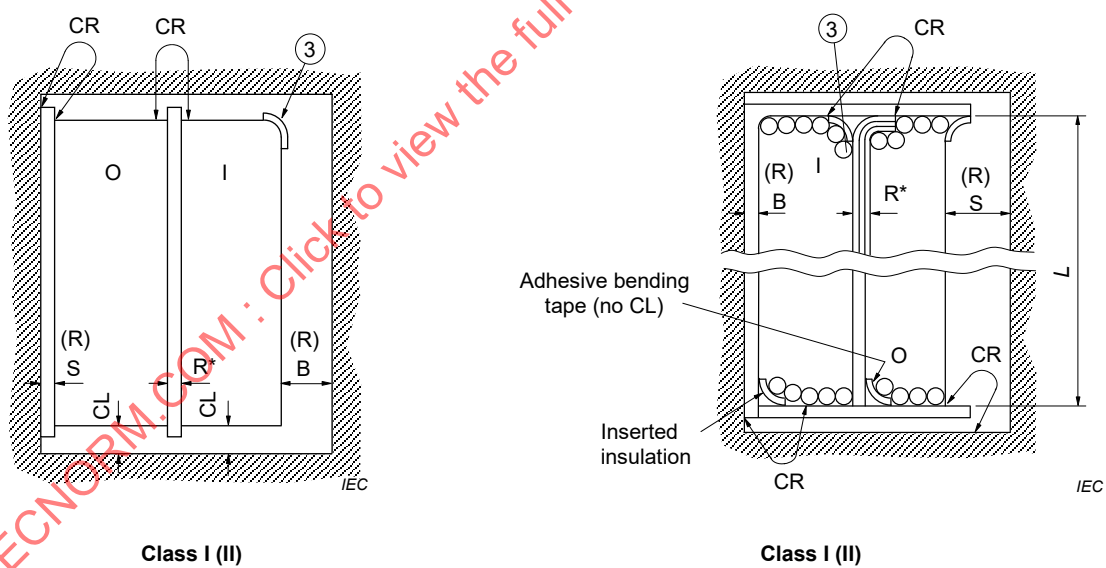
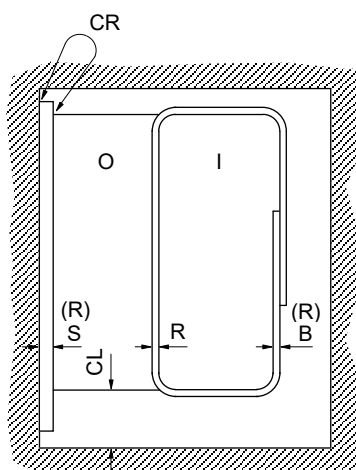


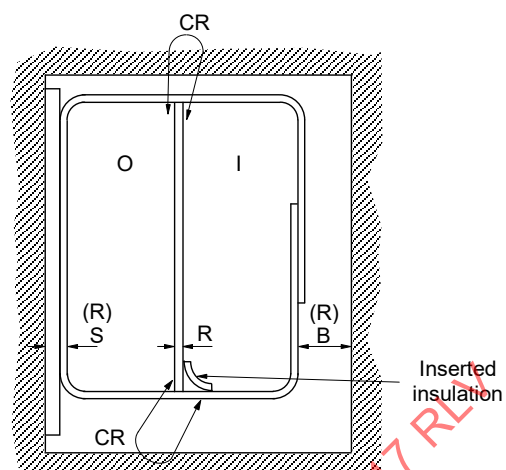
Figure M.3 – Examples for winding constructions without screen



Input or output winding wrapped with insulating material

IEC

Class I (II)



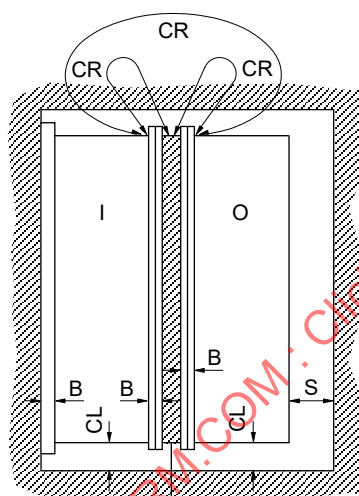
Input and output winding wrapped with insulating material (no CR)

IEC

Class I (II)

Figure M.4 – Examples for wrapped winding constructions

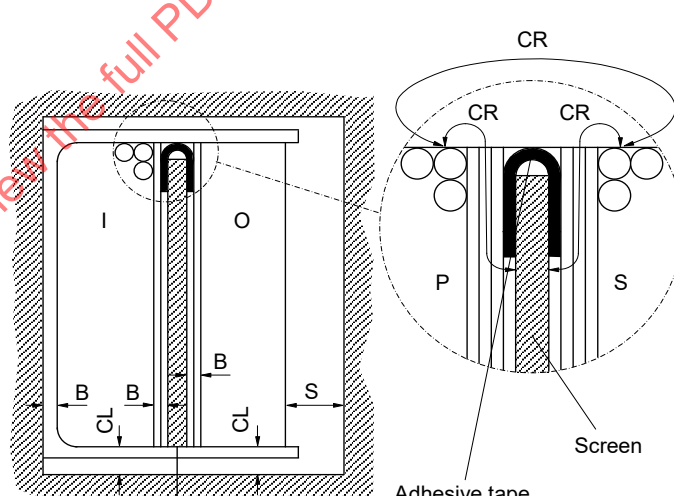
M.3.2 With screen



Earthed

IEC

Class I



Earthed

IEC

Class I

Figure M.5 – Examples for winding constructions with screen

NOTE For class II constructions the abbreviations are given in brackets.

Annex N (informative)

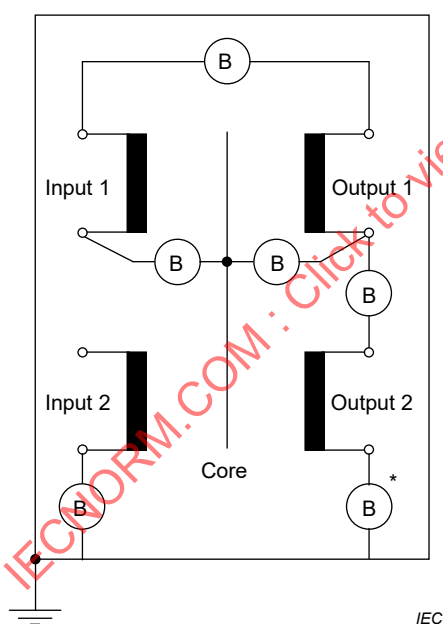
Examples of for checking points of application of dielectric strength test voltages

~~NOTE—Numbers in circles refer to certain items in Table 8a. Other methods of construction or layout may be used.~~

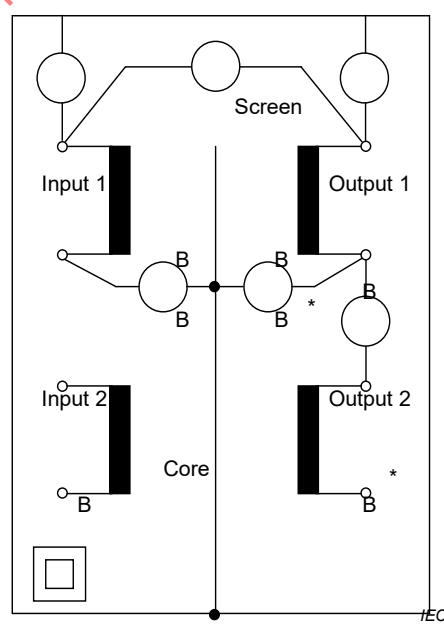
Figure N.1, Figure N.2 and Figure N.3 are specified for a separating transformer according to IEC 61558-2-1.

Explanation of test voltage value requirements for different types of insulation using the example of a separating transformer (see 19.1.3):

- (F) functional insulation (e.g. for polyfilar windings according to Table 20, Table 21 and Table 22)
- (B) basic insulation
- (B)* basic insulation (for the level of the applied voltage to the output winding)
- (S) supplementary insulation
- (D) double or reinforced insulation



a) Transformer of class I construction



b) Transformer of class I construction
with earthed metal screen

Figure N.1 – Transformer of class I construction with metal enclosure

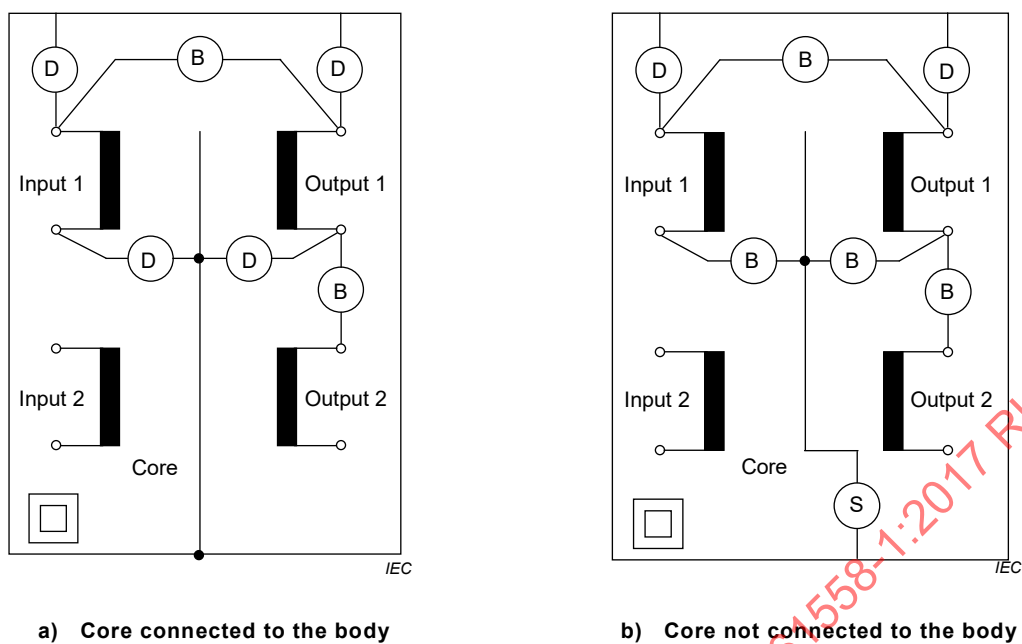


Figure N.2 – Transformer of class II construction with metal enclosure

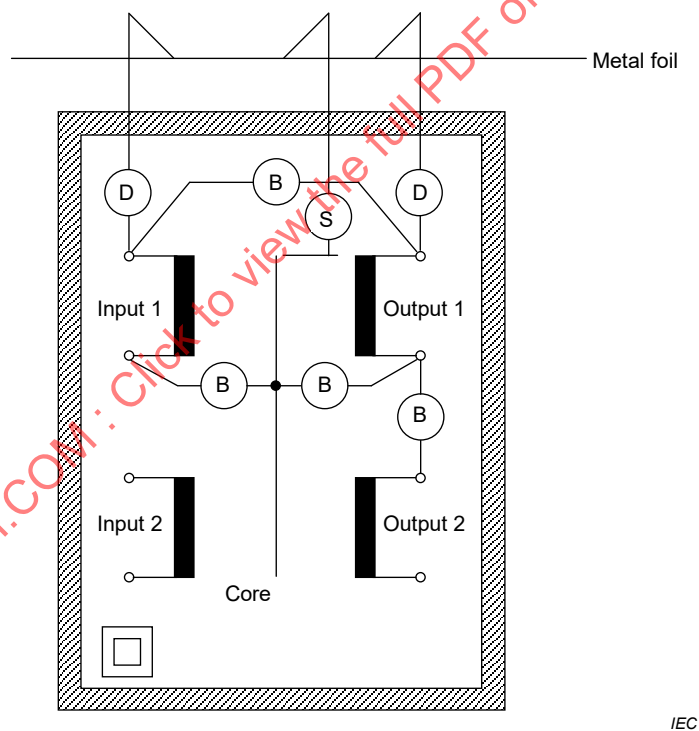


Figure N.3 – Transformer of class II construction with enclosure of insulating material

Annex O

(void)

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Annex P (informative)

Examples of measurement points of creepage distances and clearances

NOTE Numbers in circles refer to certain items in Table 13, Table C.1 and Table D.1. Other methods of construction or layout may be used.

Figure P.1, Figure P.2, Figure P.3 and Figure P.4 are specified for a separating transformer according to IEC 61558-2-1.

Explanation using the example of an separating transformer where each insulation is required (see 19.1.3):

(F) functional insulation (e.g. for polyfilar windings according to Table 20, Table 21 and Table 22)

(B) basic insulation

(B)* basic insulation (for the level of the applied voltage to the output winding)

(S) supplementary insulation

(D) double or reinforced insulation

(C) between terminals for the connections (see Table 23)

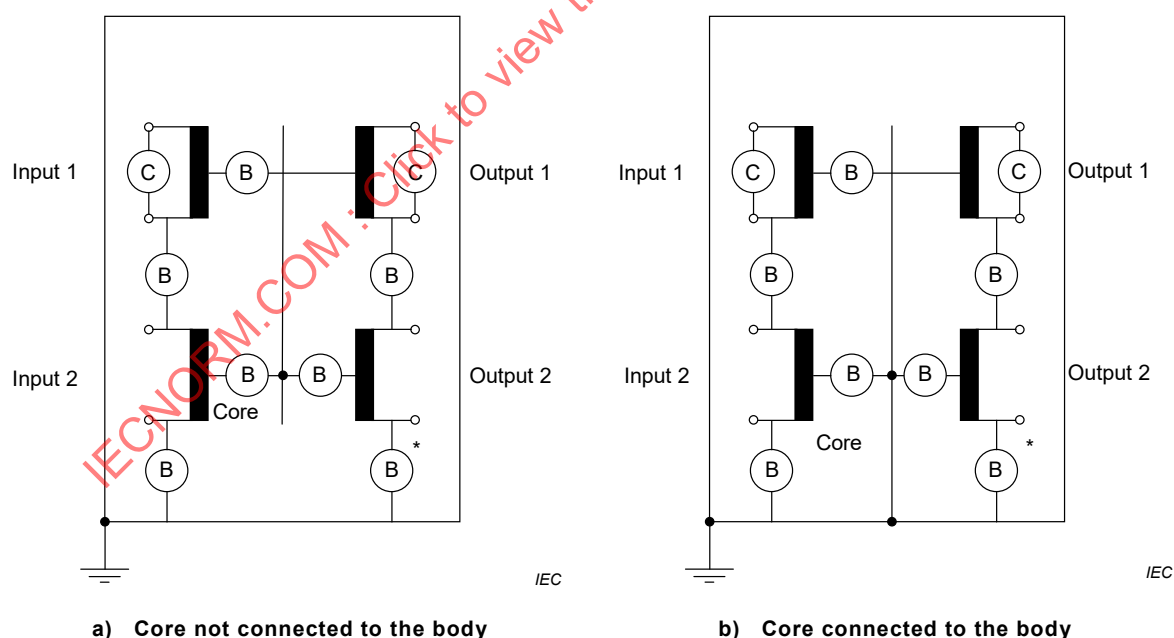


Figure P.1 – Transformer of class I construction

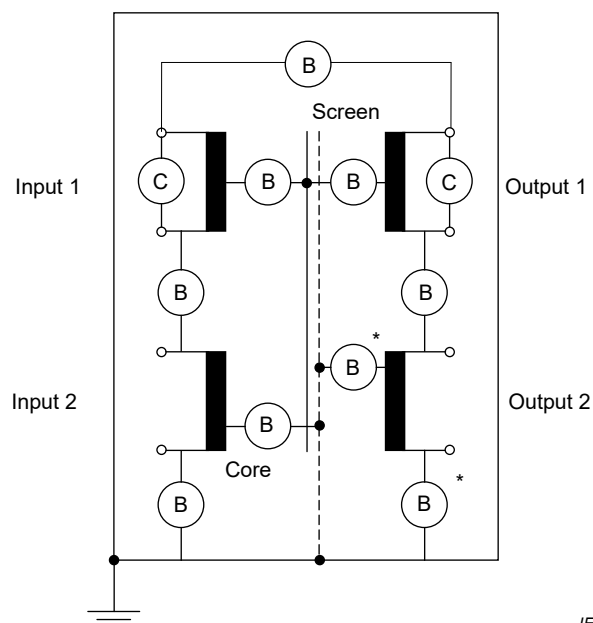


Figure P.2 – Transformer of class I construction with earthed metal screen

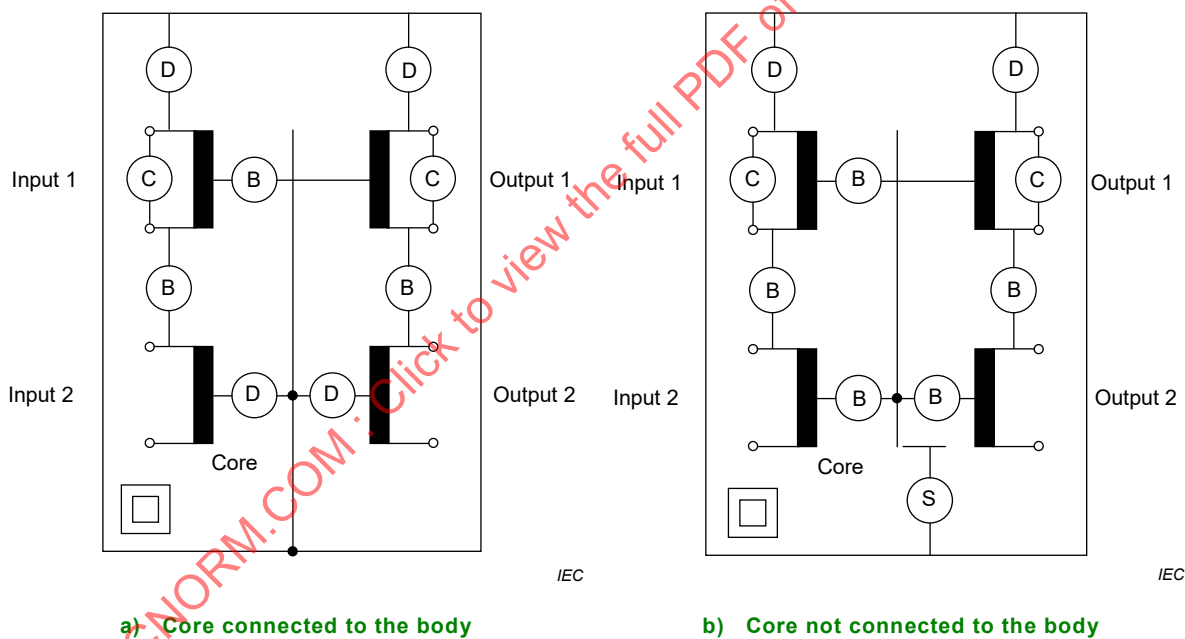
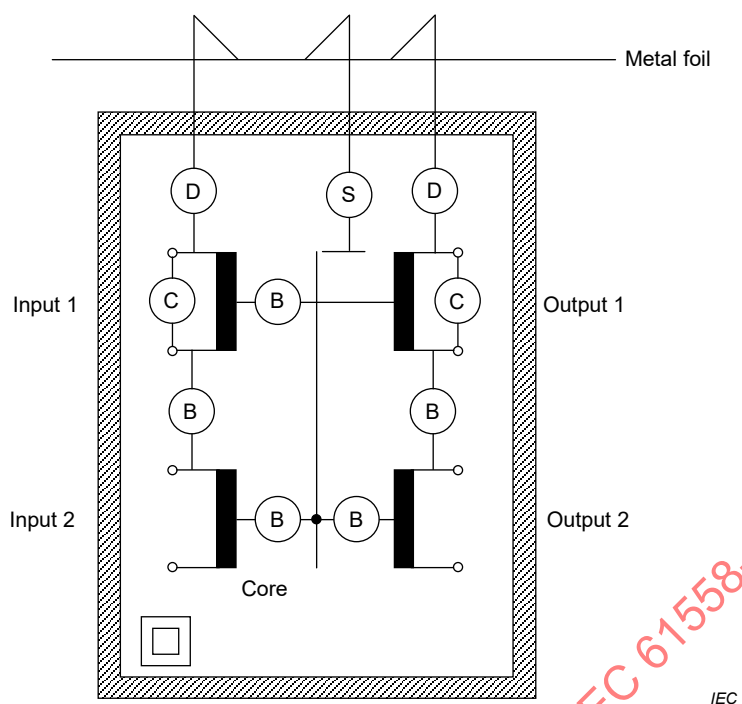


Figure P.3 – Transformer of class II construction with metal enclosure



IEC

Figure P.4 – Transformer of class II construction with enclosure of insulating material

Annex Q (informative)

Explanation of IP numbers for degrees of protection

Q.1 General

For full details see IEC 60529 from which the following is an extract.

The designation indicating the degrees of protection consists of the characteristic letters IP followed by two numerals (the "characteristic numerals") indicating conformity with the conditions stated in Tables Q.1, Table Q.2 and Table Q.3 respectively. The first numeral indicates the degree of protection described under item Q.2 a) and b) and the second numeral the degree of protection described under item Q.3.

An additional letter (optional) may be used to indicate the degree of protection against the access to hazardous parts more detailed (see IEC 60529:1989, Clause 7).

A supplementary letter (optional) may be used for supplementary information (see IEC 60529:1989, Clause 8).

~~Q.2 Protection of the equipment inside the enclosure against harmful ingress of water.~~

Q.2 Degrees of protection against access to hazardous parts and against solid foreign objects

The type of protection covered by this system of classification is as follows:

- a) protection of persons against contacts with, or approach to, **live parts** and against contact with moving parts (other than smooth rotating shafts and the like) inside the **enclosure**;
- b) protection of the equipment against ingress of solid foreign objects.

Table Q.1 – Degrees of protection against access to hazardous parts indicated by the first characteristic numeral

First characteristic numeral	Degree of protection	
	Short description	Brief details of objects which will be "excluded" from the enclosure
0	Non-protected	No special protection
1	Protected against solid objects greater than 50 mm	A large surface of the body, such as a hand (but no protection against deliberate access). Solid objects exceeding 50 mm in diameter
2	Protected against solid objects greater than 12,5 mm	Fingers or similar objects not exceeding 80 mm in length. Solid objects exceeding 12,5 mm in diameter
3	Protected against solid objects greater than 2,5 mm	Tools, wires, etc., of diameter or thickness greater than 2,5 mm. Solid objects exceeding 2,5 mm in diameter
4	Protected against solid objects greater than 1,0 mm	Wires or strips of thickness greater than 1,0 mm. Solid objects exceeding 1,0 mm in diameter
5	Dust-protected	Ingress of dust is not totally prevented but dust does not enter in sufficient quantity to interfere with satisfactory operation of the equipment
6	Dust-tight	No ingress of dust

First characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non-protected	-
1	Protected against access to hazardous parts with the back of a hand	The access probe, sphere of 50 mm Ø, shall have adequate clearance from hazardous parts.
2	Protected against access to hazardous parts with a finger	The jointed test finger of 12 mm Ø, 80 mm length, shall have adequate clearance from hazardous parts
3	Protected against access to hazardous parts with a tool	The access probe of 2,5 mm Ø shall not penetrate.
4	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm Ø shall not penetrate.
5	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm Ø shall not penetrate.
6	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm Ø shall not penetrate.

Due to the simultaneous requirement specified in Table Q.2, the definition "shall not penetrate" is given in Table Q.2

NOTE In case of the first characteristic numerals 3,4,5 and 6, protection against access to **hazardous-live-parts** is satisfied if adequate clearance is kept.

Table Q.2 – Degrees of protection against solid foreign objects indicated by the first characteristic numeral

First characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non-protected	-
1	Protected against solid foreign objects of 50 mm Ø and greater	The object probe, sphere of 50 mm Ø, shall not fully penetrate ¹⁾
2	Protected against solid foreign objects of 12,5 mm Ø and greater	The object probe, sphere of 12,5 mm Ø, shall not fully penetrate ¹⁾
3	Protected against solid foreign objects of 2,5 mm Ø and greater	The object probe of 2,5 mm Ø, shall not penetrate at all. ¹⁾
4	Protected against solid foreign objects of 1,0 mm Ø and greater	The object probe of 1,0 mm Ø, shall not penetrate at all. ¹⁾
5	Dust-protected	Ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the apparatus or to impair safety
6	Dust-tight	No ingress of dust
¹⁾ The full diameter of the object probe shall not pass through an opening of the enclosure.		

Q.3 Degrees of protection against ingress of water

Protection of the equipment inside the **enclosure** against harmful ingress of water.

Table Q.3 – Degrees of protection indicated by the second characteristic numeral

Second characteristic numeral	Degree of protection	
	Short description	Details of the type of protection provided by the enclosure
0	Non-protected	No special protection
1	Protected against dripping water	Dripping water (vertically falling drops) shall have no harmful effect
2	Protected against dripping water when enclosure tilted up to 15°	Vertically dripping water shall have no harmful effect when the enclosure is tilted at any angle up to 15° from its normal position
3	Protected against spraying water	Water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effects Water falling as a spray at an angle up to 60° from the vertical shall have no harmful effect
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effect
5	Protected against water jets	Water projected by a nozzle against the enclosure from any direction shall have no harmful effect
6	Protected against powerful waterjet	Water projected in powerful jets shall not enter the enclosure in harmful quantities
7	Protected against the effects of temporary immersion in water	Ingress of water in a harmful quantity shall not be possible when the enclosure is temporarily immersed in water under defined conditions of pressure and time
8	Protected against the effects of continuous immersion in water	The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer ^a
^a Normally, this will mean that the equipment is hermetically sealed. However, with certain types of equipment it can mean that water can enter but only in such a manner that it produces no harmful effects.		

Second characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non-protected	-
1	Protected against vertically falling water drops	Vertically falling drops shall have no harmful effects
2	Protected against vertically falling water drops when enclosure tilted up to 15°	Vertically falling drops shall have no harmful effects when the enclosure is tilted at any angle up to 15° on either side of the vertical
3	Protected against spraying water	Water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effects
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effects
5	Protected against water jets	Water projected in jets against the enclosure from any direction shall have no harmful effects
6	Protected against powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effects
7	Protected against the effects of temporary immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under standardized conditions of pressure and time
8	Protected against the effects of continuous immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is continuously immersed in water under conditions which shall be agreed between manufacturer and user but which are more severe than for numeral 7
9	Protected against high pressure and temperature water jets	Water projected at high pressure and high temperature against the enclosure from any direction shall not have harmful effects

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Annex R (normative)

Explanations of the application of ~~4.1.1.2.1~~ 6.1.2.2.1 of IEC 60664-1:2007 (~~see 26.2~~)

R.1 Impulse dielectric test

- wave-form: 1,2 / 50 µs
- three impulses of each polarity
- interval between impulses at least 1 s
- impulse voltage according to Table F.5 of IEC 60664-1:2007
- rated impulse voltage according to **working voltage** and overvoltage category of Table F.1 of IEC 60664-1:2007
- for **double** or **reinforced insulation** the next higher value according to ~~2.1.1.2~~ 4.2.3 of IEC 60664-1:2007 is to be used (see ~~3.1.5~~ 5.1.6 of IEC 60664-1:2007). With this value the applicable impulse voltage in Table F.5 of IEC 60664-1:2007 can be found.
- An abstract of the impulse test voltage according to 6.1.2.2.1 of IEC 60664-1:2007 can be found in Table R.1.

R.2 Example

Working voltage: 300 V (r.m.s.) OVC III

- ⇒ according to Table F.1: 4 000 V (rated impulse voltage)
- ⇒ **double insulation** ⇒ 6 000 V (next higher value according to ~~2.1.1.2~~ 4.2.3 rated impulse voltage)
- ⇒ according to Table F.5 (6 000 V) = ~~7.3~~ 7,385 kV (impulse test voltage at sea level)

Table R.1 – Impulse test voltage according to ~~4.1.1.2.1~~ 6.1.2.2.1 of IEC 60664-1:2007

Working voltage	Overtoltage category IV		Overtoltage category III		Overtoltage category II		Overtoltage category I	
	Double or reinforced insulation	Basic insulation	Double or reinforced insulation	Basic insulation	Double or reinforced insulation	Basic insulation	Double or reinforced insulation	Basic insulation
V AC	V AC	V AC	V AC	V AC	V AC	V AC	V AC	V AC
50	2 920	1 751	~~1 750~~ 1 751	~~910~~ 934	934	541	541	357
100	4 923	2 920	~~2 950~~ 2 920	~~1 750~~ 1 751	1 751	934	934	541
150	7 385	4 923	~~4 800~~ 4 923	~~2 950~~ 2 920	2 920	1 751	1 751	934
300	9 847	7 385	~~7 300~~ 7 385	~~4 800~~ 4 923	4 923	2 920	2 920	1 751
600	14 770	9 847	~~9 800~~ 9 847	~~7 300~~ 7 385	7 385	4 923	4 923	2 920
1 000	n.a.	14 770	~~14 800~~ 14 770	~~9 800~~ 9 847	9 847	7 385	7 385	4 923

Values of test voltage for intermediate values of **working voltage** are found by interpolation between tabulated values.

Example:

AC 230 V	~~6 130~~ 8 698 V	~~3 940~~ 6 236 V	~~3 940~~ 6 236 V	~~2 390~~ 3 989 V	3 989 V	2 375 V	2 375 V	1 370 V

NOTE Definitions of **overvoltage categories** are given in ~~2.2.2.1~~ 4.3.3.2 of IEC 60664-1:2007.

Transformers for general use are in **overvoltage category III** or higher.

Transformers e.g. for use in household appliances or audio/video, information and communication technology equipment are in **overvoltage category II** or higher.

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Annex S

(void)

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Annex T

(void)

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Annex U (void) (informative)

Optional t_w -marking of transformers

For ~~transformers~~ with t_w marking, the following requirements apply additionally.

Based on empirical data, the t_w test is only applicable to ~~transformers~~ with a **rated output** up to 1 000 VA. Similarly, the maximum t_w temperature has been limited to 140 °C.

For checking the rated maximum operating temperature t_w , this standard specifies an endurance test period of 30 days as the standard method. In other standards where t_w marking occurs other test periods may be used.

This standard permits the use of constants S other than 4 500 in t_w tests. If a claim is not made to the contrary, the endurance testing of ~~transformers~~ is based on the constant S , given in U.5.2, having a value of 4 500. A manufacturer may claim the use of other values if this can be justified by either of the tests specified.

Windings of t_w -marked ~~transformers~~ shall have adequate thermal endurance.

Compliance is checked by applying the indicated changes in the different clauses/subclauses specified and by carrying out the tests described.

U.1 General notes on tests (addition to Clause 5)

Introduce the following third and fourth paragraphs in 5.2:

For t_w -marked ~~transformers~~ the type test is carried out on one sample consisting of eight ~~transformers~~ submitted for the purpose of type test. Seven ~~transformers~~ are for the endurance test and one for all other tests. For conditions of compliance test, see 14.4.

The t_w tests are made under the conditions specified in U.5. In general all tests are made for each type of ~~transformer~~ or, where a range of similar ~~transformers~~ is involved, for each **rated output** in the range or on a representative selection from the range as agreed with the manufacturer. A reduction of the number of samples for the endurance test according to 14.4 including the use of constants S other than 4 500 according to U.5.2, or even the omission of these tests is allowed when ~~transformers~~ of the same construction but with different characteristics are submitted together for approval, or when test reports from the manufacturer or other authority are accepted by the testing station.

Amend the present fifth paragraph of 5.2 as follows: "... in 14.3 and 14.4."

U.2 Heating (addition to Clause 14)

Change the heading of Clause 14 to "**Heating and endurance**".

Add the following phrase to the first sentence in 14.1:

"... and windings shall have adequate thermal endurance."

Amend the second paragraph of 14.1 to read as follows:

~~"Compliance is checked by the test of 14.2 when the temperature of Table 1 shall not be exceeded. When applicable, the thermal endurance of windings is checked by the tests in 14.3 or 14.4. Moreover, the following conditions apply to the windings of not t_w -marked transformers. Materials in windings complying with the requirements in 14.4 are regarded as classified materials."~~

~~Add the following sentence to the end of the ninth paragraph of 14.1:~~

~~For the determination of the average temperature of a winding with t_w -marking the test voltage shall not be increased.~~

~~Introduce the following new first indent in Table 1:~~

Parts	Temperature °C
– with t_w -marking	t_w

~~Introduce the following new subclause 14.4:~~

~~14.4 Thermal endurance~~

~~Windings of t_w -marked transformers shall have adequate thermal endurance.~~

~~Compliance is checked by the following test.~~

~~The windings of the transformers are subjected to the thermal endurance test described in U.5. The test is carried out on seven new transformers, which have been subjected to measurements according to 11.1. They shall not be used for further testing.~~

~~This test may also be applied to transformers which form an integral part of an appliance and which cannot be tested separately, thereby enabling such integral transformers to be assigned with a t_w -value.~~

~~The thermal conditions shall be so adjusted that the objective duration of the test is as indicated by the manufacturer. If no indication is given, the test period shall be 30 days.~~

~~After the test, when the transformers have returned to room temperature, they shall satisfy the following requirements:~~

- ~~a) The output voltage shall not have changed from the value measured before the test by more than the percentages given for the relevant type of transformer in 11.1.~~

~~NOTE This test is to determine any adverse change in the transformer setting.~~

- ~~b) The insulation resistance between the input and output winding(s) for safety isolating, isolating and separating transformers and for all kind of transformers between winding(s) and the transformer enclosure/body measured at 500 V d.c. shall be not less than 1 M Ω .~~

- ~~c) The transformer shall withstand a dielectric strength test; the test voltage being 35 % of the values specified in Clause 18 Table 8a. The test voltage is applied as specified in item b) above.~~

~~The result of the test is considered to be satisfactory if at least six of the seven transformers satisfy these requirements. The test is considered to be failed if more than two transformers fail the test.~~

~~In the case of two failures, the test is repeated with seven more transformers and no failure of these transformers is permitted.~~

U.3 — Short circuit and overload protection (addition to Clause 15)

Add the following new column at the right side of Table 3:

Insulation classification		t_w
Retain the present text without change		See Table U.1

Introduce the following new table U.1:

Table U.1 — Example of maximum temperatures of windings under short circuit or overload conditions and at 110 % of rated voltage for transformers subjected to an endurance test duration of 30 days and a life expectancy of 10 years

Constant S	Maximum temperature °C					
	S4.5	S5	S6	S8	S11	S16
For $t_w = 90$	171	161	147	131	119	110
95	178	168	154	138	125	115
100	186	176	161	144	131	121
105	194	183	168	150	137	126
110	201	190	175	156	143	132
115	209	198	181	163	149	137
120	217	205	188	169	154	143
125	224	212	195	175	160	149
130	232	220	202	182	166	154
135	240	227	209	188	172	160
140	248	235	216	195	178	166
Unless otherwise indicated on the transformer, the limiting temperatures specified in column S4.5 apply.						
Maximum temperatures for a life expectancy of 5 years will be found by calculation using Equation (U.2) in U.5.1						

U.4 — Testing a series of transformers (modification to Annex B)

Change Annex B as follows:

Clause B.1

Replace the first line of item c) by the following:

c) They are designed for the same minimum and maximum ambient temperature and, if relevant, for the same t_w -marking.

Clause B.2

Add the following new item d):

- d) for t_w -marked **transformers**, the parameters above apply with the addition that the samples used for the thermal endurance test shall be of the type in the series having the highest current density (i.e. the highest current per mm² copper conductor area).

U.5 — General requirements and information about thermal endurance test on windings

U.5.1 — Thermal endurance test

The test is carried out in an appropriate oven.

~~The transformer shall function electrically in a manner similar to that in normal use, and in the case of capacitors, components or other auxiliaries which should not be subjected to the test, these shall be disconnected and reconnected again in the circuit but outside the oven. Other components which do not influence the operating conditions of the windings may be removed.~~

~~Transformers incorporating a protective device shall comply with the thermal endurance test on windings with the protector short-circuited.~~

NOTE 1 In the case, e.g. of type testing, where it is necessary to short-circuit protectors and disconnect capacitors, components or other auxiliaries which should not be subjected to the test, it is recommended that the manufacturer supplies special **transformers** with these parts short-circuited or removed and if applicable, any necessary additional connections brought out from the **transformer**.

~~In general, to obtain normal operating conditions, the transformer is tested with the rated output.~~

~~The transformer enclosure, if of metal, is earthed. Loads are always kept outside the oven.~~

~~The seven transformers are placed in the oven, and the rated voltage applied to each of the circuits.~~

~~The oven thermostats are then regulated so that the internal temperature of the oven attains a value such that the temperature of the hottest winding in each of the transformers is approximately equal to the objective value given in Table U.2.~~

Table U.2 – Theoretical test temperatures for transformers subjected to an endurance test duration of 30 days and a life expectancy of 10 years

Constant S	Theoretical test temperatures t °C					
	S4.5	S5	S6	S8	S11	S16
For $t_w = -90$	163	155	142	128	117	108
95	171	162	149	134	123	113
100	178	169	156	140	128	119
105	185	176	162	146	134	125
110	193	183	169	152	140	130
115	200	190	175	159	146	136
120	207	197	182	165	152	141
125	215	204	189	171	157	147
130	222	211	196	177	163	152
135	230	219	202	184	169	158
140	238	226	209	190	175	163
Unless otherwise indicated on the transformer , the theoretical test temperatures specified in column S4.5 apply. The use of a constant other than S4.5 shall be justified in accordance with U.5.2						
Theoretical test temperatures for a life expectancy of 5 years will be found by calculation using Equation (U.2) of this clause.						

After 4 h, the actual temperature of the winding is determined by the "change in resistance" method, and if necessary the oven thermostats are readjusted to approximate as closely as possible the objective test temperature. Thereafter a daily reading of the air temperature in the oven is taken to ensure that the thermostats are maintained at the correct value to within $\pm 2^\circ\text{C}$.

The winding temperatures are measured again after 24 h and the final test period for any transformer is determined from Equation (U.2). Figure U.1 illustrates this in graphical form. The permissible difference between the actual temperature of the hottest winding of any of the transformers under test and the theoretical value shall be such that the final test period is at least equal to, but not more than twice, the objective test period.

NOTE 2 – For the measurement of winding temperature by the "change in resistance" method, the following Equation (U.1) is applicable:

$$t_2 = \frac{R_2}{R_1} (234,5 + t_1) - 234,5 \quad (\text{U.1})$$

where:

t_1 — initial temperature ($^\circ\text{C}$);

t_2 — final temperature ($^\circ\text{C}$);

R_1 — resistance at temperature t_1 ;

R_2 — resistance at temperature t_2 .

The constant 234,5 relates to copper windings, for aluminium this constant should be 225.

~~No attempt shall be made to hold the winding temperature constant after the measurement at 24 h. Only the ambient air temperature shall be stabilized by the thermostatic control.~~

~~The test period for each transformer starts from the time the transformer is connected to the supply. At the end of its test, the relevant transformer is disconnected from the supply, but is not removed from the oven until the test on the other transformer have been completed.~~

NOTE 3—The theoretical test temperatures given in Table U.2 correspond to a working life of 10 years continuous operation at the rated maximum operating temperature t_w .

~~They are computed using the following equation (see Figure U.B1):~~

$$\log L = \log L_o + S \left(\frac{1}{T} - \frac{1}{T_w} \right) \quad (\text{U.2})$$

~~where:~~

~~L is the objective endurance test life in days (30)~~

~~L_o is 3 652 days (10 years)~~

~~T is the theoretical test temperature ($t + 273$) K~~

~~T_w is the rated maximum operating temperature ($t_w + 273$) K~~

~~S is the constant depending on the design of the transformer and the materials used. If no claim is made to the contrary, S is taken to be 4 500 but a manufacturer may claim the use of other values if this is justified by the relevant tests.~~

~~Consequently the endurance test can be carried out in a much shorter time than 10 years or the chosen life expectancy at a related higher winding temperature.~~

~~U.5.2 The use of constants S other than 4 500 in t_w tests~~

~~U.5.2.1 The tests outlined in this annex are intended to enable the manufacturer to prove a claimed value of S other than 4 500.~~

~~Theoretical test temperatures T for use in ballast endurance tests are calculated from equation (U.2) in U.5.1.~~

~~If no claim is made to the contrary, S shall be taken to be 4 500 but a manufacturer may claim the use of any of the values in Table U.2 if this can be justified by procedures a) and b) below.~~

~~If the use of a constant other than 4 500 for a particular transformer has been proved on the basis of procedures a) and b), then that constant may be used in endurance tests for that transformer and others using the same construction and materials.~~

~~U.5.2.2 Procedure a)~~

~~The manufacturer submits experimental data relating life to winding temperature for the transformer design concerned, based on enough samples, but no fewer than 30.~~

~~From these data, the regression line relating T to $\log L$, together with the 95 % confidence lines associated with it, are computed.~~

~~A straight line is then drawn through the points where the 10 days and 120 days abscissae intersect the upper and lower 95 % confidence lines respectively. See Figure U.2 for a typical presentation. If the inverse of the slope of this is greater than or equal to the claimed value of S , then the latter has been proved within 95 % confidence limits. For failure criteria, see procedure b).~~

NOTE 1 The points at 10 days and 120 days represent the smallest interval needed for the application of the confidence lines. Other points may be used provided a similar or greater interval is covered.

NOTE 2 Information in respect of the techniques involved and the method of calculating regression lines at confidence limits are given in IEC 60216.

U.5.2.3 Procedure b)

The testing authority shall test 14 new **transformers** submitted by the manufacturer in addition to those required for the endurance test, divided at random into two groups of seven. The manufacturer shall state the value of S claimed and the test temperature T_1 , required to achieve a nominal average **transformer** life of 10 days, together with the corresponding test temperature T_2 , for a nominal average **transformer** life of at least 120 days, calculated using T_1 and the claimed value of S in the following version of the Equation (U.2).

$$\frac{1}{T_2} = \frac{1}{T_1} + \frac{1}{S} \log \frac{120}{10} \text{ or } \frac{1}{T_2} = \frac{1}{T_1} + \frac{1\,079}{S} \quad (\text{U.3})$$

where

T_1 = theoretical test temperature in K for 10 days

T_2 = theoretical test temperature in K for 120 days

S = claimed constant

Endurance tests are then carried out using the basic method in U.5.1 on the two groups of seven **transformers**, based on the theoretical temperature T_1 (Test 1) and T_2 (Test 2) respectively.

If the current deviates more than 15 % from the initial value measured 24 h after the commencement of the test, the test is repeated at a lower temperature. The duration of the test is calculated with the help of Equation (U.2) in U.5.1. A **transformer** is considered to have failed if during operation in the oven:

a) the **transformer** becomes open circuit;

b) breakdown of the insulation occurs, as indicated by the operation of a fast acting fuse with a current rating of 150 % – 200 % of the initial supply current measured after 24 h.

Test 1, the duration of which shall be equal to or greater than 10 days, is continued until all the **transformers** have failed and the mean life L_1 , has been calculated from the mean of the logarithm of the individual lives at temperature T_1 . From this, the corresponding mean life L_2 at temperature T_2 is calculated with the help of another arrangement (Equation U.4) of Equation (U.2):

$$L_2 = L_1 \exp \left[\frac{S}{\log e} \frac{1}{T_2} - \frac{1}{T_1} \right] \quad (\text{U.4})$$

where

L_1 is the mean life

L_2 is the corresponding mean life (the mean life for T_2)

T_1 is the theoretical test temperature in K for 10 days

T_2 is the theoretical test temperature in K for 120 days

S is the claimed constant

NOTE 1 Care should be taken to ensure that the failure of one or more **transformers** does not affect the temperature of the remaining **transformers** on test.

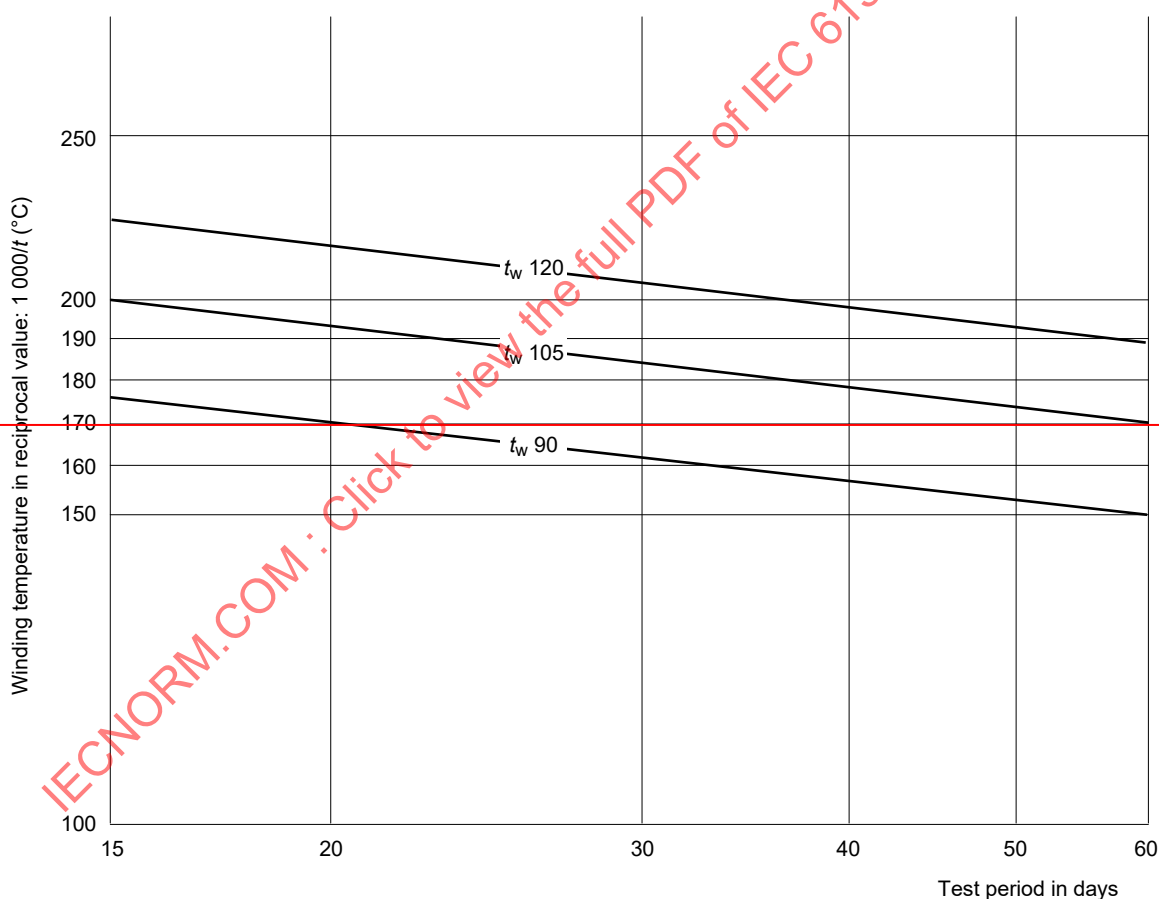
Test 2 is continued until such time as the mean life at temperature T_2 exceeds L_2 ; this result implies that the constant for the sample is at least that claimed. If all the samples in Test 2 fail before the mean life reaches L_2 , then the constant claimed for the samples has not been verified.

The test lives shall be normalized from the actual test temperature to the theoretical test temperature using the claimed constant S .

NOTE 2 It is not generally necessary to continue Test 2 until all the transformers have failed. Calculation of the necessary duration of the test is simple but needs to be updated whenever a failure occurs.

In the case of transformers incorporating temperature sensitive materials, a nominal transformer life of 10 days might not be appropriate. In such cases, the manufacturer may adopt a longer life providing this is shorter than the appropriate endurance test period of 30 days. In such cases, the longer nominal transformer life shall be at least ten times that of the shorter (e.g. 15/150 days, 18/180 days, etc.).

These curves are for information only and illustrate equation (2) using a constant S of 4 500 (see Annex U.1).



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Figure U.1 – Relation between winding temperature and endurance test duration

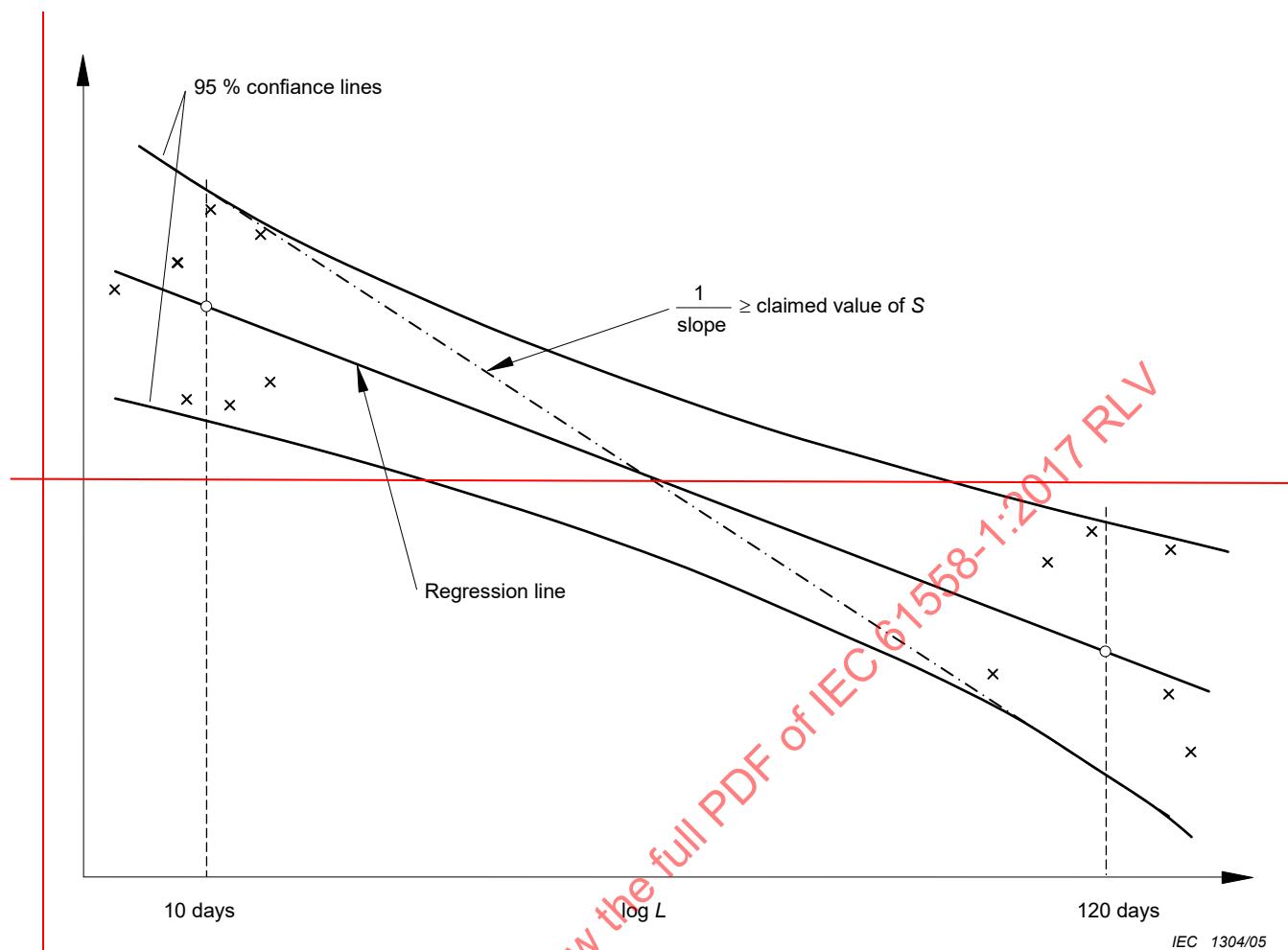


Figure U.2 – Assessment of claimed value of S

Annex V (informative)

Symbols to be used for thermal cut-outs

V.1 Introduction General

The purpose of this annex is to give information to the equipment manufacturer and the end user on the way to proceed for resetting the **transformer** after operation of the thermal cut-out.

When the symbols are used, they are intended for information. In the future, when they are known and recognized, the intention is to make them mandatory.

The symbols, when used, are placed on the **transformer**. They apply to both **independent** and **associated transformers**.

Figure V.1, Figure V.2, Figure V.3 and Figure V.4 should be used.

NOTE θ is the symbol used to show that the device is operated by temperature.

V.2 Non-self-resetting thermal cut-out (see 3.3.4)

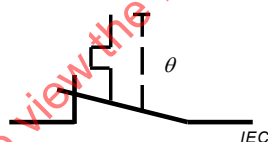


Figure V.1 – Restored by manual operation

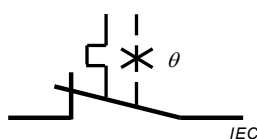


Figure V.2 – Restored by disconnection of the supply

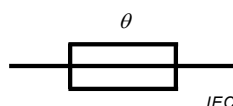


Figure V.3 – Thermal link (see 3.3.5)

V.3 Self-resetting thermal cut-out (see 3.3.3)

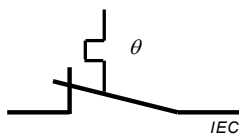


Figure V.4 – Self-resetting thermal cut-out

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Annex W (normative)

Coated printed circuit boards

W.1 Preamble

The testing of protective coatings of printed circuit boards is carried out in accordance with IEC 60664-3 with the modifications described in W.2 to W.5.

W.2 General

The requirements of 5.1 of IEC 60664-3:2016 apply, but when production samples are used, three samples of the printed circuit board are tested

W.3 Cold

The test of 5.7.2 of IEC 60664-3:2016 is carried out at –25 °C.

W.4 Rapid change of temperature

In the requirement of 5.7.4 of IEC 60664-3:2016, severity 1 is specified.

W.5 Additional tests

The requirements of 5.9 of IEC 60664-3:2016 are not applicable.

Bibliography

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GROUP SAFETY PUBLICATION
PUBLICATION GROUPEE DE SÉCURITÉ

**Safety of transformers, reactors, power supply units and combinations thereof –
Part 1: General requirements and tests**

**Sécurité des transformateurs, bobines d'inductance, blocs d'alimentation et
des combinaisons de ces éléments –
Partie 1: Exigences générales et essais**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SAFETY OF TRANSFORMERS, REACTORS,
POWER SUPPLY UNITS AND COMBINATIONS THEREOF –****Part 1: General requirements and tests****FOREWORD**

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International Standard IEC 61558-1 has been prepared by IEC technical committee 96: Transformers, reactors, power supply units and combinations thereof.

This third edition cancels and replaces the second edition published in 2005 and Amendment 1:2009. This edition constitutes a technical revision.

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

- a) fully insulated winding wires (FIW), new tables and aging tests for FIW constructions,
- b) overvoltage categories 1, 2, 3 and 4 for clearances and dielectric strength tests (new tables) are included,
- c) development of new symbols for the different overvoltage categories,
- d) symbol for maximum altitudes, if higher than 2 000 m,
- e) symbol for plug in power supply units, if the pins are damaged (tumbling barrel test),

- f) symbol for minimum temperature (even during the transportation),
- g) alternative temperature measurement, simulated load and back to back method according to IEC 60076-11,
- h) short circuit and overload protection, simulated load and back to back method according to IEC 60076-11,
- i) adjustment of temperatures in Table 2 according to CENELEC Guide 29,
- j) establishing partial discharge test above 750 V for FIW constructions,
- k) requirements for toroidal core constructions, division for basic and for supplementary isolation,
- l) modification of protection indexes for enclosures (IP-code),
- m) dimensioning of rectangular cross section connectors for transformers,
- n) repetition test, 80 % of required dielectric strength test voltage of Table 14,
- o) vibration test for vehicles and railway applications,
- p) two Y1 Capacitors for working voltages above 250 V and not exceeding 500 V with overvoltage category 3.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
96/466/FDIS	96/468/RVD

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

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

It has the status of a group safety publication in accordance with IEC Guide 104.

A list of all parts of the IEC 61558 series, published under the general title *Safety of transformers, reactors, power supply units and combination thereof*, 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.

In this document, the following print types are used:

- proper requirements: in roman type;
- *test specifications: in italic type;*
- explanatory matters: in smaller roman type.

In the text of the document, the words in **bold** are defined in Clause 3.

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

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

INTRODUCTION

This document covers safety requirements for **transformers**. Where the term **transformer** is used, it covers **transformers**, **reactors** and **power supply units** where applicable.

During the development of this document, to the extent possible, the requirements of IEC 60364 (all parts) were taken into consideration, so that a **transformer** can be installed in accordance with the wiring rules contained in that document. However, national wiring rules can differ.

This document recognizes the internationally accepted levels of protection against the possible electrical, mechanical, and fire hazards caused by **transformers** operating under normal conditions in accordance with the manufacturer's instructions. It also covers abnormal conditions which can occur in practice.

A **transformer** complying with this document will not necessarily be judged to comply with the safety principles of this document if, when examined and tested, it is found to have other features that impair the level of safety covered by these requirements.

A **transformer** employing materials or having forms of construction differing from those detailed in this document may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the safety principles of this document.

The document dealing with non-safety aspects of electromagnetic compatibility (EMC) of **transformers** is IEC 62041. However, that document also includes tests that can subject the **transformer** to conditions involving safety aspects.

The objective of IEC 61558-1 is to provide a set of requirements and tests considered to be generally applicable to most types of **transformers**, and which can be called up as required by the relevant part of IEC 61558-2. IEC 61558-1 is thus not to be regarded as a specification by itself for any type of **transformer**, and its provisions apply only to particular types of **transformers** to the extent determined by the appropriate part of IEC 61558-2. IEC 61558-1 also contains normative routine tests.

Each part of IEC 61558-2 in conjunction with this document contains all the necessary requirements for the **transformer** being covered and does not contain references to other parts of IEC 61558-2. For **transformers** with a protection index IP00 and associated **transformers**, it is possible to have circuits corresponding to different parts of IEC 61558-2 within the same construction (e.g. SELV output circuit according to IEC 61558-2-6 and a 230 V output circuit according to IEC 61558-2-4). However, if the **transformer** is covered by different parts IEC 61558-2, to the extent reasonable, the relevant part of IEC 61558-2 is applied to each function/application separately. If applicable, the effect of one function on the other is taken into consideration.

If an appropriate part of IEC 61558-2 does not exist for a particular **transformer** or group of **transformers**, the nearest applicable part may be used as a guide to the requirements and tests.

However, individual countries may wish to consider its application, to the extent reasonable, to transformers not mentioned in the IEC 61558-2 series, and to transformers designed on new principles.

Where the requirements of any of the clauses of a part of IEC 61558-2 refer to IEC 61558-1 by the phrase "This clause of Part 1 is applicable", this phrase means that all the requirements of that clause of IEC 61558-1 are applicable, except those requirements that are clearly not applicable to the particular type of **transformer** covered by that part of IEC 61558-2.

The principle for the preparation of the different parts of IEC 61558-2 is as shown in Figure 1.

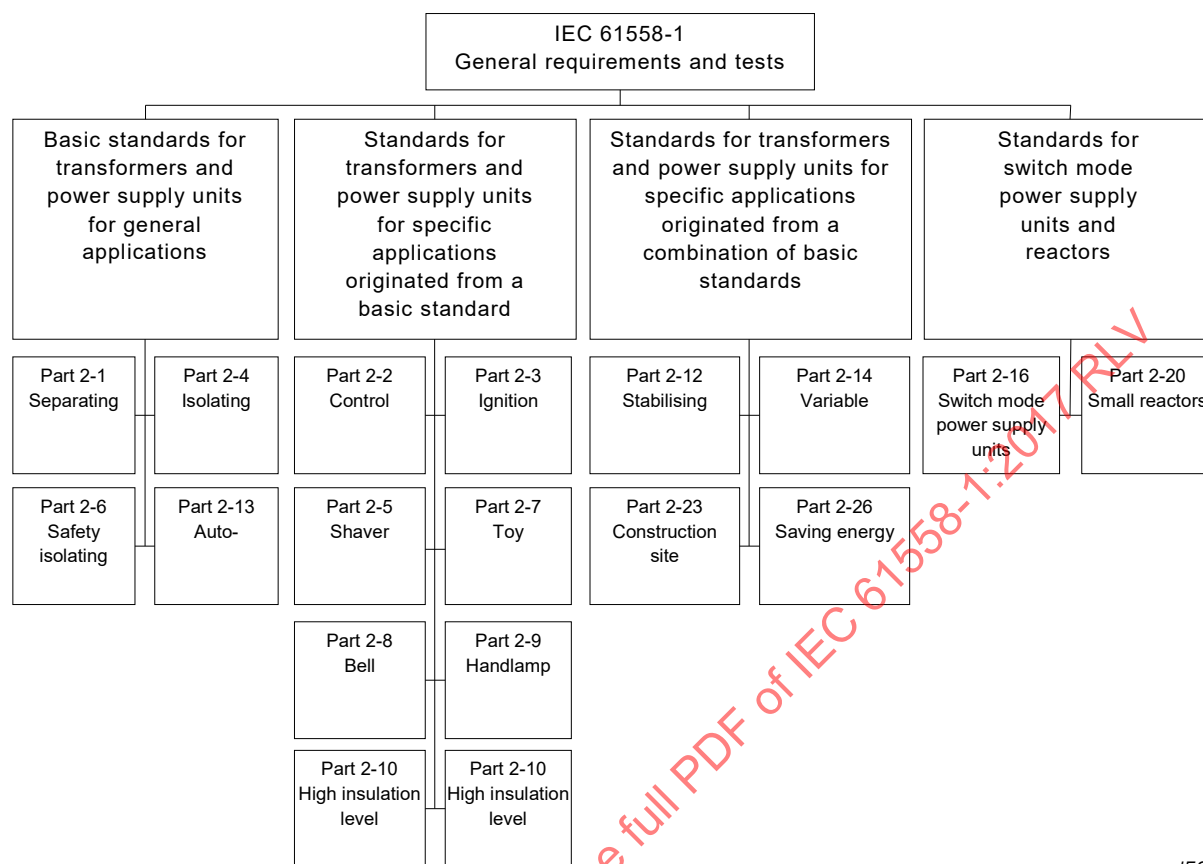


Figure 1 – IEC 61558 principle

Relevant clauses of this document (e.g. clauses dealing with thermal endurance test for windings) apply also to **transformers** forming an integral part of an appliance and which cannot be tested separately.

The IEC 61558 series consists of the following parts, under the general title *Safety of transformers, reactors, power supply units and combination thereof*:¹

- Part 1: General requirements and tests
- Part 2-1: Particular requirements and tests for separating transformers for general applications
- Part 2-2: Particular requirements and tests for control transformers
- Part 2-3: Particular requirements and tests for ignition transformers for gas and oil burners
- Part 2-4: Particular requirements and tests for isolating transformers
- Part 2-5: Particular requirements and tests for shaver transformers and shaver supply units
- Part 2-6: Particular requirements and tests for safety isolating transformers
- Part 2-7: Particular requirements and tests for transformers for toys
- Part 2-8: Particular requirements and tests for transformers for bells and chimes
- Part 2-9: Particular requirements and tests for transformers for class III handlamps for tungsten filament lamps

¹ Some of the parts of this series published earlier appeared under the general title *Safety of power transformers, power supplies, reactors and similar products* or *Safety of power transformers, power supply units and similar* or *Safety of power transformers, power supply units and similar devices*. Future editions of these parts will be issued under the new general title indicated above.

- Part 2-10: Particular requirements and tests for separating transformers with high insulation level and separating transformers with output voltages exceeding 1 000 V
 - Part 2-12: Particular requirements and tests for constant voltage transformers
 - Part 2-13: Particular requirements and tests for auto transformers
 - Part 2-14: Particular requirements and tests for variable transformers
 - Part 2-15: Particular requirements and tests for isolating transformers for the supply of medical locations
 - Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units
 - Part 2-20: Particular requirements and tests for small reactors
 - Part 2-23: Particular requirements and tests for transformers and power supply units for construction sites
 - Part 2-26: Particular requirements and tests for transformers and power supply units all for saving energy and other purposes
- Other parts are under consideration.

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SAFETY OF TRANSFORMERS, REACTORS, POWER SUPPLY UNITS AND COMBINATIONS THEREOF –

Part 1: General requirements and tests

1 Scope

This part of IEC 61558 deals with safety aspects of **transformers**, reactors, power supply units and combinations thereof such as electrical, thermal and mechanical safety.

This document covers the following **independent** or **associated** stationary or portable types of **dry-type transformers**, **power supply units**, including **switch mode power supply units**, **reactors** and combinations thereof in the field of safety. The windings can be encapsulated or non-encapsulated. They are not forming a part of the distribution network.

NOTE 1 The distinction between transformers, power supply units and switch mode power supply units is as follows:

- for **transformers**, there is no change in frequency. However, **transformers** (e.g. constant voltage transformers) can have an internal resonance frequency not exceeding 30 kHz;
- for **power supply units**, the **internal operational frequency** and waveform are different from the **supply frequency** and waveform, and the **internal operational frequency** does not exceed 500 Hz (see definition 3.1.19);
- for **switch mode power supply units**, the **internal operational frequency** and waveform are different from the **supply frequency** and waveform and the **internal operational frequency** exceeds 500 Hz and does not exceed 100 MHz.

The relevant parts of IEC 61558-2 can be found in the Introduction of this document.

a) Stationary or portable, single-phase or poly-phase, air-cooled (natural or forced), **isolating** and **safety isolating transformers**, **independent** or **associated** with the following characteristics:

- **rated supply voltage** not exceeding 1 000 V AC;
- **rated supply frequency** not exceeding 500 Hz;

and complying with the following values, unless otherwise specified in the relevant part of IEC 61558-2:

- for **isolating transformers**:
 - rated output for single phase **transformers**, not exceeding 25 kVA, and for poly-phase **transformers** not exceeding 40 kVA;
 - **no-load output voltage** and the **rated output voltage** exceeding 50 V AC, and not exceeding 500 V a.c, or 1 000 V AC to be in accordance with the national wiring rules or for a special application.
- for **safety isolating transformers**:
 - **rated output** for single phase **transformers** not exceeding 10 kVA, and for poly-phase **transformers** not exceeding 16 kVA;
 - **no-load output voltage** and the **rated output voltage** not exceeding 50 V AC between conductors, or between any conductor and protective earthing.

NOTE 2 **Isolating** and **safety isolating transformers** are used where **double** or **reinforced insulation** between circuits is required by the installation rules or by the appliance specification (for example toys, bells, portable tools, handlamps).

b) **Stationary** or **portable**, single-phase or polyphase, air-cooled (natural or forced) **separating transformers**, **auto-transformers**, **variable transformers** and small **reactors**, **independent** or **associated** with the following characteristics:

- **rated supply voltage** not exceeding 1 000 V AC;

- **rated supply frequency** not exceeding 500 Hz;

and complying with the following values, unless otherwise specified in the relevant part of IEC 61558-2:

- no-load output voltage or a rated output voltage for both independent and associated **transformers** not exceeding 15 kV AC, and for independent **transformers**, a rated output voltage not less than 50 V AC;
- **rated output** not exceeding the following values:
 - 1 kVA for single-phase **transformers**;
 - 2 kVAR for single-phase **reactors**;
 - 5 kVA for polyphase **transformers**;
 - 10 kVAR for polyphase **reactors**.

NOTE 3 **Separating transformers** are used where **double** or **reinforced insulation** between circuits is not required by the installation rules or by the appliance specification.

NOTE 4 Normally, the **transformers** of type b) are intended to be associated with the equipment to provide voltages different from the supply voltage for the functional requirements of the equipment. The protection against electric shock can be provided or completed by other features of the equipment, such as the **body**. Parts of **output circuits** can be connected to the **input circuit** or to the protective earthing.

- c) **Stationary** or **portable**, single-phase or polyphase, air-cooled (natural or forced), **independent** or **associated power supply units** and **switch mode power supply units** incorporating one or more **transformer(s)** of type a) or b) with the following characteristics:

- **rated supply voltage** not exceeding 1 000 V AC;
- **rated supply frequency** not exceeding 500 Hz;
- internal operational frequency for power supply units not exceeding 500 Hz and for switch mode power supply units not exceeding 100 MHz;

and with the following values, unless otherwise specified in the relevant part of IEC 61558-2:

- for power supply units and switch mode power supply units incorporating **isolating transformers**:
 - **rated output** for single- phase or polyphase **power supply units** or **switch mode power supply units** not exceeding 1 kVA;
 - **no-load output voltage** and the **rated output voltage** exceeding 50 V AC or 120 V ripple-free DC, and not exceeding 500 V AC or 708 V ripple-free DC, or 1 000 V AC or 1 415 V ripple- free DC to be in accordance with national wiring rules or for a special application;
- for **power supply units** and **switch mode power supply units** incorporating **safety isolating transformers**:
 - **rated output** for single- phase or polyphase **power supply units** and **switch mode power supply units** not exceeding 1 kVA;
 - **no-load output voltage** and **rated output voltage** not exceeding 50 V AC or 120 V ripple-free DC between conductors, or between any conductor and protective earthing.

NOTE 5 **Power supply units** and **switch mode power supply units** incorporating **isolating** and **safety isolating transformers** are used where **double** or **reinforced insulation** between circuits is required by the installation rules or by the appliance specification (for example toys, bells, portable **tools**, handlamps).

- for **power supply units** and **switch mode power supply units** incorporating **separating transformers**, **auto-transformers**, and **variable transformers**:
 - **rated output** for single-phase or polyphase **power supply units** and **switch mode power supply units** not exceeding 1 kVA;

- **no-load output voltage** and **rated output voltage** for both, **independent** and **associated transformers** not exceeding 15 kV AC, and for **independent transformers**, a **rated output voltage** not less than 50 V AC.

NOTE 6 **Power supply units** and **switch mode power supply units** incorporating **separating transformers** are used where **double** or **reinforced insulation** between circuits is not required by the installation rules or by the appliance specification.

This document also applies to **transformers**, **power supply units**, **switch mode power supply units** and **reactors** incorporating electronic circuits.

This document is applicable to **transformers** without limitation of the **rated output** subject to an agreement between the purchaser and the manufacturer.

This document does not apply to external circuits and their components intended to be connected to the input or output terminals or socket-outlets of the **transformers**, **power supply units** and **switch mode power supply units**, and **reactors**.

Attention is drawn to the following:

- for **transformers** intended to be used in vehicles, on board ships, and aircraft, additional requirements (from other applicable standards, national rules, etc...) may be necessary;
- measures to protect the **enclosure** and the components inside the enclosure against external influences like fungus, vermin, termites, solar-radiation, and icing are considered;
- the different conditions for transportation, storage, and operation of the **transformers** should also be considered;
- additional requirements in accordance with other appropriate standards and national rules can be applicable to **transformers** intended for use in special environments, such as tropical environments.

Future technological development of **transformers** can necessitate a need to increase the upper limit of the frequencies; until then this document can be used as a guidance document.

2 Normative references

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

IEC 60065:2014, *Audio, video and similar electronic apparatus – Safety requirements*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test FC: Vibration (sinusoidal)*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-31, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

IEC 60068-2-75, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60076-11:2004, *Power transformers – Part 11: Dry-type transformers*

IEC TR 60083, *Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC*

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

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

IEC 60127 (all parts), *Miniature fuses*

IEC 60127-3, *Miniature fuses – Part 3: Sub-miniature fuse-links*

IEC 60216 (all parts), *Electrical insulating materials – Thermal endurance properties*

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

IEC 60227-5:2011, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 5: Flexible cables (cords)*

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

IEC 60245-4:2011, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 4: Cords and flexible cables*

IEC 60269 (all parts), *Low voltage fuses*

IEC 60269-2:2013, *Low voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to K*

IEC 60269-3:2010, *Low voltage fuses – Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household or similar applications) – Examples of standardized systems of fuses A to F*

IEC 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes*

IEC 60317 (all parts), *Specifications for particular types of windings wires*

IEC 60317-0-7:2012, *Specifications for particular types of winding wires – Part 0-7: General requirements – Fully insulated (FIW) zero-defect enamelled round copper wire with nominal conductor diameter of 0,040 mm to 1,600 mm*

IEC 60317-56, *Specifications for particular types of winding wires – Part 56: Solderable fully insulated (FIW) zero-defect polyurethane enamelled round copper wire with nominal conductor diameter 0,040 mm to 1,600 mm, class 180*

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

IEC 60320-2-3, *Appliance couplers for household and similar general purposes – Part 2-3: Appliance couplers with a degree of protection higher than IPX0*

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, *Graphical symbols for use on equipment*
(available at <http://www.graphical-symbols.info/equipment>)

IEC 60454 (all parts), *Pressure-sensitive adhesive tapes for electrical purposes*

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

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

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

IEC 60664-3:2016, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

IEC 60691:2015, *Thermal-links – Requirements and application guide*

IEC 60695-2-10:2013, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:2014, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products*

IEC 60721-3-2, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 2: Transportation*

IEC 60730 (all parts), *Automatic electrical controls*

IEC 60730-1:2013, *Automatic electrical controls – Part 1: General requirements*

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 60851-6:2012, *Winding wires – Test methods: Part 6: Thermal properties*

IEC 60884-1:2002, *Plugs and socket-outlets for household and similar purposes – Part 1: General requirements*

IEC 60884-1:2002/AMD1:2006

IEC 60884-1:2002/AMD2:2013

IEC 60884-2-4, *Plugs and socket-outlets for household and similar purposes – Part 2-4: Particular requirements for plugs and socket-outlets for SELV*

IEC 60898 (all parts), *Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations*

IEC 60906-1, *IEC system of plugs and socket-outlets for household and similar purposes – Part 1: Plugs and socket-outlets 16 A 250 V a.c.*

IEC 60906-3, *IEC system of plugs and socket-outlets for household and similar purposes – Part 3: SELV plugs and socket-outlets, 16 A 6 V, 12 V, 24 V, 48 V, a.c. and d.c.*

IEC 60947-7-1, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*

IEC 60998-2-1, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-1: Particular requirements for connecting devices as separate entities with screw-type clamping units*

IEC 60998-2-2, *Connecting devices for low-voltage circuits for household and similar purposes – Part 2-2: Particular requirements for connecting devices as separate entities with screwless-type clamping units*

IEC 60999-1, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units – Part 1: General requirements and particular requirements for clamping units for conductors from 0,2 mm² up to 35 mm² (included)*

IEC 61032, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61058-1:2016, *Switches for appliances – Part 1: General requirements*

IEC 61058-1-1:2016, *Switches for appliances – Part 1-1: Requirements for mechanical switches*

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61373, *Railway applications – Rolling stock equipment – Shock and vibration tests*

ISO 8820 (all parts), *Road vehicles – Fuse-links*

EN 50075:1990, *Specification for flat non-wirable two-pole plugs 2.5 A 250 V, with cord, for the connection of class II-equipment for household and similar purposes*

DIN 43671:1975, *Copper bus bars; design for continuous current*

DIN 43670:1975, *Aluminium bus bars; design for continuous current*

DIN 43670-2:1985, *Aluminium bus bars copper cladding; design for continuous current*

3 Terms and definitions

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

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>

NOTE Further definitions of **transformers** intended for particular use are indicated in the relevant parts of IEC 61558-2.

When the term **transformer** is used it covers **transformer**, **reactor** and **power supply unit** where applicable.

Unless otherwise specified, the terms “voltage” and “current” imply the RMS values of alternating voltage and current, and for direct voltage and current, they imply the corresponding arithmetic mean values.

“Ripple-free” is conventionally an RMS ripple voltage not more than 10 % of the DC component.

An index of often used terms and definitions is provided at the end of this document.

3.1 Transformers

3.1.1

transformer

static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current usually of different values and at the same frequency for the purpose of transmitting electrical power

Note 1 to entry: The term frequency also implies that the waveform remains the same.

[SOURCE: IEC 60050-421:1990, 421-01-01, modified – “power” deleted and “NOTE” added]

3.1.2

isolating transformer

transformer with **protective separation** between the **input winding(s)** and **output winding(s)**

3.1.3

safety isolating transformer

isolating transformer designed to deliver **SELV** (safety extra-low voltage) or **PELV** (protective extra-low voltage)

3.1.4

separating transformer

transformer with **input winding(s)** separated from the **output winding(s)** by at least **basic insulation**

3.1.5

auto-transformer

transformer in which **input** and **output windings** have a common part

Note 1 to entry: **Auto-transformers** may have supplementary windings or tapings for adjustment purposes.

Note 2 to entry: Transformers with windings separated at least by functional insulation and electrically connected, will be treated as **auto-transformers**.

3.1.6

associated transformer

transformer designed to supply a specific appliance or equipment, or a part of them, and being either an **incorporated transformer** or a **transformer for specific use**

3.1.6.1

incorporated transformer

associated transformer designed to be built into a specific appliance or equipment, or into a part of them, and the **enclosure** of which provides protection against electric shock

3.1.6.2

transformer for specific use

associated transformer fixed to or delivered with the appliance or equipment, without being incorporated in this appliance or equipment and having its own **enclosure** which provides protection against electric shock

3.1.7

independent transformer

transformer designed to supply unspecified appliances and intended to be used without any additional **enclosure** which provides protection against electric shock

Note 1 to entry: Such a **transformer** can be either a portable **transformer** or a stationary **transformer**.

3.1.8

void

3.1.9

short-circuit proof transformer

transformer not exceeding the specified temperature limits when overloaded or short-circuited, and which continues to meet all the requirements of this document after removal of the overload or short-circuit and is not required to operate continuously under short-circuit or overload condition

Note 1 to entry: "Continues to meet all the requirements of this document" does not imply that all types of short-circuit proof **transformers** continue to operate.

3.1.9.1

non-inherently short-circuit proof transformer

short-circuit proof transformer equipped with a protective device or with an **intentional weak part** which opens the **input circuit** or the **output circuit**, or reduces the current in the **input circuit** or the **output circuit** when the **transformer** is overloaded or short-circuited, and continues to meet all the requirements of this document after removal of the overload or short circuit

3.1.9.1.1

non-inherently short-circuit proof transformer with resettable, self-resetting or replaceable protective device

short-circuit proof transformer equipped with a protective device which after resetting or replacing continues to operate

Note 1 to entry: Examples of self-resetting or non self-resetting protective devices are fuses, **overload relays**, thermal fuses, thermal links, **thermal cut-outs** and PTC resistors and automatic break-off mechanical devices.

3.1.9.1.2

non-inherently short-circuit proof transformer with non-self-resetting or non-replaceable protective device

short-circuit proof transformer equipped with a non-self-resetting or non-replaceable protective device or with a non-replaceable **intentional weak part**, which continues to meet all the requirements of this document after removal of the overload or short circuit, but does not continue to operate after the overload or short-circuit is removed

3.1.9.2

inherently short-circuit proof transformer

short-circuit proof transformer not equipped with any device for protection against overload or short circuit

Note 1 to entry: The **transformer**, by construction, does not exceed the specified temperature limits, and continues to operate and meet all the requirements of this document after the removal of the overload or short circuit.

3.1.10

non-short-circuit proof transformer

transformer intended to be protected against excessive temperature by means of a protective device, not provided with but stated on the **transformer**, and which continues to meet all the requirements of this document after the removal of the overload or short circuit and, if applicable, after resetting or replacing the protective device

3.1.11

fail-safe transformer

transformer equipped with a protective device or with an **intentional weak part**, which permanently fails to function by the interruption of the **input circuit** when the **transformer** is overloaded or short-circuited, but presents no danger to the user or surroundings

Note 1 to entry: It continues to meet all the requirements of this document after removal of the overload or short circuit.

Note 2 to entry: "Continues to meet all the requirements of this document" does not imply that the fail-safe **transformer** continues to operate. After failing it fulfils the dielectric strength test based on 35 % of the original values (see 15.5).

3.1.12

portable transformer

either a **transformer** which is moved while in operation, or a **transformer** which can easily be moved from one place to another while connected to the supply or being a plug-in **transformer**

3.1.13

flush-type transformer

transformer designed to be mounted in a flush-type mounting box

3.1.14

fixed transformer

transformer intended to be used while fastened to a support in a position which may be specified by the manufacturer

3.1.15

stationary transformer

either a **fixed transformer** or a **transformer** having a mass exceeding 18 kg and provided with no carrying handle(s)

3.1.16

hand-held transformer

portable **transformer** intended to be held in the hand during normal use

3.1.17

void

3.1.18

dry-type transformer

transformer incorporating non-liquid dielectric media, and the windings may be impregnated or encapsulated

3.1.19

power supply unit

electronic device incorporating **transformer(s)** and electronic circuitry(ies), that converts electrical power into single or multiple power outputs

Note 1 to entry: It may also isolate the **input circuit** from the **output circuit**, and regulate and/or convert the output voltage and current. The device may consist of one or more individual units with identical or different waveforms and frequencies including DC output, and the **internal operating frequency** and waveform are different from the supply frequency and waveform and the **internal operating frequency** does not exceed 500 Hz.

3.1.20

switch mode power supply unit

electronic device incorporating **transformer(s)** and electronic circuitry(ies), that converts electrical power into single or multiple power outputs

Note 1 to entry: It may also isolate the **input circuit** from the **output circuit**, and regulate and/or convert the output voltage and current. The device may consist of one or more individual units with identical or different waveforms and frequencies including DC output, and the **internal operating frequency** and waveform are different from the supply frequency and waveform and the **internal operating frequency** does exceed 500 Hz, but not exceed 100 MHz.

3.1.21**reactor**

arrangement comprising one or more windings with an impedance depending on the frequency, working in accordance with the principle of self-induction whereby a magnetising current generates a magnetic field through a magnetically effective core or through air

Note 1 to entry: **Reactors** with toroidal cores are also included in this definition.

3.2 General terms**3.2.1****external flexible cable****external flexible cord**

flexible cable or cord for external connection to the **input** or **output circuit**, fixed to or assembled with the **transformer** according to type X, type Y or type Z attachment

3.2.1.1**type X attachment**

method of attachment enabling easy replacement of the ordinary or especially prepared cable or cord

3.2.1.2**type Y attachment**

method of attachment intended to be replaced only by the manufacturer, his service agent, or similar qualified person

Note 1 to entry: **Type Y attachments** may be used either with ordinary flexible cables or cords, or with special cables or cords.

3.2.1.3**type Z attachment**

method of attachment preventing replacement of the flexible cable or cord without breaking or destroying a part of the transformer

3.2.2**power supply cord**

external flexible cable or cord used to supply the **input circuit**

Note 1 to entry: **Power supply cords** are:

- fixed to or assembled with the **transformer** by type X, Y or Z attachment, or
- connected to the **transformer** by an appliance coupler.

3.2.3**connecting lead**

lead connecting the end of a winding to the terminal of the **transformer**

Note 1 to entry: **Connecting leads** are considered as an internal wire.

3.2.4**body**

accessible **conductive parts**, shafts, handles, knobs, grips and the like, accessible metal fixing screws and metal foil applied on accessible surfaces of insulating material

3.2.5**accessible part**

parts which may be touched with the standard test finger after correct installation of the **transformer**

3.2.6

detachable part

part which can be removed without the aid of a **tool**

3.2.7

non-detachable part

part which can be removed only with the aid of a **tool**

3.2.8

tool

screwdriver, a coin, or any other object which may be used to operate a screw or similar fixing means

3.2.9

enclosure

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

Note 1 to entry: Protection against for example mechanical impacts, corrosion, fungi, vermin, solar radiation, icing and moisture.

[SOURCE: IEC 60050-195:1998, 195-02-35, modified – “NOTE” added]

3.2.10

intermediate conductive part

non-accessible conductive part situated between **hazardous-live-parts** or the **body** and other **hazardous-live-part**

3.2.11

conductive part

part which can carry electric current

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

3.2.12

electronic component

part in which conduction is achieved principally by electrons moving through a vacuum, gas or semiconductor

Note 1 to entry: Neon indicators are not considered to be electronic components

3.2.13

electronic circuit

circuit incorporating at least one electronic component

3.2.14

void

3.2.15

electrical separation

separation between conductive parts by means of air and/or solid insulation

3.3 Operations and protections

3.3.1

all pole disconnection

disconnection of all live conductors by a single switching action

Note 1 to entry: **Protective earthing conductor** is not considered to be a supply conductor.

Note 2 to entry: A neutral conductor is considered to be a supply conductor.

Note 3 to entry: National wiring rules may or may not require the disconnection of the neutral conductor.

3.3.2

thermal cut-out

temperature sensitive device which limits the temperature of a **transformer**, or of parts of it, during abnormal operation by automatically opening the circuit or by reducing the current, and which is so constructed that its setting cannot be altered by the user

3.3.3

self-resetting thermal cut-out

thermal cut-out which automatically restores the current after the relevant part of the **transformer** has cooled down sufficiently, or the load has been removed

3.3.4

non-self-resetting thermal cut-out

thermal cut-out requiring manual resetting or replacement of a part to restore the current

3.3.5

thermal-link

thermal cut-out which operates only once

3.3.6

overload relay

current-operated switch which protects a circuit from overload by opening when the current in that circuit reaches a predetermined value and which remains in the open position

3.3.7

intentional weak part

part other than overload protective device (fuses, circuit-breaker, thermal cut-outs, etc.) intended to rupture under conditions of abnormal operation to prevent the occurrence of a condition which could impair compliance with this document

Note 1 to entry: Such a part may be a replaceable component, such as a resistor or a capacitor or a non replaceable part of a component such as an inaccessible weak point in a winding.

3.3.8

working voltage

highest RMS value of the AC or DC voltage which may occur (locally) across any insulation at **rated supply voltage** under no-load or normal operating conditions, transients being disregarded

Note 1 to entry: When considering the insulation system between windings not intended to be connected together, the **working voltage** is considered to be the highest voltage occurring on any of these windings.

Note 2 to entry: On three phase systems, the **working voltage** can be different from the nominal voltage.

3.3.9

short-circuit voltage

voltage to be applied to the **input winding**, when the windings are at ambient temperature, to produce in the short-circuited **output winding** a current equal to the **rated output current**

Note 1 to entry: The **short-circuit voltage** is usually expressed as a percentage of the **rated supply voltage**.

3.3.10

duty-type

continuous or conventional periodic duty consisting of one or more sets of loads remaining constant for the durations specified

3.3.10.1

continuous duty

operation for an unlimited period

3.3.10.2

short-time duty cycle

operation for a specified period, starting from cold, the intervals between each period of operation being sufficient to allow the **transformer** to cool down to approximately ambient temperature

3.3.10.3

intermittent duty cycle

operation in a series of specified identical cycles

3.3.11

protective earthing conductor

PE

protective conductor provided for protective earthing

[SOURCE: IEC 60050-195:1998, 195-02-11]

3.4 Circuits and windings

3.4.1

input circuit

circuit intended to be connected to the supply consisting of the **input winding** and the **internal circuits**

3.4.2

output circuit

circuit to which the distribution circuit, appliance or other equipment is to be connected, consisting of the **output winding** and the **internal circuits**

3.4.3

input winding

winding of the **input circuit**

3.4.4

output winding

winding of the **output circuit**

3.4.5

internal circuit

circuit which consists of components, interconnections and connections to the terminals and the windings, excluding protective earthing circuit

3.4.6

fully insulated winding wire

FIW

wire according to IEC 60317-0-7, IEC 60317-56 and tested according to IEC 60851-5:2008 which is a zero-defect wire construction

3.4.7

grade of FIW

range of overall diameter of a wire (FIW3 to FIW9)

3.4.8**insulated winding wire**

winding wire for basic-, supplementary-, or reinforced insulation

Note 1 to entry: Requirements are provided in Annex K.

3.4.9**extruded winding wire****TIW**

winding wires with basic-, supplementary-, or reinforced insulation obtained by extrusion

Note 1 to entry: The term TIW is commonly used to cover all types of extruded winding wires.

3.5 Ratings**3.5.1****rated supply voltage**

supply voltage (for polyphase supply, the phase-to-phase voltage) assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.2**rated supply voltage range**

supply voltage range assigned to the **transformer** by the manufacturer, expressed by its lower and upper limits

3.5.3**rated frequency**

frequency assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.3.1**rated supply frequency**

frequency on the input of the **transformer** assigned by the manufacturer

Note 1 to entry: The supply frequency is the frequency of the mains.

3.5.3.2**internal operational frequency**

highest internal frequency assigned by the manufacturer as the operating frequency of a **transformer** or other components built into a **power supply unit**

3.5.4**rated output current**

output current at **rated supply voltage**, **rated supply frequency** and **rated output voltage**, at **rated power factor**, assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.5**rated output voltage**

output voltage (for polyphase supply, the phase-to-phase voltage) at **rated supply voltage**, **rated supply frequency** and **rated output current**, at **rated power factor**, assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.6**rated power factor**

power factor assigned to the **transformer** by the manufacturer for the specified operating conditions of the **transformer**

3.5.7**rated output**

product of the **rated output voltage** and the **rated output current** or, for three-phase **transformers**, $\sqrt{3}$ times the product of the **rated output voltage** and the **rated output current**

Note 1 to entry: If the **transformer** has more than one **output winding** or a tapped **output winding**, the **rated output** denotes the maximum sum of the products of **rated output voltage** and **rated output current** for **output circuits** intended to be loaded simultaneously.

3.5.8**rated ambient temperature** t_a

maximum temperature at which the **transformer** may be operated continuously under normal conditions of use

Note 1 to entry: The value of the **rated ambient temperature** (t_a) does not preclude temporary operation of the **transformer** at a temperature not exceeding ($t_a + 10$) °C.

3.5.9**rated minimum ambient temperature** t_{amin}

minimum temperature at which the **transformer** may be operated continuously under normal conditions of use

3.5.10**rated minimum temperature** t_{min}

minimum temperature only for transportation and storage

3.5.11**overvoltage category**

numeral defining a transient overvoltage condition

Note 1 to entry: Overvoltage categories I, II, III and IV are used, see IEC 60664-1:2007, 4.3.3.2.

[SOURCE: IEC 60050-581:2008, 581-21-02, modified – “NOTE” added]

3.5.11.1**overvoltage category I****OVC I**

equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level

Note 1 to entry: Examples of such equipment are those containing electronic circuits protected to this level. However, unless the circuits are designed to take the temporary overvoltages into account, equipment of overvoltage category I cannot be directly connected to the mains supply.

3.5.11.2**overvoltage category II****OVC II**

energy-consuming equipment to be supplied from the fixed installation

Note 1 to entry: Examples of that equipment are transformers for household appliances, telecommunications, toys, and similar loads.

3.5.11.3**overvoltage category III****OVC III**

equipment used in fixed installations and for cases where the reliability and the availability of the equipment is subject to special requirements

Note 1 to entry: Examples of such equipment are transformers in fixed installations and **transformers** for industrial use with permanent connection to the fixed installation.

3.5.11.4

overvoltage category IV OVC IV

equipment used at the origin of installation

Note 1 to entry: Examples of such equipment are **transformers** in fixed installations of power plants or immediate to such installations.

3.6 No-load values

3.6.1

no-load input

input of the **transformer** when connected to **rated supply voltage** at **rated supply frequency**, with no load on the output

3.6.2

no-load output voltage

output voltage when the **transformer** is connected to **rated supply voltage** at **rated supply frequency**, with no load on the output

3.7 Insulation

3.7.1

basic insulation

insulation of **live parts** which provides basic protection

Note 1 to entry: **This concept does not apply to insulation used exclusively for functional purposes**, for example wire enamel.

[SOURCE: IEC 60050-195:1998, 195-06-06, modified – “hazardous” deleted and “,for example wire enamel” added]

3.7.1.1

functional insulation

insulation between conductive parts, necessary for the proper functioning of the transformer

Note 1 to entry: For **transformers**, proper functional insulation may have influence on the safety. **Functional insulation** is checked by the requirements of this document but additional requirements may exist in IEC 61558-2 (all parts).

[SOURCE: IEC 60050-195:1998, 195-02-41, modified – “transformer” replaces “equipment” and “NOTE” added]

3.7.2

supplementary insulation

independent insulation of **hazardous-live-parts** applied in addition to **basic insulation**, for fault protection

Note 1 to entry: Fault protection means in order to provide protection against electric shock in the event of a **basic insulation** failure.

[SOURCE: IEC 60050-195:1998, 195-06-07, modified – “hazardous-live-parts” and “NOTE” added]

3.7.3

double insulation

insulation comprising both **basic insulation** and **supplementary insulation**

[SOURCE: IEC 60050-195:1998, 195-06-08]

3.7.4

reinforced insulation

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

Note 1 to entry: Reinforced insulation may comprise several layers which cannot be tested singly as basic insulation or supplementary insulation.

[SOURCE: IEC 60050-195:1998, 195-06-09]

3.7.5

class I transformer

transformer in which protection against electric shock does not rely on **basic insulation** only, but which includes an additional safety precaution such as a protective earthing terminal for the connection of accessible **conductive parts** to the fixed wiring of the installation

Note 1 to entry: The protective earthing connection prevents that accessible **conductive parts** become live in the event of a **basic insulation** failure.

Note 2 to entry: **Class I transformers** may have parts with **double** or **reinforced insulation**.

3.7.6

class II transformer

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

Note 1 to entry: A **class II transformer** may be provided with means for maintaining the continuity of protective earthing circuits, provided that such means are inside the **transformer**, and are insulated from accessible surfaces according to the requirements of **class II**.

Note 2 to entry: In certain cases, it may be necessary to distinguish between "all insulated" and "metal encased" **class II transformers**.

Note 3 to entry: A **transformer** having a durable and substantially continuous **enclosure** of insulating material which envelops all **conductive parts**, with the exception of small **conductive parts**, such as nameplates, screws and rivets, which are isolated from **hazardous-live-parts** by insulation at least equivalent to **reinforced insulation**, is called an all insulated **class II transformer**.

Note 4 to entry: A **transformer** having a substantially continuous metal **enclosure**, in which **double insulation** is used throughout, except for those parts where **reinforced insulation** is used because the application of **double insulation** is manifestly impracticable, is called a metal encased **class II transformer**.

Note 5 to entry: If a **transformer** with **double insulation** and/or **reinforced insulation** throughout has a protective earthing terminal, it is deemed to be of **class I** construction.

Note 6 to entry: A **class II transformer** may be provided with functional earthing circuit.

3.7.7

class III transformer

transformer in which protection against electric shock relies on supply at **SELV**, and in which voltages higher than those of **SELV** are not generated

Note 1 to entry: The classification I, II or III does not refer to the insulation system between **input windings** and **output windings**.

3.7.8

clearance

CL

shortest distance in air between two **conductive parts**

Note 1 to entry: For the purpose of determining a **clearance** to **accessible parts**, the accessible surface of an insulating **enclosure** is to be considered conductive as if it were covered by a metal foil wherever it can be touched by the standard test finger (see Figure 4).

[SOURCE: IEC 60664-1:2007, 3.2, modified – “NOTE” added]

3.7.9

creepage distance

CR

shortest distance (through air) along the surface of an insulating material between two **conductive parts**

Note 1 to entry: For the purpose of determining a **creepage distance** from **transformer conductive parts** to **accessible parts**, the accessible surface of an insulating **enclosure** is to be considered conductive as if it were covered by a metal foil wherever it can be touched by the standard test finger (see Figure 4).

[SOURCE: IEC 60050-151:2001, 151-15-50, modified – “through air” and “NOTE” added]

3.7.10

pollution

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

[SOURCE: IEC 60664-1:2007, 3.11]

3.7.11

micro-environment

immediate environment of the insulation which particularly influences the dimensioning of the **creepage distances** or **clearances**

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

[SOURCE: IEC 60664-1:2007, 3.12.2, modified – “or clearances” and “NOTE” added]

3.7.12

degree of pollution

degree of pollution in the **micro-environment** established for the purpose of evaluating **clearances** and **creepage distances**

3.7.12.1

pollution degree 1

P1

pollution degree in which no **pollution** or only dry, non-conductive **pollution** occurs

Note 1 to entry: The **pollution** has no influence.

3.7.12.2

pollution degree 2

P2

pollution degree in which only non-conductive **pollution** occurs, except that occasionally a temporary conductivity caused by condensation is to be expected

Note 1 to entry: **Transformers** having a reasonably tight **enclosure** are considered to have **pollution degree 2** (P2), hermetic sealing is not required.

3.7.12.3

pollution degree 3

P3

pollution degree in which conductive **pollution** occurs, or dry non-conductive **pollution** occurs which becomes conductive due to the condensation which is to be expected

3.7.13

protective separation

separation between circuits by means of basic and supplementary protection (**basic insulation** plus **supplementary insulation** or **protective screening**) or by an equivalent protective provision (for example **reinforced insulation**)

[SOURCE: IEC 60050-195:1998, 195-06-19, modified – “(electrically)” removed and definition redrafted]

3.7.14

protective screening

separation from **hazardous-live-parts** by means of an interposed conductive screen, connected to the means of connection for an external protective earthing conductor

[SOURCE: IEC 60050-195:1998, 195-06-18, modified – “(electrically)” removed and definition redrafted]

3.7.15

ELV

extra-low voltage

voltage which does not exceed 50 V AC or 120 V ripple free DC between conductors, or between any conductor and protective earthing

3.7.16

SELV

safety extra low voltage

ELV in a circuit which is isolated from the mains supply by such means as a **safety isolating transformer**

Note 1 to entry: Maximum voltage lower than 50 V AC or 120 V ripple-free DC may be specified in particular requirements, especially when direct contact with **live parts** is allowed.

Note 2 to entry: The maximum peak value does not exceed 140 V for a nominal 120 V ripple-free DC system and 70 V for a nominal 60 V ripple-free DC system.

3.7.17

SELV-circuit

ELV circuit with **protective separation** from other circuits, and which has no provisions for earthing of the circuit nor of the exposed **conductive parts**

3.7.18

PELV-circuit

protective extra low voltage

ELV circuit with **protective separation** from other circuits and which, for functional reasons, may be earthed and/or the exposed **conductive parts** of which may be earthed

Note 1 to entry: **PELV-circuits** are used where the circuits are earthed and **SELV** is not required.

3.7.19

FELV-circuit

functional extra low voltage-circuit

ELV circuit having the **ELV** voltage for functional reasons and not fulfilling the requirements for **SELV** or **PELV**

3.7.20

live part

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

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

Note 2 to entry: For definitions of PEM and PEL see IEC 60050-195:1998, 195-02-13 and 195-02-14

[SOURCE: IEC 60050-195:1998, 195-02-19, modified – “NOTE 2” added]

3.7.21

hazardous-live-part

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

Note 1 to entry: In case of high voltage, a hazardous voltage may be present on the surface of solid insulation. In such a case, the surface is considered to be a **hazardous-live-part**

[SOURCE: IEC 60050-195:1998, 195-06-05, modified – “NOTE” added]

3.8 Touch current and protective earthing conductor current

3.8.1

touch current

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

[SOURCE: IEC 60050-195:1998, 195-05-21]

3.8.2

protective earthing conductor current

current which flows in a protective earthing conductor

Note 1 to entry: This current may have influence on the operation of RCDs (residual current protection devices) connected in the same circuit.

4 General requirements

4.1 Transformers shall be so designed and manufactured that when used, installed and maintained according to the manufacturer's instructions, they cause no danger which could reasonably be foreseen to persons or surroundings, even in the event of careless use as may occur in normal service.

In general, compliance is checked by carrying out all the relevant tests.

4.2 When associated transformers are used in an appliance or equipment for which a relevant appliance or equipment standard exists, they may be tested under the conditions present in the appliance or equipment for which they are intended.

*If a **transformer** is tested under the conditions present in the appliance or equipment for which it is intended, it shall comply with the following clauses or subclauses thereof of this document:*

1 – 2 – 3 – 4 – 5.1 – 5.2 – 5.3 – 5.4 – 5.5 – 5.6 – 5.7 – 7.1 – 7.2 – 7.5 – 7.6 – 7.8 – 8.2 – 8.11 – 14.1 – except for the requirements in Table 2 starting with the first: “external enclosures”..., 14.2 – 14.3 – 15.1, restricted to the first box of Table 5 – 18.1 – 18.2 – 18.3 only between input and output circuits – 18.4 – 19.1 – 19.12 – 20.10 – 26.1 – 26.2 – 26.3 – Annexes A, G, L, M, N, P

Other clauses shall be taken from the relevant product standard. If the product standard does not fully cover the remaining clauses, the corresponding missing clauses of this **transformer** document shall be used instead.

4.3 For other hazards not covered by this document (e.g. EMF, functional safety linked to electric, magnetic and electromagnetic disturbances, etc.), the manufacturer has to perform a risk assessment.

5 General notes on tests

5.1 Tests according to this document are:

- type tests (defined from 8.1 up to Clause 28);
- routine tests (defined in Annex L).

*Each sample **transformer** shall comply with all the relevant tests. In order to reduce the testing time and allow for any tests which may be destructive, the manufacturer may submit additional **transformers** or parts of **transformers**, provided that they are of the same materials and designs as the original **transformer**, and that the results of the tests are the same as if carried out on an identical **transformer**. Where the test for compliance is shown as being "by inspection", this shall include any necessary handling.*

Unless otherwise specified, the tests shall be carried out under steady-state conditions.

Transformers intended to be used with **non-detachable** flexible cables or cords are tested with the flexible cable or cord connected to the **transformer**.

5.2 Tests are carried out on specimens as delivered and installed as in normal use taking into account the manufacturer's installation instructions. If it is not necessary to do the tests of 14.3, 15.5, 16.4 and 26.2, the number of specimens is one for all **rated outputs**.

If the tests of 14.3 need to be performed, three additional specimens shall be used. Three more specimens are required if the tests need to be repeated.

If the tests of 15.5 need to be performed, three additional specimens shall be used. These specimens are used only for the tests of 15.5.

If the tests of 16.4 need to be performed, they are carried out on four additional specimens.

If the tests of 26.2 need to be performed, they are carried out on three additional specimens.

*For components tested under conditions prevailing in the **transformer**, the number of specimens is that required by the relevant standard.*

*For testing a series of **transformers**, see Annex B.*

All specimens shall withstand all the relevant tests, except as mentioned in 14.3.

NOTE 1 For **associated transformers**, the equipment standard can prescribe other numbers of specimens to be tested.

NOTE 2 In case of non-replaceable and non-resettable protective devices, the compliance is checked on a specially prepared specimen.

5.3 Tests are carried out in the order of the clauses and subclauses, unless otherwise specified.

5.4 If the test results are not influenced by the temperature of the ambient air, the ambient temperature is, in general, maintained at $(20 \pm 5) ^\circ\text{C}$. Otherwise and if, however, the temperature attained by any part is limited by a temperature-sensitive device, or is influenced by the temperature at which a change of state occurs, the ambient temperature is, in case of doubt, maintained at $(23 \pm 2) ^\circ\text{C}$ or $(t_a \pm 2) ^\circ\text{C}$ for **transformers** with t_a marking.

The tests are carried out with the **transformer**, or any movable part of it, placed in the most unfavourable position that may occur in normal use.

5.5 For AC, test voltages are of substantially sinusoidal wave form, and, if not otherwise specified, have a frequency of 50 Hz or 60 Hz.

5.6 **Transformers** designed for more than one **rated supply voltage**, for a **rated supply voltage range** or for more than one **rated supply frequency**, are tested, unless otherwise specified in this document, at the supply voltage or supply frequency that results in the most severe test conditions for the **transformer**.

5.7 As far as possible, measurements are made with instruments which do not appreciably affect the values to be measured; if necessary, corrections shall be made.

5.8 Unless otherwise specified, **transformers** intended to be used with **external flexible cable or cords** are tested with a cord(s) (see 3.2.1) connected to the **transformer**.

5.9 If **class I transformers** have accessible conductive parts which are not connected to a protective earthing terminal or protective earthing contact, and are not separated from **hazardous-live-parts** by an **intermediate conductive part** that is connected to a protective earthing terminal or protective earthing contact, such parts are checked for compliance with the appropriate requirements specified for **class II transformers** in this document.

5.10 A **flush-type transformer** is tested with an appropriate flush-mount box of insulating material. This box is placed in an **enclosure** as indicated in Figure 2, made from plywood, with a thickness of 20 mm, the inside painted dull black, and the distance between the back of the mounting box and the rear wall of the **enclosure** being 5 mm.

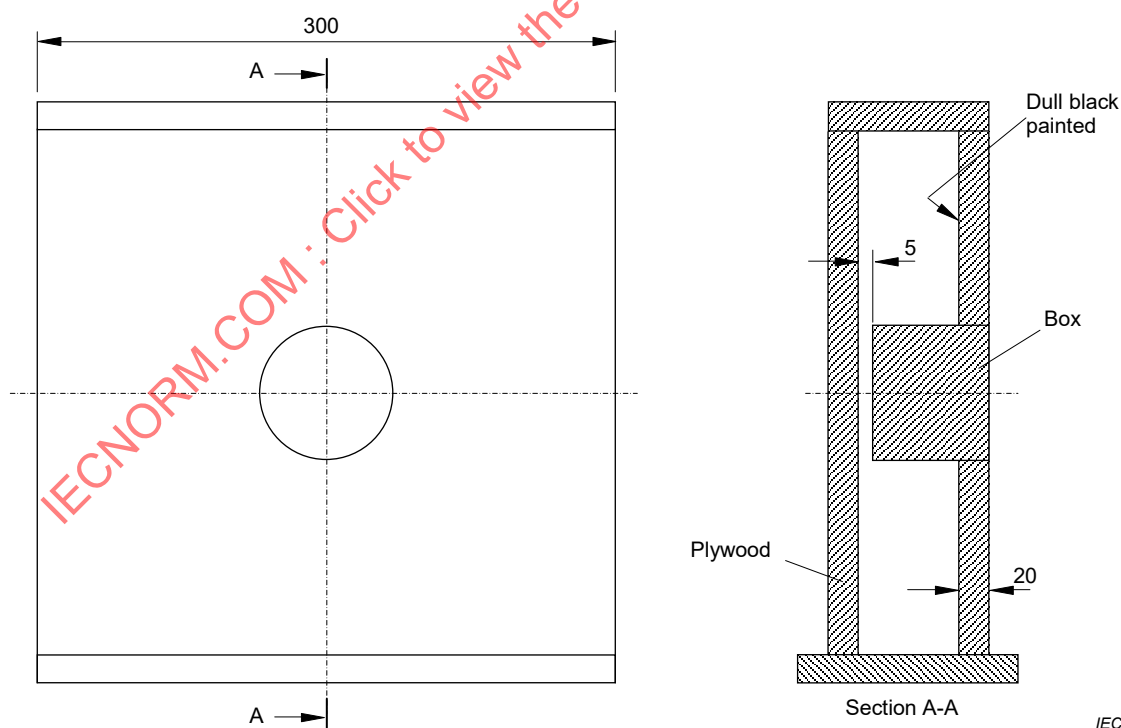


Figure 2 – Mounting box for flush-type transformer

5.11 **Transformers for specific use** for which there are no relevant appliance or equipment standards are tested as **transformers** for general use, their rating being considered as the power consumption and power factor of the appliance(s) or equipment for which they are designed.

5.12 Void

5.13 IP00 transformers with unknown end application, are tested without adding an enclosure.

For these **transformers**, the requirements of Clause 9 are not applicable. Furthermore, the test in 27.2 is not performed as the result can be influenced by the **enclosure** in the final application, for example on the fixing point of the **transformer** fixed on plastic support. For the fault condition test, if applicable, the product standard for the final product applies.

5.14 IP00 transformers, with known end application, are mounted and tested in accordance with the manufacturer's instructions.

5.15 The tests in Clauses 18 and 26 are based on an elevation of 2 000 m above sea level. If tested in elevations in excess of 2 000 m above sea level, Annex A of IEC 60664-1:2007 applies.

6 Ratings

Ratings are indicated in the relevant part of IEC 61558-2 for different types of **transformers**.

7 Classification

7.1 Transformers are classified according to their protection against electric shock:

- **class I transformers;**
- **class II transformers;**
- **class III transformers.**

NOTE **Incorporated transformers** are not classified; their degree of protection against electric shock is determined by the way in which the **transformer** is incorporated.

7.2 Transformers are classified according to the short-circuit characteristic or protection against abnormal use:

- **inherently short-circuit proof transformers;**
- **non-inherently short-circuit proof transformers;**
- **non-short-circuit proof transformers;**
- **fail-safe transformers.**

7.3 Transformers are classified according to the degree of protection ensured by the **enclosure** and defined in accordance with IEC 60529 (IP code) except IP1X.

NOTE For further information see Annex Q.

7.4 Transformers are classified according to their mobility:

- **stationary transformers;**
- **fixed transformers;**
- **portable transformers;**
- **hand-held transformers.**

7.5 Transformers are classified according to their duty type:

- **continuous duty;**
- **short-time duty cycle;**

- **intermittent duty cycle.**

7.6 Transformers are classified according to the intended use:

7.6.1 Associated

- **incorporated;**
- **for specific use.**

7.6.2 Independent

7.7 Transformers are classified according to the environmental conditions where they are intended to be used:

- normal environment;
- special environments (e.g. arctic).

7.8 Transformers are classified according to their **transient overvoltage condition**:

- **overvoltage category I;**
- **overvoltage category II;**
- **overvoltage category III;**
- **overvoltage category IV.**

Transformers for general use are in **overvoltage category III** or higher.

Transformers e.g. for use in household appliances or audio/video, information and communication technology equipment are in **overvoltage category II** or higher.

8 Marking and other information

8.1 Transformers shall be marked with the following (for symbols see Table 1):

- a) **rated supply voltage(s)** or the **rated supply voltage range(s)** in volts;

Transformers having a range of rated values and able to operate without adjustment throughout the range shall be marked with the lower and the upper limits of the range separated by a hyphen.

NOTE 1 Example 115 V – 230 V: the **transformer** is suitable for any value between 115 V and 230 V.

Transformers having different rated values, and which have to be adjusted for use at a particular value by the user or installer, shall be marked with the different values separated by an oblique stroke.

NOTE 2 Example 1: 115 V / 230 V: the **transformer** is only suitable for 115 V or 230 V (e.g. a **transformer** with a selector switch or different sets of terminals).

NOTE 3 Example 2: 230 V/400 V: The **transformer** is only suitable for 230 V or 400 V where 230 V is for single-phase operation and 400 V for three-phase operation (e.g., a **transformer** with terminals for both supplies).

- b) **rated output voltage(s)** in volts or kilovolts;

For **transformers** incorporating a rectifier, the **rated output voltage** after the rectifier shall be marked with the arithmetic mean value, or the output voltage before the rectifier shall be expressed as RMS value.

NOTE 4 The RMS value is distinguished from an arithmetic mean value by the use of RMS in the marking.

- c) **rated output** in volt-amperes or kilovolt-amperes and volt-amperes reactive or kilovolt-amperes reactive for reactors;

NOTE 5 For **transformers** incorporating a rectifier, the **rated output** can be expressed in watts, instead of volt-amperes or kilovolt-amperes.

- d) **rated output current(s)** in amperes or milliamperes as an alternative to the marking of the **rated output**;
- e) rated supply frequency(ies) in hertz;
- f) **rated power factor**, if other than unity, for **transformers** rated above 25 VA;
- g) symbol or abbreviation AC for alternating current or DC for direct current output;
- h) symbol indicating the kind of **transformer** as indicated in the relevant part of IEC 61558-2; if an IP00 **transformer** or and **associated transformers** have circuits corresponding to different parts 2 in the same construction (e.g. **SELV output circuit** according to IEC 61558-2-6 and 230 V **output circuit** according to IEC 61558-2-4) the relevant symbols have to be used;
- i) name or trade mark of the manufacturer or responsible vendor;
- j) model or type reference;
- k) vector group in accordance with IEC 60076-1 (for three-phase **transformers** if required);
- l) symbol for **class II** construction, for **class II transformers** only;
symbol for **class III** construction, for **class III transformers** only;
- m) indication of the protection index IP, if other than IP00;
- n) rated maximum ambient temperature t_a , if other than 25 °C;
It is recommended that the values of t_a are given in steps of 5 °C for $t_a \leq 50$ °C and in steps of 10 °C for $t_a > 50$ °C;
- o) **rated minimum ambient temperature** t_{amin} , if lower than +10 °C and if a temperature sensitive device is used;
It is recommended that the values of t_{amin} are given in steps of 5 °C.
- p) duty cycle, if any, unless the operating time is limited by the construction of the **transformer** or corresponds to the operating conditions specified in the relevant part of IEC 61558-2. The marking of **short-time duty cycle** or **intermittent duty cycle** shall correspond to normal use. The operating time for **transformers** with short-time duty shall be expressed in seconds (s) or minutes (min); the operating time and the resting time of **transformers** with intermittent duty cycle shall be expressed in seconds (s) or minutes (min), separated by an oblique stroke;
- q) symbol for overvoltage category, if other than OVC II;
- r) **transformers** to be used with forced air cooling where the fan is not a part of the **transformer** shall be marked with "AF" followed by the air speed, expressed in m/s;
- s) in addition, the manufacturer shall be prepared to provide the purchaser with the following information (in the literature or otherwise):
 - for **stationary transformers** with a **rated output** exceeding 1 000 VA, the **short-circuit voltage** expressed as a percentage of the **rated supply voltage**;
 - the electrical function of the **transformer**.

NOTE 6 If the **transformer** has more than one output winding, the short-circuit voltage to be marked is the lowest value for the various windings.

Additional markings are allowed provided they do not give rise to misunderstanding.

All markings except those under i) and j) may be illustrated as QR Code according ISO/IEC 18004.

- t) symbol indicating the maximum altitude of installation, if higher than 2 000 m.

8.2 Transformers with protection index IP00, or **associated transformers**, may be marked with only the name (or trade mark) of the manufacturer or responsible vendor and the type reference (or catalogue reference). Other characteristics shall then be provided in the data sheets of the **transformer** or in the manufacturer's instruction sheet.

The name of the manufacturer or responsible vendor and the type reference may be replaced by a traceable code.

This information shall enable replacement of the original **transformer** with an equivalent **transformer**.

NOTE Equivalent implies electrically, mechanically, dimensionally and functionally interchangeable.

8.3 If the **transformer** can be adjusted for different **rated supply voltages**, the adjusted voltage shall be easily and clearly discernible.

8.4 Transformers with tapped or multiple **output windings** shall be marked with:

- the **rated output voltage** for each tapping or winding, unless the **transformer** is intended for special purposes involving frequent changes in output voltage;
- the **rated output** for each tapping or winding; if the **rated output** for all tapings or windings is the same, at least one tapping or winding shall be marked.

The arrangement of the connections necessary to obtain the various output voltages shall be clearly indicated on the **transformer**.

8.5 Non-inherently short-circuit proof transformers with incorporated fuses and **non-short-circuit proof transformers** designed to be protected by fuses shall, in addition, be marked with the rated current (amperes or milliamperes) of the protecting fuse-link, followed or preceded by the symbol for the time current characteristics of the fuses in accordance with the relevant publication, if applicable.

Non-inherently short-circuit proof transformers with incorporated replaceable protective devices other than fuses, and **non-short-circuit proof transformers** designed to be protected with protective devices other than fuses shall, in addition, be marked with the manufacturer's model or type reference of the protective device, and/or the ratings of the protective device.

NOTE 1 In addition, a symbol in accordance with Annex V can be used.

NOTE 2 **Non-inherently short-circuit proof transformers** with non-replaceable protective devices need no additional marking regarding the protective device.

The marking shall contain sufficient information to ensure proper replacement of the protective device.

When replaceable protective devices other than fuses are used, appropriate information about their replacement shall be provided in an instruction sheet, or the equivalent, accompanying the **transformer**.

8.6 Terminals intended exclusively for the neutral conductor shall be identified by the symbol for neutral.

Protective earthing terminals shall be identified by the symbol for protective earthing.

Terminals of **input** and **output windings** shall be clearly identified.

If any point of a winding or a terminal is connected to the frame or core, it shall be marked with the relevant symbol.

8.7 Transformer shall be provided with markings clearly indicating the manner in which the **transformer** is to be connected, unless it is evident from the design of the **transformer**.

8.8 For **transformers** with type **X**, **Y** and **Z attachments**, the instruction sheet shall contain the following information or the equivalent:

- for **type X attachments** having a specially prepared cord:
"If the **external flexible cable or cord** of this **transformer** is damaged, it shall be replaced by a special cord or assembly available from the manufacturer or their service agent";
- for **type Y attachments**:
"If the **external flexible cable or cord** of this **transformer** is damaged, it shall be replaced by the manufacturer or their service agent or a similarly qualified person in order to avoid a hazard";
- for **type Z attachments**:
"The **external flexible cable or cord** of this **transformer** cannot be replaced; if the cord is damaged, the **transformer** shall be scrapped".

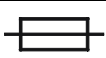
8.9 Transformers for indoor use only shall be marked with the relevant symbol.

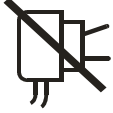
8.10 Class II transformers shall be marked with the graphical symbol IEC 60417-5172:2003-02 placed adjacent to the supply information (e.g. on the rating plate), such that it is obvious the symbol is part of the technical information and can in no way be confused with the manufacturer's name or any other identification (see 7.4.4 of IEC 61140:2016).

Class II transformers with parts to be mounted shall be delivered with all parts that make them class II after mounting according to the mounting instructions of the manufacturer and shall be marked with the class II symbol. Moreover, if the **transformer** can be mounted without the covers (e.g. on a distribution box), the marking for class II shall be placed on a part that effectively provides the class II characteristics (e.g., on a cover for terminals to connect to the supply).

8.11 When symbols are used on equipment or in instructions, they shall be as follows:

Table 1 – Symbols used on equipment or in instructions

Symbol or graphical symbol	Explanation or title	Identification
V ^a	Volts	
A ^a	Amperes	
VA or (VAR) ^a	Volt amperes (or volt-amperes reactive for reactors)	
W ^a	Watts	
Hz ^a	Hertz	
PRI	Input	
SEC	Output	
— — —	Direct current	IEC 60417-5031:2002-10
N	Neutral	
~	Alternating current	IEC 60417-5032:2002-10
3~	Three-phase alternating current	IEC 60417-5032-1:2002-10
3N~	Three-phase alternating current with neutral conductor	IEC 60417-5032-2:2002-10
cos φ	Power factor	
	Class II equipment	IEC 60417-5172:2003-02
	Class III equipment	IEC 60417-5180:2003-02
	Equipment of overvoltage category I	IEC 60417-6348:2015-10
	Equipment of overvoltage category II	IEC 60417-6349:2015-10
	Equipment of overvoltage category III	IEC 60417-6350:2015-10
	Equipment of overvoltage category IV	IEC 60417-6351:2015-10
	Fuse (add symbol for time-current characteristics)	IEC 60417-5016:2002-10
t_a	Rated maximum ambient temperature Maximum temperature at which the transformer may be operated continuously under normal conditions of use	
t_{amin}	Rated minimum ambient temperature Minimum temperature at which the transformer may be operated continuously under normal conditions of use	
t_{min}	Rated minimum temperature Minimum temperature for transportation and storage	
	Frame or chassis (or core terminal)	IEC 60417-5020:2002-10
	Protective earth (ground)	IEC 60417-5019:2006-08

Symbol or graphical symbol	Explanation or title	Identification
IPXX	IP number ^b	
	Earth (ground or functional earth)	IEC 60417-5017:2006-08
	indoor use only	IEC 60417-5957:2004-12
	To indicate that the appliance is intended to be usable up to the maximum altitude 3 000 m. The letter symbols "3 000" may be replaced by those for a different numerical value (in metres) in agreement with actual applications. The recommended value should be either 2 000, 3 000, 4 000, or 5 000 (metres).	IEC 60417-6343:2015-06
	To indicate that the power supply unit shall not be used, if pins of the plug part are damaged. NOTE See 8.8, attachment type C	IEC 60417-6352:2015-10
^a Multiple or submultiples are allowed (e.g. kV, mA...). ^b The X used in the IP number in this scheme indicates a missing numeral in the example, but both of the appropriate numerals shall be marked on the transformer , if applicable. Additional and supplementary letters mentioned in IEC 60529 may be used if necessary.		

8.12 The different positions of regulating devices and the different positions of switches shall be indicated by numbers, letters or other visual means.

If numbers are used for indicating the different positions, the "off" position shall be indicated by the number 0 and the position for a greater output, input, etc. shall be indicated by a higher number.

The number 0 shall not be used for any other indication. Indications used shall be comprehensible without the knowledge of languages, national standards, etc.

8.13 Marking shall not be placed on screws or other easily removable parts.

Marking shall, with the exceptions mentioned below, be clearly discernible when the **transformer** is ready for use.

Marking related to the terminals shall be so positioned that it is clearly discernible, if necessary after removal of the cover; it shall be such that there can be no confusion between input terminals and output terminals.

Marking related to the interchangeable protective devices shall be positioned adjacent to the bases of these devices, and shall be clearly discernible after removal of any cover and the protective device.

8.14 Visible information (symbols) shall be provided, when it is necessary to take special precautions for installation, transportation or use (in the catalogue, data sheet, instruction sheet or packaging):

- **non-inherently short-circuit proof transformer with non-self-resetting or non-replaceable protective device** and non-replaceable **intentional weak parts** shall have an information explaining the protective devices cannot be resetted or replaced after a short-circuit or an overload;

- for **transformers** generating a **protective earthing conductor current** greater than 10 mA and are intended for permanent connection, the **protective earthing conductor current** shall be clearly stated in the instruction and indication shall be given that the installation shall be made according to the wiring rules;
- for **stationary transformers** with a **rated output** exceeding 1 000 VA, the short-circuit voltage expressed as a percentage of the rated supply voltage;
- the electrical function of the **transformer**;
- the limiting temperature of the winding under abnormal conditions which shall be respected when the **transformer** is built into an appliance as information for appliance design;
- for **transformers** not designed for series and/or parallel connection with more than one output winding, that the **transformer** is not intended for series/parallel connection.

Compliance with the requirements of 8.1 to 8.14 is checked by inspection.

For IP00 **transformers**, if applicable, the test in 27.2 is not performed as the result may be affected by the **enclosure** in the final application.

8.15 Marking shall be durable and easily legible.

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

The petroleum spirit to be used for the test is aliphatic solvent hexane with an aromatic content of 0,1 % maximum, by volume, a kauributanol value of 29, initial boiling point approximately 65 °C, dry point approximately 69 °C and specific gravity of 0,68 g/cm³.

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

After all the tests of this document, the marking shall be easily legible, it shall not be possible to remove labels easily, and they shall show no curling.

8.16 Portable transformers with integrated plugs complying with EN 50075 (IEC plug type C), shall use the symbol IEC 60417-6352:2015-10.

The instruction sheet of the plug in transformer shall contain the following information, or equivalent:

if the pins of the plug parts are damaged, the plug-in power supply shall be scrapped.

NOTE The countries using this type of plug are mentioned under world plugs type C (available at <http://www.iec.ch/worldplugs/typeC.htm>).

Compliance with the requirements is checked by inspection.

9 Protection against electric shock

9.1 General

Transformers shall be enclosed and provided with adequate protection against contact with **hazardous-live-parts** and shall have no risk of an electric shock from stored charge on capacitors.

Compliance is checked by inspection and by the tests of 9.2.1, 9.2.2 and 9.3.

9.2 Protection against contact with hazardous-live-parts

9.2.1 Determination of hazardous-live-parts

9.2.1.1 A **live part** is not a **hazardous-live-part** if it is separated from the supply by **double** or **reinforced insulation** and the requirements of 9.2.1.2 or 9.2.1.3 are met when **the transformer** is supplied at **rated supply voltage**.

9.2.1.2 The voltage shall not exceed 35 V AC peak or 60 V ripple free DC.

Compliance is checked by measurements carried out between any two conductive parts.

9.2.1.3 Where the voltage exceeds 35 V (peak) AC or 60 V ripple free DC, the touch-current shall not exceed:

- for AC: 0,7 mA (peak);
- for DC: 2,0 mA.

Compliance is checked by measuring the touch current as stated in Annex J.

*In addition, when a capacitor is connected to the **live parts**:*

9.2.1.3.1 The discharge shall not exceed 45 μ C for stored voltages between 60 V and 15 kV, or

9.2.1.3.2 The energy of discharge shall not exceed 350 mJ for stored voltages exceeding 15 kV.

Compliance of 9.2.1.3.1 and 9.2.1.3.2 is checked by measurements carried out with a load of 2 000 Ω .

9.2.2 Accessibility to hazardous-live-parts

Transformers shall be constructed to provide adequate protection against accessibility to **hazardous-live-parts**.

Class I and II transformers shall be so constructed and enclosed that there is adequate protection against accidental contact **with hazardous-live-parts**.

For **class I transformers**, accessible parts shall be separated from **hazardous-live-parts** by at least **basic insulation**.

Class II transformers shall be so constructed and enclosed that there is adequate protection against accessibility to **basic insulation** and to **conductive parts** separated from **hazardous-live-parts** by **basic insulation** only. Only parts separated from **hazardous-live-parts** by **double** or **reinforced insulation** may be accessible.

Hazardous-live-parts shall not be accessible after removal of detachable parts except for:

- lamps having caps larger than B9 and E10;
- type D fuse-holders.

IP00 transformers shall comply with the end product standard after incorporation in the end product.

The insulating properties of lacquer, enamel, paper, cotton, oxide film on conductive parts and sealing compound shall not be considered as giving the required protection against accidental contact with **hazardous-live-parts** with the exception of **fully insulated winding wire (FIW)**.

NOTE 1 Self-hardening resins can be relied upon to give the required protection against accidental contact with **hazardous-live-parts**.

Shafts, handles, operating levers, knobs and the like shall not be **hazardous-live-parts**.

Compliance is checked by inspection and by the relevant tests of IEC 60529.

*In addition, openings in **class II transformers**, and openings in **class I transformers** other than those in **conductive parts** connected to a protective earthing terminal, are tested with the test pin shown in Figure 3.*

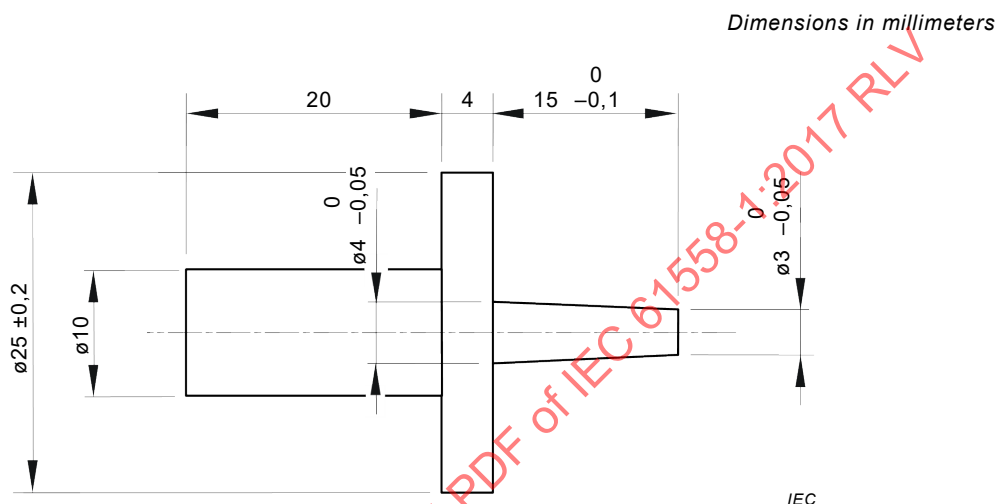
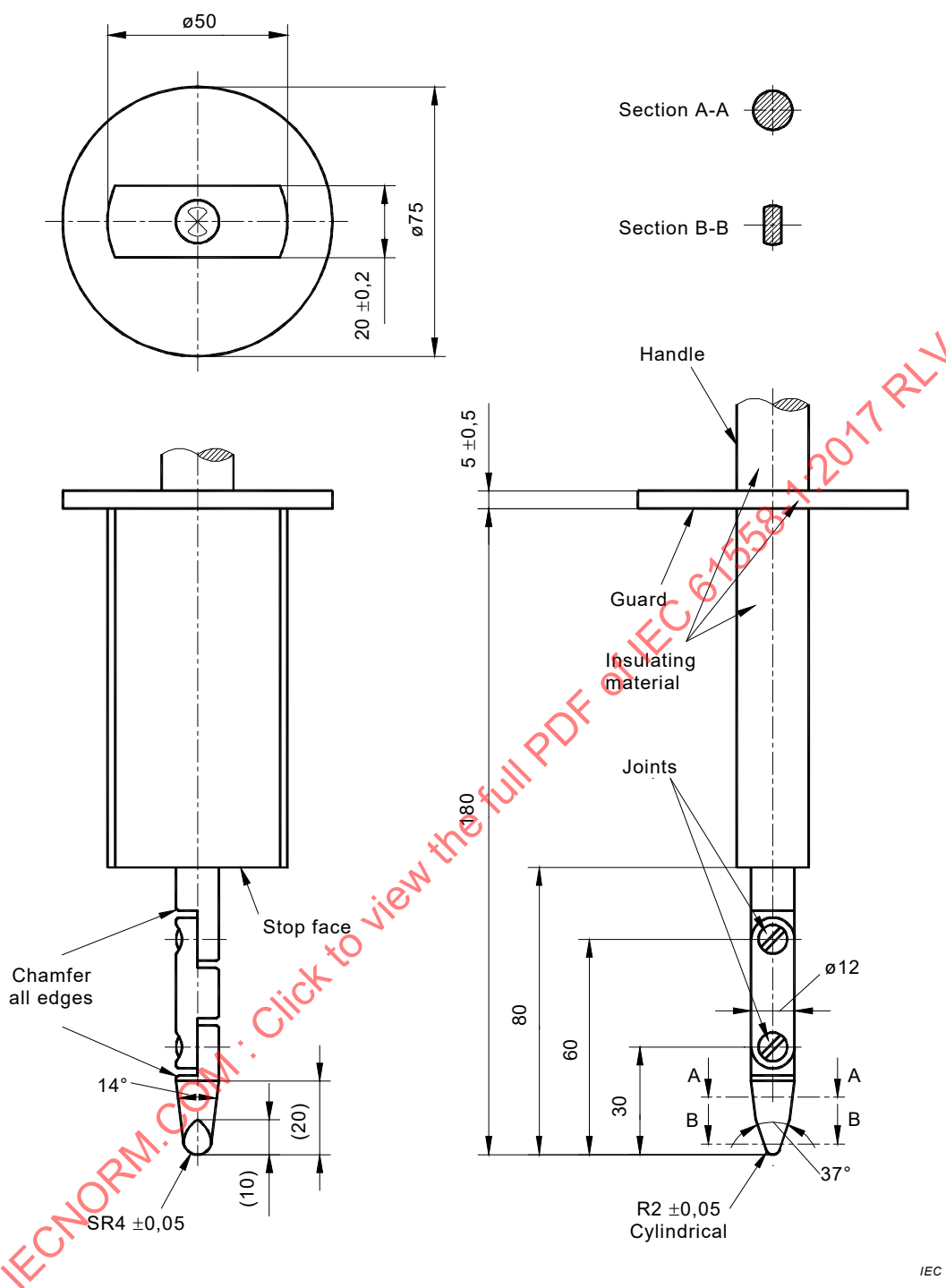


Figure 3 – Test pin (see IEC 61032, test probe 13)

The test finger and the test pin are applied, without appreciable force, in every possible position.

*The test finger of Figure 4 is applied without appreciable force, the **transformer** being in every possible position except that **transformers** normally used on the floor and having a mass exceeding 40 kg are not tilted. Through openings, the test finger is applied to any depth that the finger will permit and is rotated or angled before, during and after insertion to any position. If the opening does not allow the entry of the finger, the force on the finger in the straight position is increased to 20 N. If the finger then enters the opening, the test is repeated with the finger in the angled position.*



Material: metal, except where otherwise specified

Linear dimensions in millimetres

Tolerances on dimensions without specific tolerance:

on angles: 0/–10°

on linear dimensions:

– up to 25 mm: $\begin{matrix} 0 \\ -0,05 \end{matrix}$

– over 25 mm: ± 0,2

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

Figure 4 – Standard test finger (see IEC 61032, test probe B)

*It shall not be possible to touch with the test finger bare **hazardous-live-parts** or **hazardous-live-parts** protected only by lacquer, enamel, paper, cotton, oxide film or sealing compound, with the exception of **fully insulated winding wire (FIW)**.*

*There shall be no possibility to touch conductive parts of **class II transformers** with the test finger, which are separated from **hazardous-live-parts** only by **basic insulation**.*

*Moreover it shall not be possible to touch bare **hazardous live parts** with the test pin.*

NOTE 2 This requirement does not apply to lamp caps or socket-outlets.

In case of doubt, an electrical contact indicator, with a voltage not less than 40 V, is used with a test pin.

9.2.3 Accessibility to non hazardous-live-part

Non **hazardous-live-parts** of the **output circuit** isolated from the **input circuit** by **double** or **reinforced insulation** may be accessible under the following conditions:

- for **no-load output voltages** not exceeding 35 V peak AC or 60 V ripple-free DC, both poles may be accessible;
- for **no-load output voltages** exceeding 35 V peak AC or 60 V ripple-free DC and not exceeding 250 V AC, only one of the poles may be accessible.

9.3 Protection against hazardous electrical discharge

For **transformers** with a primary supply plug, the pins of the plug shall not be hazardous-live measured 1 s after withdrawal of the plug.

For **transformers** without a primary supply plug, the terminals provided for connecting the **transformer** to the supply source shall not be hazardous-live measured 5 s after disconnection of the supply source.

NOTE For the purpose of this subclause, plug connectors and appliance inlets are regarded as mains plugs.

Compliance is checked by the following test:

If the nominal capacitance across the pins does not exceed 0,1 μ F, no test is conducted.

*The primary supply switch of the **transformer**, if any, is in the off-position, unless it is more unfavourable in the on-position.*

The test shall be carried out 10 times or with a device used to switch off at the most unfavourable electrical angle of the supply voltage.

The voltage is measured between the input terminals or between the supply leads or between the pins of the supply plug used for the connection to the supply source after 1 s or 5 s.

If the voltage exceeds 60 V ripple free DC, the discharge is measured in the same conditions and shall not exceed 45 μ C.

10 Change of input voltage setting

Transformers with more than one **rated supply voltage** shall be so constructed that the voltage setting cannot be changed without the aid of a **tool**.

NOTE As an example, the requirement concerning the voltage setting is met if a **tool** is needed to remove a cover before the voltage setting can be changed.

Transformers which can be set to different **rated supply voltages** shall be so constructed that the indication of the voltage for which the **transformer** is set is discernible on the **transformer** when it is ready for use.

Plug connected **transformers** provided with a device to select the input connections (e.g. by tapings) to adjust supply voltages within a range of not more than 10 % of the value corresponding with the midpoint of that range, are not considered to be **transformers** with more than one supply voltage.

Plug connected **safety isolating transformers** shall have only one **rated supply voltage** unless the **transformer** is not capable of producing an output voltage exceeding the allowed output voltage limitation for **safety isolating transformers** if the higher marked voltage is connected to the lower voltage winding.

Compliance is checked by measurement and inspection.

11 Output voltage and output current under load

11.1 When the **transformer** is connected to the **rated supply voltage**, at the **rated supply frequency**, and loaded with an impedance resulting in the **rated output** at the **rated output voltage** and, for AC current, at the **rated power factor**, the output voltage shall not differ from the rated value by more than:

- a) 10 % for the output voltage of **inherently short-circuit proof transformers** with one **rated output voltage**;
- b) 10 % for the highest output voltage of **inherently short-circuit proof transformers** with more than one **rated output voltage**;
- c) 15 % for the other output voltages of **inherently short-circuit proof transformers** with more than one **rated output voltage**;
- d) 5 % for the output voltages of other **transformers**.

For **transformers** with rectifiers, the above percentage values are raised by 5.

*Compliance is checked by measuring the output voltage when steady-state conditions are established, with the **transformer** connected to the **rated supply voltage**, at the **rated supply frequency**, and loaded with an impedance resulting in the **rated output**, at the **rated output voltage** and the **rated power factor**.*

*For **transformers** incorporating a rectifier, the output voltage is measured at the terminals of the DC circuit by means of a voltmeter giving the arithmetical mean value, unless the effective value RMS is specifically stated (see 8.1).*

*For **transformers** with more than one **rated supply voltage**, the requirement is applicable for each of the **rated supply voltages**.*

*For **transformers** with multiple **output windings**, the loads are applied to every multiple section simultaneously, unless otherwise declared.*

11.2 If a **transformer** is marked with the **rated output**, the **rated output voltage**, the **rated output current**, and the **rated power factor**, these values shall be substantially in agreement with each other.

If no **rated output current** is assigned to the **transformer**, the **rated output current** for the purpose of this specification can be calculated from the **rated output** and the **rated output voltage**.

Compliance is checked by calculation.

12 No-load output voltage

The relevant requirements for the **no-load output voltage** limitation are given in IEC 61558 Part 2 for the different types of **transformers**.

*For **transformers** incorporating a rectifier, the output voltages are measured at the input and output terminals of the rectifier if they are connected to terminals or terminations. The measurement at the input terminals of the rectifier is made if they are accessible to the user. The **output voltage** is measured at the terminals of the circuit with a voltmeter giving the arithmetic mean value, unless the effective value RMS is specifically stated (see 8.1).*

13 Short-circuit voltage

If there is a **short-circuit voltage** marking, the **short-circuit voltage** measured shall not deviate by more than 20 % from the value marked.

*Compliance is checked by measuring the **short-circuit voltage**, the **transformer** being at ambient temperature.*

14 Heating

14.1 General requirements

14.1.1 Temperature-rise test

Transformers and their supports shall not attain excessive temperature in normal use.

The manufacturer may choose the simulated load methods according to 14.1.2.1 or 14.1.2.2 instead of the direct load method that may be applied.

NOTE 1 The simulated load methods are according to IEC 60076-11:2004, 23.2.1 and 23.2.2.

Temperatures are determined under the following conditions when steady-state is established.

*The test and the measurements are made in a draught-free location having dimensions such that the test results are not influenced. If the **transformer** has a t_a rating, the test is conducted at $(t_a \pm 5) ^\circ\text{C}$.*

NOTE 2 The heating test is carried out taking into consideration only the t_a (and not $t_{a\text{min}}$).

Portable transformers are placed on a dull black painted plywood support. **Stationary transformers** are mounted as in normal use, on a dull black painted plywood support. The support is approximately 20 mm thick, and has dimensions which are at least 200 mm in excess of those of the orthogonal projection of the specimen on the support.

Transformers which are provided with integral pins intended to be introduced into fixed socket-outlets are tested in a flush-mounted socket-outlet mounted in a box on a dull black painted plywood support as indicated in Figure 2.

*Flush type **transformers** are tested as described in 5.10.*

Transformers with a protection index other than IP00 are tested in their **enclosure**.

Transformers with a protection index IP00, the application of which is not known, are tested as described in 5.13

NOTE 3 In the case of **transformers** with a protection index IP00, the temperature of the support is measured, but the values given in Table 2 and Table 5 are not considered.

Transformers with terminals for **type X attachment** with a specially prepared cord and for **type Y** and **type Z attachments** shall have the connections subjected to a pull of 5 N immediately before the heating test is carried out.

Transformers are supplied at the **rated supply voltage** and loaded with impedance producing the **rated output**, at the **rated output voltage** and, for AC current, at the **rated power factor**. The value of the output current is measured when steady-state is established. Then the supply voltage is increased by 10 % and the output current is adjusted to the same value measured before. The output current is not adjusted for **independent transformer**. After this no change is made in the circuit. The test is repeated under no-load condition if this is a more unfavourable situation.

Associated transformers are operated under the conditions occurring when the appliance or other equipment is operated under the conditions of normal use as indicated in the relevant specifications. **Transformers** with intermittent ratings shall be tested at the intermittent ratings, until steady-state conditions are established.

The temperatures of windings are determined by the change of resistance method.

NOTE 4 One of the methods consists of measuring each winding separately, and of determining the resistance of windings at the end of the test by taking resistance measurements, as soon as possible after switching off, and then at short intervals, so that a curve of resistance against time can be plotted to ascertain the resistance at the instant of switching off.

The value of the temperature rise of a winding is calculated with Formula (1):

$$\Delta t = \frac{(R_2 - R_1)}{R_1} (x + t_1) - (t_2 - t_1) \quad (1)$$

Alternative calculation of the maximum temperature in reference to the ambient temperature is calculated with Formulae (2) and (3):

$$T = t_a + \frac{(R_2 - R_1)}{R_1} (x + t_1) - (t_2 - t_1) \quad (2)$$

or

$$T = t_a + \Delta t \quad (3)$$

where

$x = 234,5$ for copper;

$x = 225$ for aluminium;

Δt is the temperature rise, above t_2 so that the maximum temperature equals $\Delta t + t_2$;

R_1 is the resistance at the beginning of the test, at temperature t_1 ;

R_2 is the resistance at the end of the test, when steady conditions have been established;

t_1 is the ambient temperature at the beginning of the test;

t_2 is the ambient temperature at the end of the test;

t_a is the ambient temperature;

T is the maximum temperature.

At the beginning of the test, the windings shall be at ambient temperature.

When determining the temperature of the windings, the ambient temperature is measured at such a distance from the specimen so as not to influence the temperature reading. At this point, the ambient temperature shall not vary by more than 10 °C during the test. For t_a **transformers** the test temperature equals $\Delta t + t_a$.

For **transformers** with more than one **input** or **output winding**, or a tapped **input** or **output winding**, the results to be considered are those showing the highest temperature.

Transformers with a winding resistance less than 50 mΩ can also be measured by thermocouples. The thermocouples shall only be mounted on accessible surfaces of the transformer windings. The maximum values of Table 2 for winding temperatures shall be reduced by 10 °C for the thermocouple measurements.

Other temperatures are determined by means of thermocouples so chosen and positioned that they have the minimum effect on the temperature of the part under test.

Thermocouples used for determining the temperature of the surface of supports are attached to the back of small blackened discs of copper or brass 1 mm thick and 15 mm in diameter which are flush with the surface.

The temperature of electrical insulation (other than that of windings) is determined on the surface of the insulation at places where failure could establish a contact between **hazardous-live-parts** and accessible **conductive parts**, or a reduction of **creepage distances** or **clearances** below the values specified in Clause 26. In addition, thermocouples shall be placed at the hottest points of the insulating material to avoid a risk of fire.

During the test, the temperature shall not exceed the values shown in Table 2 when the **transformer** is operated at its **rated ambient temperature** (25 °C or t_a). In those cases where the temperature in the test area differs from the **rated ambient temperature**, this difference shall be taken into account when applying the limits in Table 2 and when establishing the test temperatures in 27.2 and 27.5.

14.1.2 Alternative temperature-rise test

14.1.2.1 Simulated load method

This method is applicable for an enclosed or non-enclosed or totally enclosed dry type unit with natural air or forced air cooling.

Temperature rise is established by combining the short-circuited test (load loss) and the open circuit test (no-load loss).

The temperature of the **transformer** shall be stabilized with that of the test laboratory environment. The resistance of the primary and secondary windings shall be measured, these values will be used as reference values for the calculation of the temperature rise of the two windings. The ambient temperature of the test laboratory shall also be measured and registered.

For three-phase **transformers**, the resistance measurements shall be made between the central and an outer phase line terminals.

The location of the measuring points (that is, the ambient temperature thermometers and sensors on the **transformer**, if any), shall be the same for the reference and final measurements.

The winding short-circuited test shall be performed with rated current flowing in one winding and the other winding short-circuited and shall continue until the steady-state condition of the windings and magnetic core are reached. The winding temperature rise, $\Delta\theta_c$, shall be established by the rise in resistance method or by superposition.

The open-circuit test, at rated voltage and **rated frequency**, shall be continued until steady-state condition of the winding and magnetic core is obtained, individual winding temperature rises, $\Delta\theta_e$, shall then be measured.

The test procedure shall be either:

- the winding short-circuited test carried out until stabilisation of the core and the winding temperature. Subsequently, an open-circuit test shall be carried out until stabilisation of the core and winding temperature is reached.

or

- the open-circuit test carried out until stabilisation of the core and the winding temperature. Subsequently, the winding short-circuited test shall be carried out until stabilisation of the core and winding temperature is reached.

The total winding temperature rise, $\Delta\theta'_c$ of each winding, with rated current in the winding and normal excitation of the core, is calculated with Formula (4):

$$\Delta\theta'_c = \Delta\theta_c \left[1 + \left(\frac{\Delta\theta_e}{\Delta\theta_c} \right)^{1/K1} \right]^{K1} \quad (4)$$

where

$\Delta\theta'_c$ is the total winding temperature rise;

$\Delta\theta_c$ is the winding temperature rise at the short-circuited test;

$\Delta\theta_e$ is the individual winding temperature rise at the open-circuited test;

$K1 = 0,8$ for natural air cooling and $0,9$ for forced air cooling.

14.1.2.2 Back-to-back method

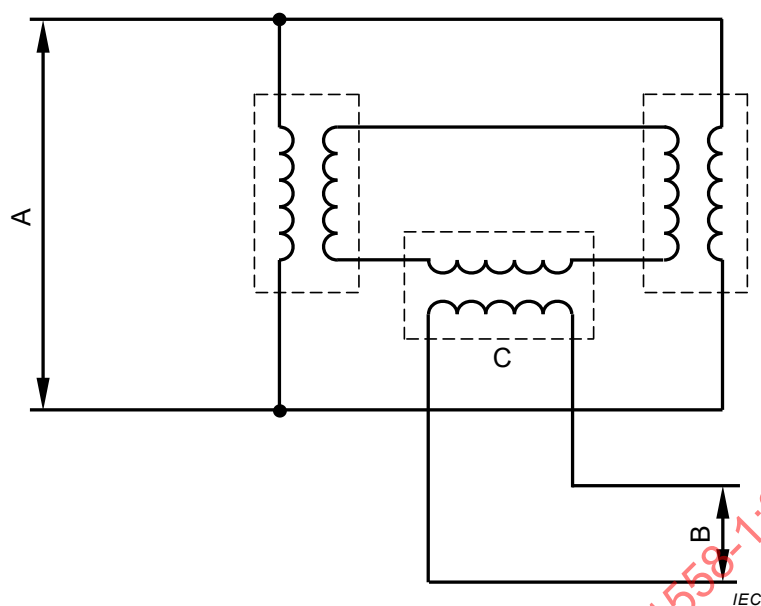
This method is appropriate when there are two similar **transformers** and the necessary test equipment is available. It is applicable for enclosed or non-enclosed dry-type units with natural air or forced air cooling.

The temperature of the **transformer** shall be stabilised with that of the test laboratory environment. The resistance of the high voltage and low voltage windings shall be measured, these values will be used as reference values for the calculation of the temperature rise of the two windings. The ambient temperature of the test laboratory shall also be measured and registered.

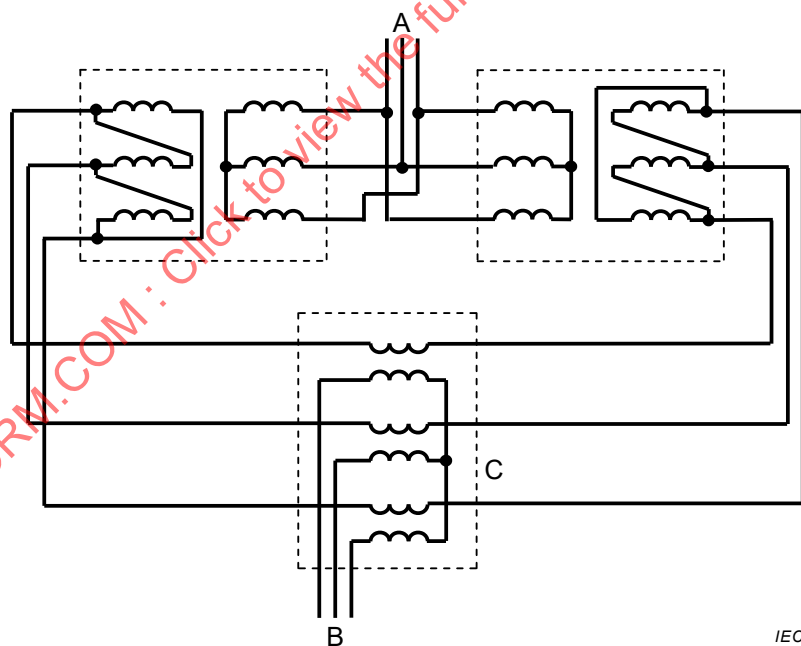
The location of the measuring points shall be the same for the reference and final measurements.

Two **transformers**, one of which is the **transformer** under test, are connected in parallel, and preferably the inner windings are excited at the rated voltage of the **transformer** under test. By means of different voltage ratios or an injected voltage, the rated current is made to flow in the **transformer** under test until stabilisation of the core and winding temperatures. See Figure 5 and Figure 6.

The duration of the test may be reduced by exciting the core for a period of time (preferably not less than 12 h) prior to the application of test current to the windings.

**Key**

- A = Voltage source at rated frequency for no-load losses
- B = Source for rated current at rated frequency for load losses
- C = Booster transformer

Figure 5 – Example of back-to-back method – Single phase**Key**

- A = Voltage source at rated frequency for no-load losses
- B = Source for rated current at rated frequency for load losses
- C = Booster transformer

Figure 6 – Example of back-to-back method – Three phase

14.1.3 Determination of steady-state conditions

The ultimate temperature rise is reached when the temperature rise becomes constant; this is considered to have been achieved when the temperature rise does not vary by more than 1 K per hour.

For the purpose of determining when steady-state conditions have been achieved, thermocouples shall be applied to the following surfaces:

- *For all types of transformers defined in Clause 3: centre of top yoke and as close as practicable to the innermost winding at the top of the winding, the measurement being on the centre leg of a three-phase transformer.*

Table 2 – Values of maximum temperatures in normal use

Parts ^a	Temperature °C
Windings, if the insulation system (i.e. bobbins and any other insulating materials that are in contact with the winding) is:	
– of class A ^b	100
– of class E ^b	115
– of class B ^b	120
– of class F ^b	140
– of class H ^b	165
– of other classes ^c	–
External enclosures ^{d,f} (which can be touched with the standard test finger) of stationary transformers , if of:	
– bare metal	65
– metal covered by lac or varnish	70
– other material	80
External enclosures ^{d,f} (which cannot be touched with the standard test finger) of stationary transformers	85
External enclosures ^{d,f} , handles and the like of portable transformers :	
– if, in normal use, these parts are continuously held (for example for hand held transformers):	
• of metal	48
• of other material	48
– if, in normal use, these parts are not continuously held:	
• of metal	60
• of other material	80
Terminals for external conductors and terminals of switches	70
Insulation of internal and external wiring ^e :	
– of rubber	65
• of polyvinyl chloride	70
Parts the deterioration of which could affect safety ^e :	
– of rubber (other than insulation of wiring)	75
• of phenolformaldehyde	105
• of ureaformaldehyde	85
• of impregnated paper and fabric	85
• of impregnated wood	85
• of polyvinyl chloride (other than insulation of wiring), polystyrene and similar thermo-plastic material	65
• of varnished cambric	75

Parts ^a	Temperature °C
Supports	85
Printed boards ^e :	
– bonded with phenol-formaldehyde, melamine-formaldehyde, phenol-furfural or polyester	105
• bonded with epoxy	140
^a If other materials are used, they shall not be exposed to temperatures in excess of those which have been proved permissible for these materials. ^b The classification is in accordance with IEC 60085 and IEC 60216 (all parts); however, the values have been adjusted to take into account the fact that, in these tests, the temperatures are mean and not hot-spot values. ^c If other insulating materials than those covered by IEC 60085 and IEC 60216 (all parts) are used, the insulation system shall withstand the test of 14.3. ^d If any component is part of the external surface of the transformer, the temperature of that component shall not exceed the value specified for the appropriate external enclosure. ^e The grades of rubber and polyvinyl chloride insulation are those covered by IEC 60245 (all parts) and IEC 60227 (all parts), respectively. ^f If the surface temperature limit of accessible parts exceeds the required values the warning symbol IEC 60417-5041 (2002-10) shall be used.	

An explanation of the appropriate hot-spot reduction for the maximum winding temperature can be found in Table 3 for each insulation classification according to IEC 60085.

Table 3 – Explanation of the maximum winding temperatures required in Table 2

Insulation classification according to IEC 60085	Maximum temperatures of Table 2 °C	Hot spot reduction K	Maximum final temperature according to IEC 60085 °C
Class A	100	5	105
Class E	115	5	120
Class B	120	10	130
Class F	140	15	155
Class H	165	15	180
The measuring of the winding temperature is based on the resistance method. So the measured values are mean values of the windings temperature. To cover also the peak values inside the winding, the hot spot reduction is necessary.			

The temperature rise on the heating elements of protective devices touching insulating material shall also be measured.

*Immediately after the test, the specimen shall withstand a dielectric strength test as specified in 18.3, the values are specified in Table 14 and the test voltage being applied between **input** and **output circuits** only.*

*During and after the test, the electrical connections shall not be loose, **creepage distances** and **clearances** shall not be reduced to less than the values specified in Clause 26, sealing compound shall not melt, and overload protective devices shall not operate.*

NOTE According to IEC 60038 the nominal voltage tolerance of $\pm 10\%$ is also applicable for an AC voltage value up to 1 000 V and a DC voltage value up to 1 415 V.

14.2 Application of 14.1 or 14.3 according to the insulation system

The following apply to the windings.

14.2.1 If the manufacturer has stated which class of insulation system has been used, the measured temperature of the winding shall not exceed the relevant value given in Table 2 (considering t_a if stated).

14.2.2 If the manufacturer has not stated which class of insulation system has been used the measured temperature of the winding shall not exceed the value given in Table 2 for class A insulation system (considering t_a if stated).

14.2.3 If the manufacturer has not stated which class of insulation system has been used and the measured temperature of the winding exceeds the value given in Table 2 for class A insulation system (considering t_a if stated), the **live parts of transformers** (core and windings) are subjected to the tests of 14.3. The temperature of the heating cabinet is chosen according to Table 4, taking the value of t_a into account. The temperature value to be chosen in Table 4 is the next highest value to the calculated temperature value.

14.3 Accelerated ageing test for undeclared class of insulation system

14.3.1 General

When applicable (see 14.2, 19.12.3 and 26.3), the **live parts** of the transformer (core and windings) are subjected to the following ageing test, each cycle consisting of a heat run, vibration, and a moisture treatment. Measurements are made according to 14.3.5.

The number of specimens is as indicated in 5.2. The specimens are subjected to 10 test cycles.

14.3.2 Heat run

Depending on the type of insulation system, the specimens are kept in a heating cabinet for the combinations of time and temperature recommended by the manufacturer in accordance with Table 4. The 10 cycles are carried out with the same combination.

The temperature in the heating cabinet is maintained within a tolerance of $\pm 3^\circ\text{C}$.

Table 4 – Test temperature and testing time (in days) per cycle

Test temperature °C	Testing time for the thermal class of the insulation system (days)				
	100 °C	115 °C	120 °C	140 °C	165 °C
220					4
210					7
200					14
190				4	
180				7	
170				14	
160			4		
150		4	7		
140		7			
130	4				
120	7				
Corresponding classification according to IEC 60085 and IEC 60216 (all parts)	A	E	B	F	H

After the heat tests, the specimens are allowed to cool down to ambient temperature before the vibration is conducted.

14.3.3 Vibration

*Specimens are fastened in their normal position of use to the vibration generator, as specified in IEC 60068-2-6 by means of straps round the **enclosure**. The direction of vibration is vertical, and the severity is:*

- *duration: 30 min;*
- *amplitude: 0,35 mm;*
- *frequency range: 10 Hz, 55 Hz, 10 Hz;*
- *sweep rate: approximately one octave per minute.*

14.3.4 Moisture treatment

The specimens are subjected for two days (48 h) to a moisture treatment according to 17.2.

14.3.5 Measurements

All the following measurements and tests are made and conducted before the cycling and after each complete cycle:

- *the no-load input current or its ohmic value.*
The no-load input current or the ohmic component of the no-load input current shall not be more than 30 % greater than the corresponding value obtained during the initial measurement;.
- *the insulation resistance is measured according to 18.1 and 18.2;*
- *a dielectric strength test according to 18.3 and 18.4. However, the values of the test voltages are reduced to 35 % of the specified values and the testing time is doubled;*
- *the following test only for **transformers** with a **rated supply frequency** of 50 Hz or 60 Hz. After the dielectric strength test, one **input circuit** is supplied by a test voltage of at least 1,2 times the **rated supply voltage** at double the **rated supply frequency** for 5 min. No load is connected to the **transformer**. During the test, polyfilar windings, if any, are connected in series. A higher test frequency than the double supply frequency may be used; the duration of the period of connection, in minutes, being equal to 10 times the **rated supply frequency** divided by the test frequency, but not less than 2 min.*

*During the above tests, there shall be no breakdown of the insulation between the turns of a winding, between **input** and **output circuits**, between adjacent **input** or **output circuits**, or between the windings and any conductive core.*

*If, after the completion of all 10 cycles, one or more specimens fail, the **transformer** is considered as not having complied with the accelerated ageing test.*

15 Short circuit and overload protection

15.1 General requirements

15.1.1 Short circuit and overload test method

Transformers shall not become unsafe due to short circuits and overloads that may occur in normal use.

*Compliance is checked by inspection and by the following tests, which are carried out immediately after the test according to 14.1 at the same ambient temperature, and without changing the position of the **transformer**, at 1,1 times the **rated supply voltage**, or, for **non-***

inherently short-circuit proof transformers, at any value of the supply voltage between 0,9 times and 1,1 times the **rated supply voltage**:

- for **inherently short-circuit proof transformers**, by the tests of 15.2;
- for **non-inherently short-circuit proof transformers**, by the tests of 15.3;
- for **non-short-circuit proof transformers**, by the tests of 15.4;
- for **fail-safe transformers**, by the tests of 15.5;
- for **transformers** combined with a rectifier, the tests of 15.2 or 15.3 are carried out twice, once with the short circuit applied on the input terminals of the rectifier, and again with the short circuit applied on the output terminals of the rectifier;
- for **transformers** with more than one **output winding** or a tapped **output winding**, the results to be considered are those showing the highest temperature. In the first case, all windings intended to be loaded at the same time are loaded at the **rated output** and then the selected **output winding** is short-circuited.

For the tests of 15.2, 15.3 and 15.4, the temperatures shall not exceed the values given in Table 5 when the **transformer** is operated at its **rated ambient temperature** (25 °C or t_a). In the cases where the temperature in the test area differs from the **rated ambient temperature**, this difference shall be taken into account when applying the limits in Table 5.

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Table 5 – Maximum values of temperatures under short-circuit or overload conditions

Insulation classification	A	E	B	F	H
	Maximum temperature °C				
Winding protected inherently Subclause 15.2	150	165	175	190	210
Winding protected by protective device:					
a) Subclauses 15.3.2 – 15.3.3 – 15.3.4 – during the time required or the time <i>T</i> given in Table 6 ^a	200	215	225	240	260
b) Subclause 15.3.1 – during the first hour, peak value – after the first hour, peak value – after the first hour, arithmetic mean value ^b	200 175 150	215 190 165	225 200 175	240 215 190	260 235 210
c) Subclause 15.3.5	175	190	200	215	235
External enclosures (which can be touched with the standard test finger)	105				
Rubber insulation of wiring	85				
PVC insulation of wiring	85				
Supports (i.e. any area on the pine plywood surface covered by the transformer)	105				

^a The maximum temperature to be considered is the maximum temperature reached during and after the test due to the thermal inertia of the **transformer**.

^b The arithmetic mean value is determined as follows:

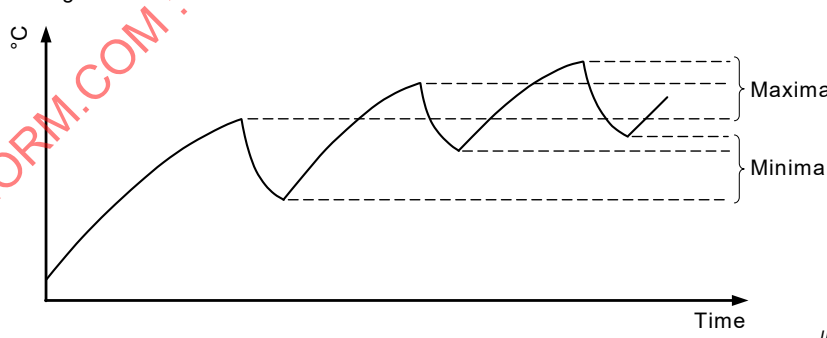
The graph of temperature versus time, while the power to the **transformer** is cycling on and off, is plotted for a period of test under consideration. The arithmetic average temperature (*t_A*) is determined by Formula (5):

$$t_A = (t_{\max} + t_{\min})/2 \tag{5}$$

where

t_{max} is the average of the maxima;

t_{min} is the average of the minima.



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During the test, the **transformer** shall not emit flames, molten metal, poisonous or ignitable gas in hazardous amounts, and temperatures shall not exceed the values shown in Table 5.

During and after all the tests, the **transformer** shall comply with Clause 9.

After the tests, the insulation system, when it has cooled down to approximately ambient temperature, shall withstand the dielectric strength test in 18.3.

NOTE The humidity treatment of 17.2 is not applied before this dielectric strength test.

15.1.2 Alternative short circuit and overload test method

The manufacturer may choose to apply any of the following methods described in 14.1.2.1 and 14.1.2.2. These test procedures are according to IEC 60076-11:2004, 23.2.1 and 23.2.2.

15.2 Inherently short-circuit proof transformers

Inherently short-circuit proof transformers are tested by short-circuiting the **output windings** until steady-state conditions are reached.

15.3 Non-inherently short-circuit proof transformers

Non-inherently short-circuit proof transformers are tested as follows:

15.3.1 The output terminals are short-circuited. The incorporated overload protective device shall operate before the temperature exceeds the values shown in Table 5 for any value of the supply voltage between 0,9 times and 1,1 times the **rated supply voltage**.

15.3.2 If protected by a fuse in accordance with either IEC 60269-2 or IEC 60269-3, or a technically equivalent fuse, the **transformer** is loaded for a time T and with a current equal to k times the current marked on the **transformer** as the rated current of the protective fuse-link, where k and T have the values shown in Table 6. The current in the fuse shall be kept constant during the test. The fuse-link is replaced by a link of negligible impedance.

Table 6 – Values of T and k for fuses

Values marked as rated current I_n of protective fuse-link for gG and gTr A	T h	k
$I_n \leq 4$	1	2,1
$4 < I_n \leq 16$	1	1,9
$16 < I_n \leq 63$	1	1,6
$63 < I_n \leq 160$	2	1,6
$160 < I_n \leq 200$	3	1,6
$200 < I_n \leq 1\,000$	2	1,5

NOTE 1 For cylindrical fuses gG type B for use by unskilled persons according to IEC 60269-3:2010, and for fuses for use by authorised persons with fuse-links for bolted connections according to IEC 60269-2:2013, the value of k is 1,6 for $I_n < 16$ A.

NOTE 2 For D-type fuses for use by unskilled persons according to IEC 60269-3:2010 for a rated current of 16 A, the value of k is 1,9.

15.3.3 If protected by miniature fuses in accordance with IEC 60127 (all parts), or by road vehicle blade type electric fuse-links according to ISO 8820 (all parts), or by a technically equivalent fuse, the **transformer** is loaded for a period corresponding to the longest pre-arcing time with the relevant current as specified in the appropriate standard sheet. The current in the fuse shall be kept constant during the test. The fuse-link is replaced by a link of negligible impedance.

NOTE A technically equivalent fuse is a fuse-link having the same time-current characteristics as one of those indicated in IEC 60127 (all parts) or in ISO 8820 (all parts).

If the **transformer** is protected by miniature fuses in accordance to IEC 60127 (all parts), an additional overload test shall be performed at 1,5 times the rated fuse current until steady-state condition.

15.3.4 If protected by a circuit-breaker in accordance with IEC 60898 (all parts), or a technically equivalent circuit-breaker, the **transformer** is loaded for the time indicated in IEC 60898 (all parts) with a current equal to 1,45 times the value of the rated current of the circuit-breaker. The current in the fuse shall be kept constant during the test. The circuit breaker is replaced by a link of negligible impedance.

15.3.5 If protected by:

- an overload protective device other than a fuse according to IEC 60127 (all parts) or IEC 60269 (all parts), or a circuit-breaker or
- an **intentional weak part**

the **transformer** is loaded by a current equal to 0,95 times the value of the lowest current which causes the protective device to operate, until steady-state conditions are reached. The lowest current causing the protective device to operate is determined by initially operating the transformer at 100 % of the **rated output**, and gradually increasing the output current in steps of 2 %, (each step is maintained until steady-state condition is achieved) until the protective device operates.

If the protective device is an **intentional weak part**, the above test is repeated on two new samples. During the test on the first sample, the weak part shall operate in the same manner and place as above. During the test on the second sample, the temperatures shall not exceed the values in Table 5 in the steady-state condition.

15.4 Non-short-circuit proof transformers

Non-short-circuit proof transformers are tested as indicated in 15.3 with the appropriate protective device specified by the manufacturer installed in the relevant **input** or **output circuit**.

Associated **non-short-circuit proof transformers** are tested under the most unfavourable conditions of normal use with the appropriate protective device specified by the manufacturer installed in the **input** or **output circuit**, and in the most unfavourable load conditions for the type of equipment or circuit for which the **transformer** is designed. Examples of unfavourable load conditions are: continuous, short-time, or intermittent functioning.

15.5 Fail-safe transformers

15.5.1 Three additional new specimens are used only for the following test.

During this test when the **transformer** fails, the interruption shall be in the **input circuit**.

Each of the three specimens is mounted as in normal use on a 20 mm thick dull black painted plywood surface and heated in accordance with 14.1 until the temperatures stabilise. Each **transformer** is then operated at 1,1 times the **rated input voltage**, the **output winding** which produced the highest temperature during the test of 14.1 being initially loaded with 1,5 times the **rated output current** (or, if this is not possible, the maximum value of the output current obtainable) until steady-state conditions are reached, or the **transformer** fails (whichever occurs first).

If the **transformer** fails, it shall comply, during and after the tests, with the criteria given in 15.5.2.

If the **transformer** does not fail, the time to reach steady-state conditions is noted, and the chosen **output winding** is then short-circuited. The test is continued until the **transformer** fails. For this part of the test, each specimen shall fail within the time duration being no longer than the time necessary to reach steady-state conditions, but not exceeding 5 h.

The **transformer** shall fail safely and comply, during and after the tests, with criteria given in 15.5.2.

15.5.2 At any time during the tests of 15.5.1:

- the temperature of any part of the **enclosure** of the **transformer** which can be touched with the standard test finger Figure 4 shall not exceed 175 °C;
- the temperature of the plywood support shall nowhere exceed 125 °C;
- the **transformer** shall not emit flames, molten material, glowing particles, or burning drops of insulating material.

After the tests of 15.5.1, and after cooling down to ambient temperature:

- the **transformer** shall withstand a dielectric strength test, the test voltage being 35 % of the values according to Clause 18, Table 14. The test is made input-to-body for all kinds of **transformers** and, in addition, input-to-output for **safety isolating, isolating and separating transformers**;
- **enclosures**, if any, shall have no holes allowing the standard test finger (Figure 4) to touch **hazardous-live-parts**. In case of doubt, contact with **hazardous-live-parts** is detected by means of an electrical contact indicator, the voltage being not less than 40 V.

If the **transformer** fails any part of this subclause, the **transformer** is considered as not complying with the above test.

16 Mechanical strength

16.1 General

Transformers shall have adequate mechanical strength, and be so constructed as to withstand rough handling as may be expected in normal use.

Compliance is checked by the tests of 16.2 for **stationary transformers** and by the tests of 16.2, 16.3 and 16.4, as appropriate, for **portable transformers**.

After the tests, the **transformer** shall show no damage in accordance with the requirements of this document. In particular, **hazardous-live-parts** shall not become accessible, when checked as described in 9.2.2. Insulating barriers shall not be damaged, and handles, levers, knobs and the like shall not move on their shafts.

NOTE 1 Damage to the finish, small dents which do not reduce **creepage distances** or **clearances** below the values specified in Clause 26, and small chips which do not adversely affect the protection against electric shock or moisture, are ignored.

NOTE 2 Cracks not visible with normal vision or corrected vision without magnification, and surface cracks in fibre reinforced mouldings and the like are ignored.

In addition, in regard to the test of 16.4, bending of the pins during the test is ignored.

16.2 Stationary transformers

The **transformer**, with covers and the like fitted, is held firmly against a rigid support and is subjected to three blows from a spring-operated impact hammer according to test Ehb of IEC 60068-2-75 with an energy of $(0,5 \pm 0,05)$ J applied to every point of the exterior that protects **hazardous-live-parts** and is likely to be weak, including handles, levers, switch knobs and the like, by pressing the hammer nose perpendicularly to the surface. Before applying the blows, the fixing screws of bases and covers are tightened with a torque equal to two-thirds of that specified in Table 18.

If there is a doubt as to whether a defect has occurred by the application of the preceding blows, the defect is neglected, and the group of three blows is applied to the same place on a new sample which shall then withstand the test.

*Parts of IP00 **transformers**, which are not accessible when the **transformer** is mounted in an appliance or other equipment, are not subjected to the test.*

16.3 Portable transformers (except portable transformers with integral pins for introduction in socket-outlet in the fixed wiring)

Portable transformers except those **portable transformers** with integral pins for introduction in socket-outlets of the fixed wiring are held in their normal position of use, and are then allowed to fall from a height of 25 mm onto a smooth steel plate at least 5 mm thick, placed on a flat concrete support. One hundred falls are carried out at a rate not exceeding one fall per 5 s.

The height shall be measured from the part of the specimen nearest to the test surface when the specimen is suspended prior to letting it fall.

The method of releasing the specimen shall be such as to allow free fall from the position of suspension with a minimum of disturbance at the moment of release.

*If the **transformer** is provided with fixed **external flexible cable(s)** or **cord(s)**, they are cut to a length of 100 mm.*

16.4 Portable transformers provided with integral pins for introduction in socket-outlets of the fixed wiring

16.4.1 General requirements

Portable transformers with integral pins for introduction into fixed socket-outlets shall have adequate mechanical strength.

Plug in power supply units with integral main plug complying with IEC TR 60083, without plugs complying with EN 50075 (IEC plug type C) shall be tested according 16.4.1.

Plug in power supply units with integral main plug complying with EN 50075 (IEC plug type C), shall be tested according 16.4.2, if no additional national standard or regulation for a plug complying with IEC TR 60083 is required.

NOTE 1 The countries using this type of plug are mentioned under world plugs type C (available at <http://www.iec.ch/worldplugs/typeC.htm>).

Compliance is checked by carrying out the tests a), b) and c). The test a) is carried out on three specimens that all shall withstand the tests. Both the test of b) and c) shall be carried out on a new specimen.

- a) *The test is carried out in a tumbling barrel as described in IEC 60068-2-31. If the **transformer** is provided with fixed external cord(s) they are cut to a length of 100 mm. Each specimen is tested individually.*

The barrel is turned at a rate of five revolutions per minute, 10 falls per minute thus taking place, the number of falls being:

- 50 if the mass of the specimen does not exceed 250 g;*
- 25 if the mass of the specimen exceeds 250 g.*

After the test, the specimen shall show no damage within the meaning of this document, but it need not be operable.

Small pieces may brake off, provided that the protection against electric shock is not affected.

*Distortion of pins and damage to the finish and small dents which do not reduce the **creepage distances** or **clearances** below the values specified in 27.1 of IEC 60884-1:2002, IEC 60884-1:2002/AMD1:2006 and IEC 60884-1:2002/AMD2:2013 are neglected.*

- b) *The pins shall not turn when a torque of 0,4 Nm is applied, first in one direction for 1 min and then in the opposite direction for 1 min.*

NOTE 2 This test is not carried out when rotation of the pins does not impair the safety, in the sense of this document.

- c) *A pull force as given in Table 7 is applied without jerks for 1 min on each pin, in turn, and in the direction of the longitudinal axis of the pin.*

The pull force is applied within a heating cabinet at a temperature of $(70 \pm 2) ^\circ\text{C}$, 1 h after the device has been placed in the heating cabinet.

Table 7 – Pull force on pins

Rating of the equivalent plug type	Number of poles	Pull force N
Up to and including 10 A 130/250 V	2 3	40 50
Above 10 A up to and including 16 A 130/250 V	2 3	50 54
Above 10 A up to and including 16 A 440 V	3 More than 3	54 70

For the purpose of this test, protective earthing contacts, irrespective of their number, are considered as one pole.

After the test, and after the device has cooled down to ambient temperature, no pin shall be displaced in the body of the device by more than 1 mm.

16.4.2 Portable transformers provided with integral pins according to EN 50075 (IEC plug type C) for introduction in socket-outlets of the fixed wiring

Portable transformers with integral pins for introduction into fixed socket-outlets shall have adequate mechanical strength.

Compliance is checked by carrying out the tests a), and b). The test are carried out on three specimens that all shall withstand the tests.

- a) *The test is carried in a tumbling barrel as described in IEC 60068-2-31. If the **transformer** is provided with fixed external cord(s) they are cut to a length of 100 mm. Each specimen is tested individually.*

The barrel is turned at a rate of five revolutions per minute, 10 falls per minute thus taking place, the number of falls being:

- 1 000 if the mass of the specimen does not exceed 100 g;
- 500 if the mass of the specimen exceeds 100 g but does not exceed 200 g
- 100 if the mass of the specimen exceeds 200 g

After the test the following requirements shall be fulfilled:

- 1) *The specimen shall show no damage within the meaning of this document, but it need not be operable.*
- 2) *Small pieces may break off, provided that the protection against electric shock is not affected.*
- 3) *A pin of the plug shall not break*

- 4) *Distortion of pins and damage to the finish and small dents are neglected.*
- 5) *The pull test according to IEC 60884-1:2002, 24.10 shall be done with the same samples which have been in the tumbling barrel test. For the pull test, the pins, if distorted, shall be accurate into the vertical position. The pin shall not break.*

The pull force is applied within a heating cabinet at a temperature of $(70 \pm 2) ^\circ\text{C}$, 1 h after the device has been placed in the heating cabinet. After the test, and after the device has cooled down to ambient temperature, no pin shall be displaced in the body of the device by more than 1 mm.

- b) *The torque test shall be done with new samples. The pins shall not turn when a torque of 0,4 Nm is applied, first in one direction for 1 min and then in the opposite direction for 1 min.*

NOTE This test is not carried out when rotation of the pins does not impair the safety, in the sense of this document.

16.5 Additional requirements for transformers to be used in vehicles and railway applications

16.5.1 Transformers to be used in vehicles and railway applications

An additional test according IEC 61373 shall be performed with conditions of Table 8 and Table 9 and the frequency values depending on the weight of the specimen are defined in Table 10

Table 8 – Conditions for vibration testing (random)

Directions	Testing duration	RMS value m/s ²	Frequency range
X-Y-Z	5h per axis	5,72	Figure 7

Table 9 – Amplitude spectrum density ASD values for accelerated life testing

Directions	ASD value (m/s ²) ² /Hz
X-Y-Z	0,964

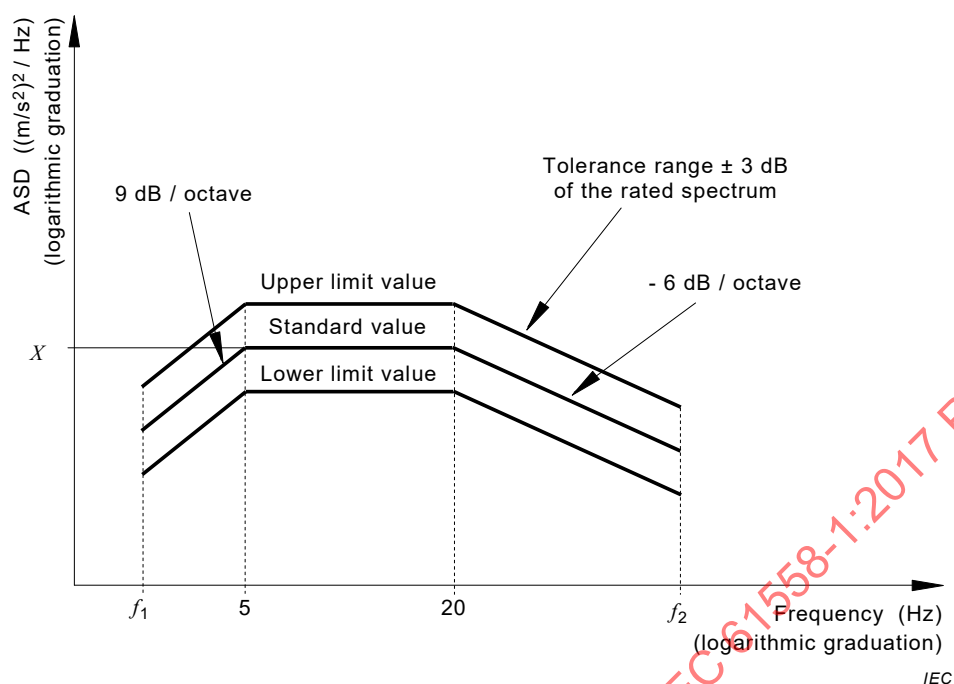


Figure 7 – Amplitude spectrum density for random testing

Table 10 – Frequency values depending on the weight of the specimen

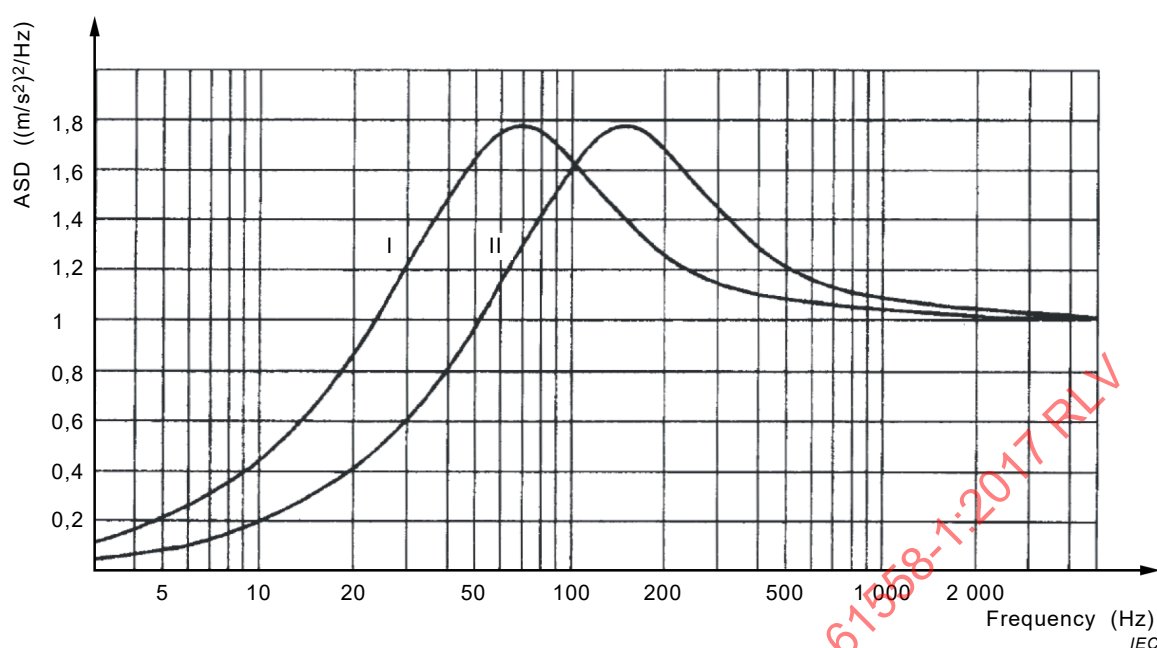
Frequency values		
For a mass ≤ 500 kg	$f_1 = 5$ Hz	$f_2 = 150$ Hz
For a mass > 500 kg and $\leq 1\,250$ kg	$f_1 = \frac{1\,250}{mass} \times 2$ Hz	$f_2 = \frac{1\,250}{mass} \times 60$ Hz
For a mass $> 1\,250$ kg	$f_1 = 2$ Hz	$f_2 = 60$ Hz

16.5.2 Test requirements for the transportation of transformers

Shock and vibration testing requirements for transformers subjected to while being transported per IEC 60721-3-2 with conditions according to Table 11 and Figure 8.

Table 11 – Excitation values for vibration testing

Type of vibration	Unit	Values		
Swept sine	mm	3,5		
	m/s^2		10	15
	Hz	2 to 9	9 to 200	200 to 500
Random	$(m/s^2)^2/Hz$	1		0,3
	Hz	10 to 200		200 to 2 000
Shock	Type I m/s^2	100		
	Type II m/s^2	300		



Example due to the duration of a half-sine impulse

Spectrum I

Duration 11 ms

Spectrum II

Duration 6 ms

Figure 8 – Normalised spectrum of shock

17 Protection against harmful ingress of dust, solid objects and moisture

17.1 Degrees of protection provided by enclosures (IP code)

17.1.1 General requirements

The **enclosure** of a **transformer** shall provide the degree of protection against ingress of dust, solid objects and moisture in accordance with the classification of the **transformer** and the IP number marked on the **transformer**, except IP1X which shall be marked and tested as IP00.

NOTE 1 An explanation of the IP code system is given in Annex Q.

NOTE 2 The degree of protection IP00 is not covered by Clause 17.

*Compliance is checked by the appropriate test specified in 17.1.2, and for other IP ratings by the appropriate test specified in IEC 60529. If additional letters are used, the transformers shall comply with the relevant requirements of IEC 60529 where the test probe shall not touch **hazardous-live-parts** and hazardous moving parts.*

*Before the test of second characteristic numeral, with the exception of IPX8 and higher, the **transformer** shall be switched on under the **rated output** conditions and brought to a stable operating temperature at the rated voltage.*

The water for the test shall be at a temperature of $(15 \pm 10) ^\circ\text{C}$.

Transformers shall be mounted and wired as in normal use with, where relevant, a suitable plug inserted in the **output circuit**.

Transformers not provided with an **external flexible cable or cord**, are fitted with external wiring, as specified in Clause 22, using the most unfavourable type and cross-sectional area.

For tests of 17.1.2 A to J, a **fixed transformer** intended for mounting with its **body** in contact with a surface shall be tested on a board equal in overall size to the projection of the **transformer**, if not otherwise specified.

Transformers with enclosure having provisions for draining water by means of drain holes shall be mounted with the lowest drain hole open unless otherwise specified in the manufacturer's installation instructions. Ventilation openings are left open during the test.

Portable transformers wired as in normal use, shall be placed in the most unfavourable position of normal use.

Glands, if any, shall be tightened with a torque equal to two-thirds of that applied to glands in the test of 25.6.

After completion of the tests, the **transformer** shall withstand the dielectric strength test specified in 18.3 and inspection shall show:

- a) no access with **hazardous-live-parts** or hazardous moving parts with the relevant test probe according to the test described in 17.1.2, items A 1), B 1) and C 1). The test finger may penetrate but the stop face ($\varnothing$ 50 x 20 mm) shall not pass through the openings for the number 2 of the first characteristic numeral
- b) no entry into the **transformer** enclosure by the relevant test probe for solid-object-proof **transformers** according to test described in 17.1.2, items A 2) and B 2). The protection is satisfactory if the full diameter of the probe does not pass through any openings;
- c) no deposit of talcum powder inside enclosures for dust-proof **transformers**, so that, if the powder were conductive, the insulation would fail to meet the requirements of this document (test described in 17.1.2, item C 2);
- d) no deposit of talcum powder inside **enclosures** for dust-tight **transformers** (test described in 17.1.2, item C 2);
- e) no trace of water on **live parts** except SELV parts below 15 V AC or 25 V DC or on insulation where it could become a hazard for the user or surroundings, for example where it could reduce the **creepage distances** below the values specified in Clause 26;
- f) no accumulation of water inside the enclosures of drip-proof, spray-proof, splash-proof and jet-proof **transformers**, which may impair safety;
- g) no water or trace of water entered inside the enclosure of a watertight **transformer**.

17.1.2 Tests on transformers with enclosure

A Solid-object-proof **transformers** (first characteristic IP numeral 2) shall be tested as follows:

- 1) with the standard test finger specified in IEC 60529 applied with a force of 10 N, with a relative tolerance of $\pm 10\%$ and the test pin specified in Figure 3 according to the requirements of Clause 9 and 26.2;
- 2) with a rigid sphere without handle or guard $12,5^{+0,2}_{-0}$ mm diameter applied with a force of 30N, with a relative tolerance of $\pm 10\%$

B Solid-object-proof **transformers** (first characteristic IP numerals 3 and 4) shall be tested as follows:

- 1) at every possible point with a probe according to test probe C or D of IEC 61032, applied with a force as given in Table 12:

Table 12 – Solid-object-proof transformer test

	Test probe according to IEC 61032	Probe wire diameter mm	Application force
First IP numeral 3	C	$2,5^{+0,05}_0$	$(3 \pm 0,3) \text{ N}$
First IP numeral 4	D	$1^{+0,05}_0$	$(1 \pm 0,1) \text{ N}$

The end of the probe wire shall be cut at right angles to its length and be free from burrs.

- 2) *With a rigid steel rod with $2,5^{+0,05}_0$ mm diameter with edges free from burrs applied with a force of 3 N, with a relative tolerance of $\pm 10\%$, for first characteristic IP numeral 3 and with a rigid steel wire with $1^{+0,05}_0$ mm diameter with edges free from burrs applied with a force of 1 N, with a relative tolerance of $\pm 10\%$, for first characteristic IP numeral 4. The probes are intended to simulate foreign objects which may be spherical. Where an enclosure has an indirect or tortuous entry path and there is any doubt about ingress of a spherical object capable of motion, it may be necessary to examine drawings or to provide special access for the object probe to be applied with the specified force to the opening (s) where ingress has to be checked.*

C Dust-proof transformers (first characteristic IP numeral 5) are tested as follows:

- 1) *At every possible point with a probe according to test probe D of B 1).*
- 2) *In a dust chamber similar to that shown in Figure 2 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999, in which talcum powder is maintained in suspension by an air current; during the test the vacuum pump as shown is not connected. The chamber shall contain 2 kg of powder for every cubic metre of its volume. The talcum powder used shall pass through a square-meshed sieve whose nominal wire diameter is 50 μm , and whose nominal free distance between wire is 75 μm . It should not have been used for more than 20 tests.*

The test shall be carried out as follows:

- a) *the **transformer** is suspended outside the dust chamber and operated at **rated output** until operating temperature is achieved;*
- b) *the **transformer**, while still operating, is placed with the minimum disturbance in the dust chamber;*
- c) *the door of the dust chamber is closed;*
- d) *the fan/blower causing the talcum powder to be in suspension is switched on;*
- e) *after 1 min the **transformer** is switched off and allowed to cool for 3 h while the talcum powder remains in suspension.*

NOTE 1 The 1 min interval between the switching on of the fan/blower and the switching off of the **transformer** is to ensure that the talcum powder is properly in suspension around the **transformer** during initial cooling, which is most important with smaller **transformers**. The **transformer** is operated initially as in item a) to ensure that the test chamber is not overheated.

NOTE 2 This treatment of test condition correspond to category 1 of IEC 60529.

D Dust-tight transformers (first characteristic IP numeral 6) are tested in accordance with C.

E Drip-proof transformers (second characteristic IP numeral 1) are subjected for 10 min to an artificial rainfall of $1^{+0,05}_0$ mm/min by means of a device as shown in Figure 3 of IEC 60529:1989, falling vertically from a height of 200 mm above the top of the **transformer**.

F Drip-proof transformers (second characteristic IP numeral 2) are tilted in any angle up to 15° and subjected for 10 min (2,5 min in each of the four fixed position of tilt) to a artificial

rainfall of $3_0^{+0,5}$ mm/min by means of a device as shown in Figure 3 of IEC 60529:1989, falling vertically from a height of 200 mm above the top of the **transformer**.

- G **Spray-proof transformers** (second characteristic IP numeral 3) are sprayed with water for 10 min by means of a spray apparatus as shown in Figure 4 of IEC 60529:1989. The radius of the semi-circular tube shall be as small as possible and compatible with the size and position of the **transformer**.

The tube shall be perforated so that jets of water are directed towards the centre of the circle, and a water flow rate shall be 0,07 l/min, with a relative tolerance of $\pm 5\%$, per hole, multiplied by number of holes (approximately 80 kN/m²).

The tube shall be caused to oscillate through an angle of 120°, 60° on either side of the vertical, the time for one complete oscillation ($2 \times 120^\circ$) being about 4 s.

The **transformer** shall be mounted above the pivot line of the tube so that the ends of the **transformer** receive adequate coverage from the jets. The **transformer** shall be turned about its vertical axis as stated in IEC 60529.

After this 10 min period, the **transformer** shall be switched off and allowed to cool naturally while the water spray is continued for a further 10 min.

- H **Splash-proof transformers** (second characteristic IP numeral 4) are sprayed from every direction with water for 10 min by means of the spray apparatus shown in Figure 4 of IEC 60529:1989 and described in G. The **transformer** shall be mounted under the pivot line of the tube so that the ends of the **transformer** receive adequate coverage from the jets.

The tube shall be caused to oscillate through an angle of almost 360°, 180° on either side of the vertical, the time for one complete oscillation ($2 \times 360^\circ$) being about 12 s. The **transformer** shall be turned about its vertical axis as stated in IEC 60529.

The support for the equipment under test shall be grid shaped in order to avoid acting as a baffle. After this 10 min period, the **transformer** shall be switched off and allowed to cool naturally, while the water spray is continued for an additional 10 min.

- I **Jet-proof transformers** (second characteristic IP numeral 5) are switched off and immediately afterwards are subjected to a water jet for 15 min from all directions by means of a hose, having a nozzle with the shape and dimensions shown in Figure 6 of IEC 60529:1989, the dimension D' being 6,3 mm. The nozzle shall be held 3 m away from the sample.

The rate of the water flow shall be 12,5 l/min, with a relative tolerance of $\pm 5\%$.

- J **Powerful jet-proof transformers** (second characteristic IP numeral 6) are switched off and immediately afterwards are subjected to a water jet for 3 min from all directions by means of a hose, having a nozzle with the shape and dimensions shown in Figure 6 of IEC 60529:1989, the dimension D' being 12 mm. The nozzle shall be held 3 m away from the sample.

The rate of the water flow shall be 100 l/min, with a relative tolerance of $\pm 5\%$.

- K **Water-tight transformers** (second characteristic IP numeral 7) are switched off and immediately immersed for 30 min in water, so that there is at least 150 mm of water above the top of the **transformer**, and the lowest portion is subjected to at least 1 m head of water. **Transformers** shall be held in position by their normal fixing means.

NOTE This treatment is not sufficiently severe for **transformers** intended for operation under water.

- L **Pressure watertight transformers** (second characteristic IP numeral 8) are heated either by operating or by other suitable means, so that the temperature of the **transformer enclosure** exceeds that of the water in the test tank by between 5 °C and 10 °C.

The **transformer** shall then be switched off and subjected to a water pressure of 1,3 times that pressure which corresponds to the rated maximum immersion depth for a period of 30 min.

17.2 Humidity treatment

Transformers shall be proof against humid conditions which may occur in normal use.

Compliance is checked by the humidity treatment described in this subclause, followed immediately by the tests of Clause 18.

Transformers intended for fixed connection to the supply are tested with the cable fitted but with cable entries open. If several knock-outs are provided and positioned on different parts of the enclosure, the knock-out which produces the most unfavourable condition will be opened. **Transformers** intended to be used with an **external flexible cable or cord** are tested with the cord and cord entries correctly fitted.

Electrical components, covers and other parts which can be removed without the aid of a tool are removed and subjected to the humidity treatment with the main part, if necessary.

The humidity treatment is carried out in a humidity cabinet containing air with a relative humidity maintained between 91 % and 95 %. The temperature of the air, at all places where specimens can be located, is maintained to within 1 °C of any convenient value t between 20 °C and 30 °C.

Before being placed in the humidity cabinet, the specimen is brought to a temperature between t and $(t + 4)$ °C.

The specimen is kept in the cabinet for:

- two days (48 h) for **transformers** with protection index IP20, or lower;
- seven days (168 h) for **transformers** with other protection index.

In most cases, the specimens may be brought to the specified temperature by keeping them at this temperature for at least 4 h before the humidity treatment.

A relative humidity between 91 % and 95 % can be obtained by placing a saturated solution of sodium sulphate (Na_2SO_4) or potassium nitrate (KNO_3) in water, the solution having a sufficiently large contact surface with the air in the humidity cabinet. In order to achieve the specified conditions within the cabinet, it is necessary to ensure constant circulation of the air and, in general, to use a cabinet which is thermally insulated.

*After this treatment and the tests of Clause 18, the **transformer** shall show no damage within the meaning of this document.*

18 Insulation resistance, dielectric strength and leakage current

18.1 General

The insulation resistance, the dielectric strength and the leakage current of **transformers** shall be adequate.

Compliance is checked by the tests of 18.2 to 18.5 which are carried out immediately after the test of 17.2, in the humidity cabinet or in the room where the specimen was brought to the prescribed temperature, after reassembling those parts which may have been removed.

Reducing the overvoltage category classification by about one category lower after the secondary side of the transformer is allowed, except for auto-transformers, under the following conditions:

- an earthed screen shall be between the primary and secondary winding or the secondary circuits have to be connected to functional earthing.

18.2 Insulation resistance

The insulation resistance shall not be less than that shown in Table 13.

The insulation resistance is measured with a DC voltage of approximately 500 V applied, the measurement being made 1 min after application of the voltage.

Table 13 – Values of insulation resistance

Insulation to be tested	Insulation resistance MΩ
Between hazardous-live-parts and the body :	
– for basic insulation	2
– for reinforced insulation	7
Between input circuits and output circuits (basic insulation)	2
Between input circuits and output circuits (double or reinforced insulation)	5
Between each input circuit and all other input circuits connected together	2
Between each output circuit and all other output circuits connected together	2
Between hazardous-live-parts and conductive parts of class II transformers which are separated from hazardous-live-parts by basic insulation only	2
Between conductive parts of class II transformers which are separated from hazardous-live-parts by basic insulation only, and the body	5
Between two metal foils in contact with the inner and outer surfaces of enclosures of insulating material of class II transformers	7

18.3 Dielectric strength test

Immediately after the test of 18.2, the insulation is subjected for 1 min to a dielectric strength voltage of substantially sinusoidal-wave form at 50/60 Hz. The value of the dielectric strength test voltage is given in Table 14.

Resistors, capacitors and other components are disconnected before carrying out the test.

Table 14 – Table of dielectric strength test voltages

Overvoltage category	Type of insulation	Working voltage V					
		<50	100	150	300	600	1 000
OVC I	Functional insulation	250	350	Working voltage + 500			
	Basic insulation	250	350	700	1 100	1 500	2 250
	Supplementary insulation						
	Double or reinforced insulation	500	700	1 400	2 200	3 000	4 500
OVC II	Functional insulation	250	350	Working voltage + 500			
	Basic insulation	250	500	1 250	1 500	2 100	2 500
	Supplementary insulation						
	Double or reinforced insulation	500	1 000	2 500	3 000	4 200	5 000
OVC III	Functional insulation	250	350	Working voltage + 500			
	Basic insulation	250	700	1 400	2 100	2 500	2 750
	Supplementary insulation						
	Double or reinforced insulation	500	1 400	2 800	4 200	5 000	5 500
OVC IV	Functional insulation	250	350	Working voltage + 500			
	Basic insulation	250	850	1 700	2 500	2 800	3 000
	Supplementary insulation						
	Double or reinforced insulation	500	1 700	3 400	5 000	5 600	6 000

NOTE 1 For the construction according to 19.12.3 b) and 26.2.5.1, test B the voltage is multiplied by the factor 1,25. For the construction according to 26.2.5.2 the voltage is multiplied by the factor 1,35. This increase does not apply to routine dielectric strength tests according to L.4.

NOTE 2 Values of test voltage for intermediate values of working voltage are found by linear interpolation between the tabulated values.

No flashover or breakdown of the insulating materials and/or system shall occur during the test, corona effects and similar phenomena being disregarded. Diagrams showing examples of the application of test voltages are shown in Annex N.

Details of the test method to be used are given in IEC 61180.

The high-voltage **transformer** used for the test shall be capable of supplying a current of at least 200 mA when the output terminals are short-circuited.

Care shall be taken that the dielectric voltage applied between **input** and **output circuits** does not overstress other insulation. If it is stated by the manufacturer that a **double insulation** system exists between **input** and **output circuits**, such as from **input circuit** to core and from core to **output circuit**, each insulation is then tested separately according to 19.1 and Table 14. The same applies to a **double insulation** between input and the **body**.

For class II situations incorporating both **reinforced insulation** and **double insulation**, care shall be taken that the dielectric test voltage applied to the **reinforced insulation** does not over-stress the **basic** or **supplementary insulation**.

18.3.1 A partial discharge test according to IEC 60664-1, (see test description below) shall be performed, if FIW wires or TIW wires are used and if the recurring peak working voltage U_t across the insulation is greater than 750 V. The relevant recurring peak voltage is the maximum measured voltage between the input and the output circuit, if the secondary side is earthed. The measuring shall be done at 1,0 of the maximum rated input voltage.

A partial discharge test shall be done at the transformer with the measured recurring peak voltage U_t , greater than 750 V peak.

where

U_t is the maximum peak working voltage (V);

t_1 is a duration of 5 s;

t_2 is a duration of 15 s;

Partial discharge shall be less than or equal to 10 pC at time t_2 . The test shall be done according to the Figure 9. For other applications higher values may be required (e.g. IEC 61800-5-1).

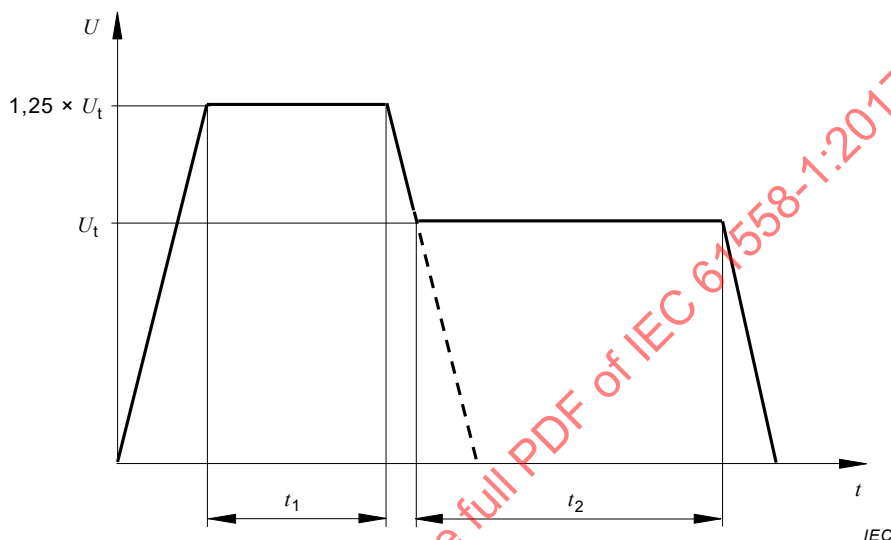


Figure 9 – Test voltage sequence

18.4 Insulation between and within windings

After the test of 18.3, one **input circuit** is connected to a voltage equal to double the **rated supply voltage**, at double the **rated supply frequency** for 5 min. No load is connected to the **transformer**. During the test polyfilar windings, if any, are connected in series. This test is only applicable for **transformers** with **rated supply frequency** lower than 500 Hz.

A higher test frequency than the double supply frequency may be used; the duration of the period of connection, in minutes, then being equal to 10 times the **rated supply frequency** divided by the test frequency, but not less than 2 min.

During the test, there shall be no breakdown of the insulation between turns of a winding, between **input** and **output circuits**, between adjacent **input** or **output circuits**, or between the windings and any conductive core.

18.5 Touch current and protective earthing conductor current

18.5.1 General

The **touch** and **protective earthing conductor current** are measured as described under 18.5.2 and 18.5.3 below.

For variable **transformers** or **transformers** with tapping, the most unfavourable setting shall be chosen. For **transformers** with more than one **input** or **output winding**, the most unfavourable combination shall be chosen.

The method of measurement described here is based on the assumption that the **transformer** is used in a star TN or TT system, i.e. the **transformer** is connected between line (L) and Neutral (N). For other systems, see relevant subclauses of the IEC 60990.

In case of multi phase connections the same procedure is used, but the measurement(s) are made on one phase at the time. The same limits apply for each phase.

The **touch current** and **protective earthing conductor current** are measured with the **transformer** loaded as described in Clause 14 and the measurements are made at steady-state condition.

To avoid unnecessary testing it is recommended that this measurement be carried out in connection with the heating test in Clause 14.

18.5.2 Touch current

In case of **enclosures** fabricated of insulating material, a metal foil 10 cm × 20 cm in size is placed in contact with the accessible surfaces and the measurement is made to this foil. In case of class II insulated parts on a **class I transformer** the **touch current** shall be measured simultaneously on the two parts.

*During the measurements, a test circuit according to Figure 10 shall be used. The test circuit shall include an **isolating transformer** and the "neutral" conductor connected to the measuring network shall be reliably earthed for safety reasons. For **class II transformers** the protective earthing conductor is ignored. The measuring network indicated is the network described in Figure J.1. However, if frequencies above 30 kHz are involved, measurement of **touch current** shall include measurement with regard to electric burn effects in addition to the measurements of Figure J.1. For the burn effects, the unweighted RMS value of the **touch current** is relevant. Unweighted **touch current** is calculated from the RMS voltage U_1 , measured across the 500 Ω resistor of Figure J.1.*

The terminal A electrode shall be applied to each accessible part in turn.

For each application of the terminal A electrode, the terminal B electrode shall be applied to protective earthing, then applied to each of the other accessible part in turn.

Measurements:

The **touch-current** is measured with the switch p in both position and the following combination of switches e and n :

- switches n and e in the on position;
- switch n in the off position and switch e in the on position;
- switch n in the on position and switch e in the off position.

For each application of the terminal A and B electrodes and for each combination of the switches p , e and n , the **touch current** measured shall be equal to or less than in Table 15.

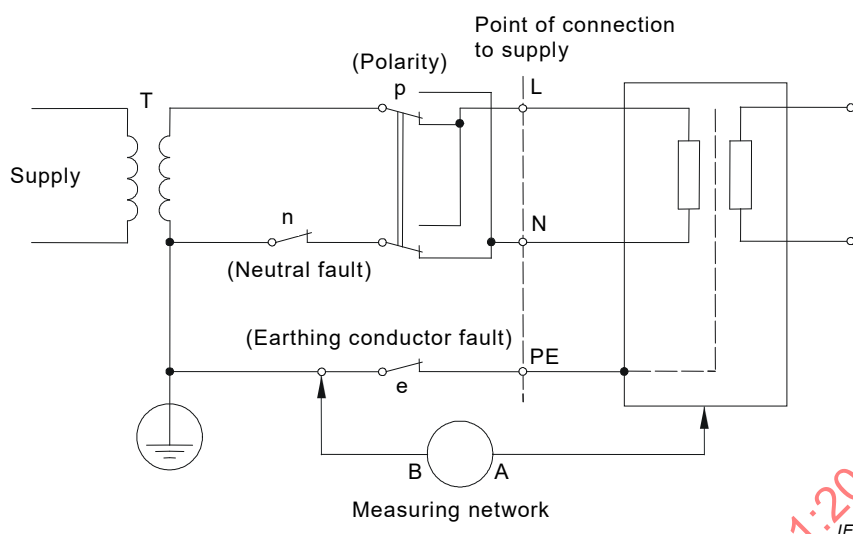


Figure 10 – Test configuration: single-phase equipment on star TN or TT system

18.5.3 Protective earthing conductor current

The **protective earthing conductor current** is measured with the **transformer** connected as described in Clause 14. In addition an ammeter of negligible impedance (less than $0,5 \Omega$) is connected between the earthing terminal of the **transformer** and the protective earthing conductor.

The **protective earthing conductor current** (s) shall not exceed the values of Table 15.

Table 15 – Limits for currents

Type of current	Rated current	Max limit (RMS)
Touch current: All class I and class II transformers equipped with a plug according to IEC TR 60083	–	0,5 mA
Protective conductor current:	< 4 A	2 mA
– Class I transformers fitted with a single or multiphase plug rated up to and including 32 A	> 4 A but < 10 A	0,5 mA/A
	> 10 A	5 mA
– Class I transformers intended for permanent connection	< 7 A	3,5 mA
	> 7 A but < 20 A	0,5 mA/A
	> 20 A	10 mA

The value to be observed during the measurement is a peak value. The peak value can be transformed into true RMS using a good quality oscilloscope.

NOTE Further explanations regarding the measurement of **touch current** and **protective conductor current** can be found in IEC 60990 and IEC 61140:2016 (7.6).

19 Construction

19.1 General construction

19.1.1 General

The **input** and **output circuits** shall be electrically separated from each other as specified in the relevant part of IEC 61558-2. The construction shall be such that there is no possibility of any connection between these circuits, either directly or indirectly, through other **conductive parts**, except by deliberate action.

NOTE To reflect different basic **transformer** types, this subclause is separated into the following three parts:

19.1.2 Auto-transformers

19.1.3 Separating transformers

19.1.4 Isolating and safety isolating transformers

19.1.2 Auto-transformers

19.1.2.1 Plug connected **auto-transformers** where the **rated input voltage** is higher than the **rated output voltage**, shall not have any potential to protective earthing at the output socket higher than the **rated output voltage**.

This requirement shall be fulfilled by using one of the following methods:

19.1.2.2 Polarized input and output plug and socket-outlet system

In this case, an instruction shall be given for not using such a **transformer** with a non-polarised plug and socket-outlet system.

19.1.2.3 Polarity detecting device (for non polarised input and output plug and socket-outlet system)

A polarity detecting device shall only energise the **output circuit** when the potential to protective earthing at the poles of the output socket does not exceed the **rated output voltage**. The contact separation of the breaking device shall be at least of 3 mm in each pole.

NOTE A magnetic relay is an example of a polarity detecting device.

Compliance is checked by the following test:

*The **auto-transformer** is connected to the mains at 1,1 times the **rated input voltage** under the most unfavourable condition of **load** and **output voltage**. The test is repeated with the polarity of the input reversed. During the test, the measured potential to protective earthing of each pole shall not exceed the maximum **output voltage** under load (1,1 times the **rated output voltage** taking into account the permissible deviations of Clause 11).*

Compliance is checked by measurement.

If the polarity detecting device uses a current flowing to the protective earthing for the detection, this current shall not exceed 0,75 mA and shall only be flowing for the period of measurement until the polarity is reversed.

Compliance is checked by measurement.

All the tests are repeated under the fault conditions of H.3.3. In this case, the potential to protective earthing of each pole shall not exceed 1,1 times the maximum output voltage under load for more than 5 s.

Compliance is checked by measurement.

In addition, the following requirements apply:

- for **class I transformers**, the insulation between the **input / output winding** and the **body** shall consist of at least **basic insulation** (rated for the **working voltage**);
- for **class II transformers**, the insulation between the **input / output winding** and the **body** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**).

Compliance is checked by inspection.

19.1.3 Separating transformers

19.1.3.1 The **input** and **output circuits** shall be electrically separated from each other and the construction shall be such that there is no possibility of any connection between these circuits, either directly or indirectly, via other **conductive parts**, except by deliberate action.

Compliance is checked by inspection and measurements, taking Clauses 18 and 26 into consideration.

19.1.3.2 The insulation between the **input** and **output winding(s)** shall consist of at least **basic insulation** (rated for the **working voltage**).

In addition, the following requirements apply:

- for **class I transformers**, the insulation between the **input windings** and the **body**, and between the **output windings** and the **body** shall consist of at least **basic insulation** (both **basic insulations** rated for the **working voltage**);
- for **class II transformers**, the insulation between the **input windings** and the **body**, and between the **output windings** and the **body** shall consist of **double** or **reinforced insulation** (both **double** or **reinforced insulations** rated for the **working voltage**).

19.1.3.3 For **transformers** with **intermediate conductive parts** (e.g. the iron core) not connected to the **body** and located between the **input** and **output windings**, the insulation between the **intermediate conductive parts** and the **input windings** or between the **intermediate conductive parts** and the **output windings** shall consist of at least **basic insulation** (rated for the **working voltage**).

NOTE An **intermediate conductive part** not separated from the **input** or **output windings** or the **body** by at least **basic insulation**, is considered to be connected to the relevant part(s).

If the core is not earthed and not intended to be earthed the values for **basic insulation** (**creepage distances** and **clearances**) between winding and core can be divided, but the summation of the divided distances shall not be less than the required **creepage distances** and **clearances** in Clause 26.

In addition, the following requirements apply:

- for **class I transformers**, the insulation between the **input** and **output windings** via the **intermediate conductive parts** shall consist of at least **basic insulation** (rated for the **working voltage**);
- for **class II transformers**, the insulation between the **input windings** and the **body**, and between the **output windings** and the **body**, via the **intermediate conductive parts** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**).

19.1.3.4 Parts of **output circuits** may be connected to the protective earthing.

19.1.3.5 There shall be no direct connection between the **output circuits** and the **body**, **unless** – for **associated transformers** – allowed by the relevant equipment standard.

Compliance is checked by inspection.

19.1.4 Isolating transformers and safety isolating transformers

19.1.4.1 The **input** and **output circuits** shall be electrically separated from each other and the construction shall be such that there is no possibility of any connection between these circuits, either directly or indirectly, via other **conductive parts**, except by deliberate action.

Compliance is checked by inspection and measurements taking Clauses 18 and 26 into consideration.

19.1.4.2 The insulation between **input** and **output winding(s)** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**), unless the requirements in 19.1.4.4 are complied with:

In addition, the following applies:

- for **class I transformers** not intended for connection to the mains supply by means of a plug, the insulation between the **input windings** and the **body** connected to protective earthing shall consist of at least **basic insulation** rated for the **input voltage**. The insulation between the **output windings** and the **body** connected to protective earthing, shall consist of at least **basic insulation** (rated for the **output voltage**);
- for **class I transformers** intended for connection to the mains supply by means of a plug, the insulation between the **input windings** and the **body** shall consist of at least **basic insulation**, and the insulation between the **output windings** and the **body** shall consist of at least **supplementary insulation** (both **basic** and **supplementary insulations** rated for the **working voltage**);
- for **class II transformers**, the insulation between the **input windings** and the **body** shall consist of **double** or **reinforced insulation** (rated for the **input voltage**). The insulation between the **output windings** and the **body** shall consist of **double** or **reinforced insulation** (rated for the **output voltage**).

19.1.4.3 For **transformers** with **intermediate conductive parts** (e.g. the iron core) not connected to the **body** and located between the **input** and **output windings**, the following requirements are applicable.

19.1.4.3.1 For **class I** and **class II transformers**, the insulation between the **input** and **output windings** via the **intermediate conductive parts** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**);

- for **class II transformers**, the insulation between the **input windings** and the **body**, and between the **output windings** and the **body** via the **intermediate conductive parts** shall consist of **double** or **reinforced insulation** (rated for the **input** and **output voltage**), for SELV circuits **basic insulation** only is required;
- for **transformers** other than independent (e.g. IP00), the insulation between the **input** and **output windings** via the **intermediate conductive parts** shall consist of **double** or **reinforced insulation** (rated for the **working voltage**).

19.1.4.3.2 As an alternative to 19.1.4.3.1 for **class I transformer** not intended to be connected by means of a plug and for **transformer** different from independent (e.g. IP00), if the construction assures that all laminated plates of the iron core are connected to protective earthing (e.g. by soldering / welding) and if the data sheet or instruction sheet clearly state that the safety of the **transformer** depends on the earthing connection and that is not possible to use it in **class II** equipment, then the following apply:

- the insulation between the **input windings** and the **intermediate conductive part** connected to protective earthing, and between the **output windings** and the **intermediate conductive part** connected to protective earthing, shall consist of at least **basic insulation** (rated for the input and output voltage);

19.1.4.3.3 in addition to 19.1.4.3.1 and 19.1.4.3.2, the insulation between the **intermediate conductive parts** and the **input windings**, and between the **intermediate conductive parts** and the **output windings** shall consist of at least **basic insulation** (rated for the **input** and **output voltage**). An **intermediate conductive part** not separated from the **input** or **output**

windings or the **body** by at least **basic insulation** is considered to be connected to the relevant part(s).

NOTE An intermediate metal part which is isolated from one of the windings by **double** or **reinforced insulation** is considered as being connected to the other winding.

19.1.4.4 For **class I transformers**, not intended for connection to the mains supply by means of a plug, the insulation between the **input** and **output windings** may consist of **basic insulation** plus **protective screen** instead of **double** or **reinforced insulation** provided the following conditions are complied with:

- the insulation between the **input winding** and the **protective screen** shall comply with requirements for **basic insulation** (rated for the **input voltage**);
- the insulation between the **output winding** and the **protective screen** shall comply with requirements for **basic insulation** (rated for the **output voltage**);
- the **protective screen** shall, unless otherwise specified, consist of a metal foil or of a wire wound screen extending at least the full width of one of the **input winding** and shall have no gaps or holes;
- where the protective screen does not cover the entire width of the **input winding**, additional adhesive tapes or equivalent insulation shall be used to ensure **double insulation** in that area;
- if the **protective screen** is made of a foil, the turns shall be insulated from each other. In case of only one turn, it shall have an isolated overlap of at least 3 mm;
- the wire of a wire wound screen and the lead-out wire of the **protective screen** shall have a cross-sectional area at least corresponding to the **rated current** of the overload protective device to ensure that, if a breakdown of **insulation** should occur, the overload protective device opens the circuit before the lead-out wire is destroyed in the event of the breakdown of the **insulation system**;
- the lead-out wire shall be soldered to the **protective screen** or fixed in an equally reliable manner.

For **transformers** for connection to the mains by the means of a plug of any type (incorporating or not), the alternative with **basic insulation** plus **protective screening** is not allowed.

NOTE For the purpose of this subclause, the term “winding” does not include **internal circuits**.

Examples of construction of windings are given in Annex M.

19.1.4.5 There shall be no connection between the **output circuits** and the protective earthing, unless this is allowed for **associated transformers** by the relevant equipment standard, or when 19.8 is fulfilled.

19.1.4.6 There shall be no direct connection between the **output circuits** and the **body**, unless this is allowed for **associated transformers** by the relevant equipment standard, or when 19.8 is fulfilled.

Compliance is checked by inspection.

19.1.4.7 For **isolating transformers** and **safety isolating transformers**, the **input** and **output terminals** for the connection of external wiring shall be so located that the distance measured at the point of introduction of the conductors, into these terminals, is not less than 25 mm. If a barrier is used to obtain the distance, the measurement shall be made over and around the barrier which shall be of insulating material and permanently fixed to the transformer.

*Compliance is checked by inspection and by measurement disregarding **intermediate conductive parts**.*

19.1.4.8 Portable transformers having a **rated output** not exceeding 630 VA shall be class II.

19.1.4.9 There shall be no connection between the **output circuits** and the **body**, unless – for **associated transformers** – allowed by the relevant equipment standard.

19.1.4.10 For **transformers** for connection to the mains by means of a plug of any type (incorporated or not), the alternative with **basic insulation** plus **protective screening** is not allowed.

19.2 Flammability of materials

Materials known to be highly flammable, such as celluloid, shall not be used in the construction of **transformers**.

Cotton, silk, paper and similar fibrous material shall not be used as insulation, unless impregnated.

Wax and similar impregnators shall not be used, unless suitably restrained from migration.

Compliance is checked by inspection and, in case of doubt regarding fiercely burning materials, by the glow-wire test of 27.4 at 550 °C.

NOTE Insulating material is considered impregnated if the space between the fibres of the material are substantially filled with a suitable insulating coating (i.e., epoxy resin, varnish, etc.).

Wood, even if impregnated, shall not be used as **supplementary** or **reinforced insulation**.

19.3 Short-circuit characteristics of portable transformers

Portable transformers shall be either **short-circuit proof** or **fail-safe transformers**.

Compliance is checked by inspection.

19.4 Class II transformer contact prevention of accessible conductive parts

There shall be provisions to prevent contact between accessible **conductive parts** and conduits or metal sheaths of supply wiring for **class II transformers**.

Compliance is checked by inspection.

19.5 Class II transformer insulation reassembling after service

Parts of **class II transformers** serving as **supplementary insulation** or **reinforced insulation** which might be omitted during reassembly after servicing, shall either:

- be fixed in such a way that they cannot be removed without being seriously damaged; or
- be so designed that they cannot be replaced in an incorrect position and that, if they are omitted, the **transformer** is rendered inoperable or is manifestly incomplete.

Compliance is checked by inspection and by manual test.

Sleeving may, however, be used as **supplementary insulation** on internal wiring, if it is retained in position by positive means.

NOTE 1 A sleeve is considered to be fixed by positive means if it can be removed only by breaking or cutting, or if it is clamped at both ends.

NOTE 2 Servicing includes replacement of switches, protective devices and of **power supply cords** when the type of attachment allows this.

NOTE 3 Lining metal **enclosures** with a coating of lacquer or with material in the form of a coating which does not withstand the test of 19.10 is not considered to be adequate for the purpose of these requirements.

19.6 Loosening of wires, screws or similar parts

Class I and **class II transformers** shall be so constructed that, should any wire, screw, nut, washer, spring or similar part become loose or fall out of position, they cannot, in normal use, become so disposed that **creepage distances** or **clearances** over **supplementary insulation** or **reinforced insulation** or the distance between input and output terminals are reduced to less than 50 % of the value specified in Clause 26.

Compliance is checked by inspection, by measurement and by manual test.

For the purpose of this requirement:

- it is not expected that two independent fixings will become loose at the same time;
- parts fixed by means of screws or nuts provided with locking washers are regarded as not liable to become loose, provided these screws or nuts are not removed during the replacement of the supply flexible cable or cord, or other servicing;
- conductors connected by soldering are not considered to be adequately fixed unless they are held in place near to the termination by means such as hooking in, independent of the solder;
- screwless terminals complying with IEC 60998-2-2 are considered to provide adequate fixing of the conductor without any additional means;
- wires connected to terminals are not considered to be adequately secured, unless an additional fixing of an appropriate type is provided near to the terminal. In the case of stranded conductors, this additional fixing is to clamp the insulation and not the conductor only;
- short rigid wires are not regarded as liable to come away from a terminal if they remain in position when the terminal screw is loosened.

19.7 Resistor or capacitor connection with accessible conductive parts

Conductive parts connected to accessible conductive parts by resistors or capacitors shall be separated from the **hazardous-live-parts** by **double insulation** or **reinforced insulation**.

*Compliance is checked by all relevant requirements and tests for **double insulation** or **reinforced insulation**.*

19.8 Bridging of separated conductive parts by resistors or capacitors

Conductive parts separated by **double** or **reinforced insulation** e.g. **live parts** and the **body** or **primary** and **secondary circuits**, may be bridged (conductive bridge) by resistors or Y2 capacitors provided that they consist of at least two separate components whose impedance is unlikely to change significantly during the lifetime of the **transformer**.

If the resistors are used they shall comply with the requirements of test a) in 14.2 of IEC 60065:2014. If capacitors are used, they shall comply with the relevant requirements of IEC 60384-14:2013, including its Subclause 3.4.2.

Where two capacitors are used in series, they shall each be rated for the total working voltage across the pair and shall have the same nominal capacitance value. If any one of such two components is short-circuited or open-circuited, the values specified in Clause 9 shall not be exceeded.

In addition, if the **working voltage** does not exceed 250 V AC, **conductive parts** separated by **double** or **reinforced insulation** (e.g. live parts and the body or primary and secondary circuits) may be bridged by a single Y1 capacitor complying with the relevant requirements of

IEC 60384-14:2013, including its Subclause 3.4.2. These requirements are applicable up to overvoltage category III.

For a working voltage above 250 V AC and not exceeding 500 V AC and an overvoltage category III, two Y1 capacitors are required.

NOTE A Y1 capacitor is considered to have **reinforced insulation**.

Compliance is checked by inspection and by measurement.

19.9 Insulating material separating input and output windings

Insulating material separating **input** and **output windings**, and parts of natural or synthetic rubber used as **supplementary insulation** in **class II transformers**, shall be either resistant to ageing or so arranged and dimensioned that, if any cracks occur, **creepage distances** are not reduced below the values specified in Clause 26.

Compliance is checked by inspection, by measurement and, in case of doubt concerning the ageing properties of rubber, by the following test.

Rubber parts are aged in an atmosphere of oxygen under pressure. The specimens are suspended freely in an oxygen bomb, the effective capacity of the bomb being at least 10 times the volume of the specimens. The bomb is filled with commercial oxygen not less than 97 % pure, to a pressure of (210^{+7}) N/cm².

The specimens are kept in the bomb at a temperature of (70^{+1}) °C for four days (96 h). Immediately afterwards, they are taken out of the bomb and left at ambient temperature, avoiding direct daylight, for at least 16 h.

After the test, the specimens are examined and shall show no cracks with normal vision or corrected vision without magnification.

In case of doubt with regard to materials other than rubber, an alternative method has to be used (see 14.3 and 26.3).

The use of the oxygen bomb presents some danger, unless handled with care. All precautions should be taken to avoid the risk of explosion due to sudden oxidation.

19.10 Accidental contact protection against hazardous-live-parts provided by isolating coating

When protection of **hazardous-live-parts** against accidental contact is ensured by an insulating coating, this coating shall be capable of withstanding the following tests.

a) Ageing test

The coated part is subjected to the conditions described in section one (test Na) of IEC 60068-2-14, at a temperature of (70 ± 2) °C for a period of seven days (168 h).

After this treatment, the part is allowed to cool to ambient temperature and inspection shall show that the coating has not loosened up or shrunk away from the base material.

b) Impact test

The part is then conditioned for a period of 4 h at a temperature of (-10 ± 2) °C. While still at this temperature, the coating is subjected to a blow applied to any point of the layer that is likely to be weak using a spring-operated impact hammer according to IEC 60068-2-75 with an energy of $(0,5 \pm 0,05)$ J.

After this test, the coating shall not be damaged. In particular, it shall show no cracks visible with normal vision, or corrected vision without magnification.

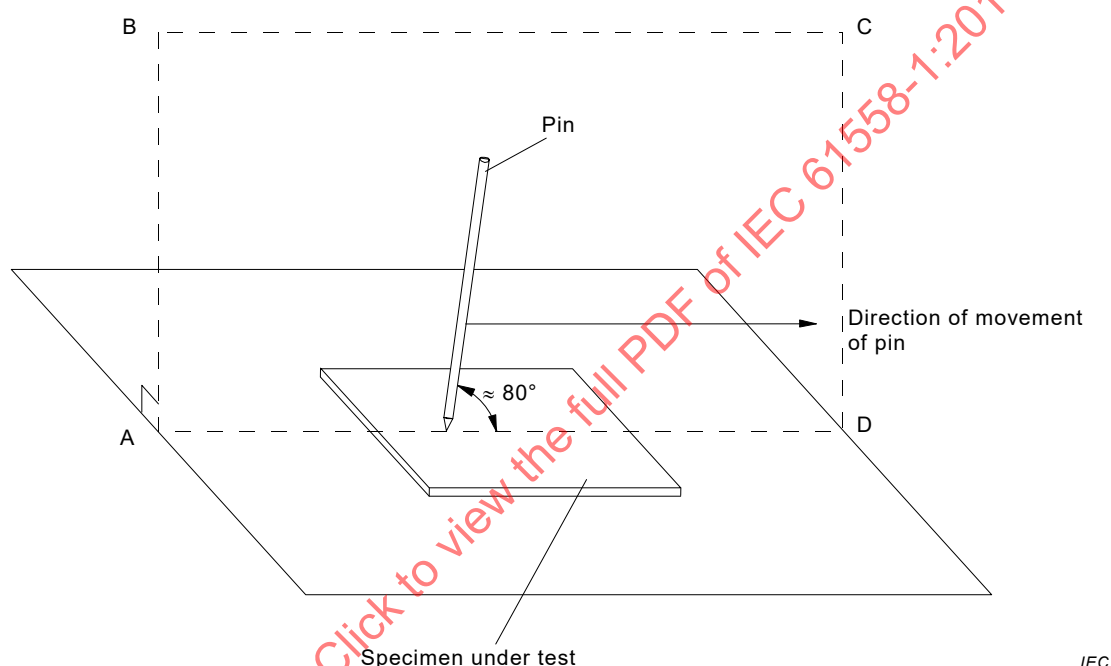
c) Scratch test

Finally, the part at the highest temperature attained under normal operating conditions is subjected to a scratch test. The scratches are made by means of a hardened steel pin, the end of which has the form of a cone having a top angle of 40° , its tip being rounded with a radius of $(0,25 \pm 0,02)$ mm.

Scratches are made by drawing the pin along the surface at a speed of about 20 mm/s as shown in Figure 11. The pin is so loaded that the force exerted along its axis is $(10 \pm 0,5)$ N. The scratches are at least 5 mm apart and at least 5 mm from the edge of the specimen.

After this test, the coating shall not loosen or be pierced, and it shall withstand a dielectric strength test as specified in 18.3, the test voltage being applied between the base material and a metal foil in contact with the coating.

The tests may be conducted on a separate specimen of the coated part.



NOTE The pin is in the plane ABCD which is perpendicular to the specimen under test.

Figure 11 – Abrasion resistance test for insulating coated layers

19.11 Insulating material of handles, operating levers, knobs and similar parts

Handles, operating levers, knobs and similar parts shall be of insulating material or be adequately covered by **supplementary insulation**, or separated from their shafts or fixing by such insulation in the event the shafts or fixing are likely to become live during an insulation breakdown.

*Compliance is checked by inspection and, if necessary, by the requirements specified for **supplementary insulation**.*

19.12 Winding construction

19.12.1 In all types of **transformers**, precautions shall be taken to prevent:

- undue displacement of **input** or **output windings** or the turns thereof;
- undue displacement of internal wiring or wires for external connections;
- undue displacement of parts of windings or of internal wiring, in the event of rupture of wires or loosening of connections.

Compliance is checked by inspection and by the tests of Clause 16.

The last turn of each winding shall be prevented from being displaced.

Means of prevention may be:

- positive means such as tape, suitable bonding agent, or anchoring the wire;
- or process technologies (e.g. manufacturing procedures).

A **protective screen**, if necessary, in order to prevent eddy current losses due to creation of a short turn, should be so arranged that both edges can neither simultaneously touch each other nor touch an iron core.

19.12.2 Where serrated tape is used as insulation, it is assumed that the serration of the different layers will coincide. For distance through insulation (DTI), the reduced values of Table 22 may be used if one additional layer of serrated tape and one additional layer without serration placed at the location of the serration are used.

NOTE An example is given in Figure M.3.

Where cheekless bobbins (bobbins without flange) are used, the end turns of each layer shall be prevented from being displaced.

Each layer can, for example, be interleaved with adequate insulation material projecting beyond the end turns of each layer and, moreover:

- either the winding(s) may be impregnated with hard-baking or cold-setting material, substantially filling the intervening spaces and effectively sealing-off the end turns;
- or the winding(s) may be held together by means of insulating material or by process technology.

Compliance is checked by inspection and by the tests of Clauses 16, 17, and 18.

19.12.3 Insulated winding wires, in an insulation system providing **basic**, **supplementary** or **reinforced insulation**, shall meet the following requirements.

Wire that has multi-layer extruded or spirally wrapped insulation (where only the finished wire can be tested) and passes the tests of Annex K.

The minimum number of constructional layers applied to the conductor shall be as follows:

- **basic insulation**: two wrapped layers or one extruded layer;
- **supplementary insulation**: two layers, wrapped or extruded;
- **reinforced insulation**: three layers wrapped or extruded.

For spirally wrapped insulation where the **creepage distances** between layers, as wrapped, are less than those given in Clause 26. For pollution degree 1, the path between layers shall be sealed as for a cemented joint in 26.2.4, Test A and the test voltages of the **type tests** in Clause K.2 are increased to 1,35 times their normal values.

One layer of material wound with more than 50 % overlap is considered to constitute two layers.

The finished component shall pass **routine test** for dielectric strength using the appropriate value of test voltages in 18.3.

Compliance is checked by inspection and measurement and, if applicable, as specified in Annex K.

- a) Where the insulation on the winding wire is used to provide **basic-** or **supplementary insulation** in a wound part:
- the insulated wire (for example polyimide or insulation of equivalent quality) shall comply with Annex K;
 - the insulation of one **insulated winding wire** shall consist of at least two layers for **supplementary insulation**;
 - the insulation of one **insulated winding wire** shall consist of at least one layer for **basic insulation**;
 - an insulation for mechanical separation which fulfil the dielectric strength test for **basic insulation** shall be provided between the insulated wires and the enamelled wires.

If for basic or supplementary insulation a triple insulated wire is used in combination with enamelled wire, an additional interleaved insulation (mechanical separation) is not required.

- b) Where the insulation on the winding wire is used to provide **reinforced insulation** in a wound part:
- the insulated wire (for example polyimide or insulation of equivalent quality) shall comply with Annex K;
 - the insulation of one **insulated winding wire** shall consist of at least three layers;
 - the insulation is subjected to the relevant dielectric strength test of 18.3.

Where the insulated winding wire is wound:

- upon metal or ferrite cores; or
- upon enamelled wire; or
- under enamelled wire,

insulation for mechanical separation which fulfils the dielectric strength test for **basic insulation** shall be provided between the insulated wires and the core or between the insulated wires and the enamelled wires. These independent windings shall not be able to contact each other or the core.

NOTE 1 This requirement takes into consideration the mechanical production stress applied to the **insulated winding wires**.

The manufacturer of the transformer shall demonstrate that the winding wire has been subjected to 100 % routine dielectric strength test as in Clause K.3.

No requirements for **creepage distances** and **clearances** are applicable for the **insulated winding wires**.

Compliance is checked by inspection of the part and the declaration of the wire manufacturer

- c) Toroidal cores used with **TIW** wires for **double or reinforced insulation** between the primary and secondary circuits shall comply with the following:
- 1) The toroidal core shall have a coating, which fulfils the requirements of **basic insulation** between a winding and the core
 - 2) The primary winding consists of **TIW** wire with 3 layers (**reinforced insulation**) and the secondary winding consists of enamelled wire. These independent windings shall not be able to contact each other either by mechanical separation or a gap which fulfil the dielectric strength tests for **basic insulation**.
 - 3) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding consists of **TIW** wire with 3 layers and the secondary winding consists of a **TIW** wire with 1 layer (requirements for primary and secondary windings can be changed). This construction also is allowed for use with EE-cores or similar.
- d) Toroidal cores used with **FIW** wires for **double or reinforced insulation** between the primary and secondary circuits shall comply with the following:
- 1) The toroidal core shall have a coating, which fulfil the requirements of **basic insulation**.

- 2) The primary winding consists of **FIW** wire for **reinforced insulation** and the secondary winding consist of **FIW** wire – of **basic insulation**. These independent windings shall not be able to contact each other either by mechanical separation or a gap which fulfil the dielectric strength test for **basic insulation**.
 - 3) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding and the secondary winding consist of **FIW** wire for **reinforced insulation**. This construction also is allowed to use for EE-core or similar.
- e) Toroidal cores used with **TIW** in combination with **FIW** wire, for **double or reinforced insulation** between the primary and secondary circuits shall comply with the following:
- 1) The toroidal core shall have a coating, which fulfils the requirements of **basic insulation**.
 - 2) The primary winding consists of **FIW** wire for **reinforced insulation**, and the secondary winding consists of **TIW** wire for **basic insulation** (1 layer). These independent windings shall not be able to contact each other either by mechanical separation or a gap which fulfil the dielectric strength tests for **basic insulation**.
 - 3) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding consists of **TIW** wire for **reinforced insulation** (3 layer) and the secondary winding consists of **FIW** wire for **reinforced insulation**. This construction also is allowed for use with EE-cores or similar.
- f) Toroidal cores used with **TIW** in combination with **FIW** wire, for **basic insulation** between the primary and secondary circuits shall comply with the following:
- 1) The toroidal core shall have a coating, which fulfils the requirements of **basic insulation**
 - 2) The primary winding consists of **FIW** wire for **basic insulation**, and the secondary winding consists of **TIW** wire for **basic insulation** (1 layer). These independent windings shall not be able to contact each other either by mechanical separation or a gap which fulfils the dielectric strength tests for **basic insulation**.
- NOTE 2 Instead of **FIW** for **basic insulation**, enamelled wire is also accepted.
- 3) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding consists of **TIW** wire for **supplementary insulation** (2 layers) and the secondary winding consists of **FIW** wire for **basic insulation**. This construction also is allowed for use with EE-cores or similar.
 - 3.1) For polyfilar windings (primary and secondary windings in contact with each other), the primary winding consists of **TIW** wire for **basic insulation** (1 layer) and the secondary winding consists of **TIW** wire for **basic insulation** (1 layer).
 - 4) Further polyfilar constructions with **FIW** and **TIW** wires in combination with enamelled wires for **basic insulation** only:
 - 4.1) Primary winding consists of enamelled wire, secondary winding consists of **FIW** wire for **reinforced insulation**
 - 4.2) Primary winding consists of enamelled wire, secondary winding consists of **TIW** wire for **reinforced insulation**

19.12.3.1 The transformer utilizing **fully insulated winding wires (FIW)** shall only be used up to and including insulation class F.

19.12.3.2 Fully insulated winding wires (FIW) shall comply with IEC 60851-5:2008, IEC 60317-0-7 and IEC 60317-56. If the wire has a nominal diameter other than defined in Table 24, the minimum high voltage strength value can be calculated according to Formula (6) in 26.3.5:

- **FIW** wires used for **basic** or **supplementary isolation** for **transformers** according to 19.1.3:
 - the test voltage required in Table 14 for **basic-/supplementary insulation** according to the **working voltage** of the **transformer**, shall comply with the minimum voltage strength of **basic insulation** for the **FIW**-wire according to Table 24;

- between a basic insulated **FIW** wire and an enamelled wire an insulation for mechanical separation shall be used. The both windings shall not touch each other. The insulation for mechanical separation shall fulfil the high voltage test of basic insulation. **Creepage distances** and **clearances** for **FIW** wire are not required.
- **FIW** wires used for **double** or **reinforced insulation** for **transformers** according to 19.1.4:
 - the test voltage required in Table 14 for **basic-/supplementary insulation** according to the **working voltage** of the **transformer**, shall comply with the minimum voltage strength of **basic insulation** for the **FIW**-wires according to Table 24. For the primary and the secondary winding a basic insulated **FIW** wire shall be used;
 - between the two basic insulated **FIW** wires an insulation for mechanical separation shall be used. These independent windings shall not be able to contact each other. The insulation for mechanical separation shall fulfil the high voltage test of basic insulation. **Creepage distances** and **clearances** between the **FIW** wires are not required.
- Alternative construction with **FIW**-wires having reinforced insulation:
 - the test voltage required in Table 14 for **reinforced insulation** according to the **working voltage** of the transformer, shall comply with the minimum voltage strength for the **FIW** wire according to Table 24;
 - between a reinforced insulated **FIW** wire and an enamelled wire an insulation for mechanical separation shall be used. These independent windings shall not be able to contact each other. The insulation for mechanical separation shall fulfil the high voltage test of **basic insulation**. **Creepage distances** and **clearances** between the **FIW** wires are not required.
- Alternative construction with **FIW** wires, basic or supplementary insulated for **transformers** with **double** or **reinforced insulation**:
 - the test voltage required in Table 14 for **basic-/supplementary insulation** according to the **working voltage** of the **transformer**, shall comply with the minimum voltage strength of **basic insulation** for the **FIW**-wire according to Table 24. For either the primary or the secondary winding a basic insulated **FIW** wire shall be used. For the non **FIW** winding, enamelled wire can be used;
 - between the basic insulated **FIW** wire and the enamelled wire, a **supplementary insulation** according to the working voltage is required. **Creepage distances** and **clearances** between the **FIW** wire and the enamelled wire are required for **supplementary insulation**.
- Where the **FIW** wire is wound:
 - upon metal or ferrite cores, an insulation for mechanical separation which fulfil the dielectric strength test for **basic insulation** shall be provided between the **FIW** wires and the core. The **FIW** wire and enamelled wire (if used) shall not touch the metal or ferrite core.

19.13 Fixing of handles, operating levers and similar parts

Handles, operating levers and similar parts shall be fixed in a reliable manner so that they will not become loose as a result of heating, vibration, etc. which may occur in normal use.

Compliance is checked by inspection and by the tests of Clauses 14 and 16.

19.14 Fixing of covers providing protection against electric shock

Covers providing protection against electric shock shall be securely fixed. The fixing shall be achieved by at least two independent means, one of which at least requires the use of a **tool**.

Compliance is checked by inspection and by manual test.

The cover may incorporate a means, such as a notch or a rim, which forms one of the required fixing means.

Screws may be used as means requiring the use of a **tool**, but knurled nuts or screws, even if they have provision for sealing, are not suitable.

19.15 Strain on fixed socket-outlets caused by pin-transformers connection

Transformers provided with pins intended to be introduced into fixed socket-outlets shall not impose undue strain on these socket-outlets.

*Compliance is checked by inserting the **transformer**, as in normal use, into a fixed socket-outlet complying with IEC TR 60083, the socket-outlet being pivoted about the horizontal axis through the central lines of the contact tubes at a distance of 8 mm behind the engagement face of the socket-outlet.*

The additional torque which has to be applied to the socket-outlet to maintain the engagement face in the vertical plane shall not exceed 0,25 Nm.

19.16 Portable transformers for use in irregular or harsh conditions

Portable transformers having a weight not exceeding 18 kg for use in irregular or harsh conditions, example indoor or outdoor heavy construction sites, exposure to high levels of dust, debris or moisture shall have a protection index IPX4 or higher.

NOTE IEC 61558-2-23 is extended to cover other kinds of rough handling.

19.17 Drain hole of transformers protected against ingress of water

Transformers having a protection index from IPX1 up to and including IPX6 shall have an effective drain hole at least 5 mm in diameter or 20 mm² in area, with a width of at least 3 mm.

The drain hole is not required if the **transformer**, including its windings and core and all uninsulated live parts, are completely embedded in a potting material.

19.18 Plug connected transformers protected against ingress of water

Transformers classified for a protection index higher than IPX1 and having a cord provided with a plug; it shall be a moulded-on plug.

19.19 Flexible cable or flexible cord connection for class I portable transformers

Class I portable transformers designed for connection by means of a flexible cable or cord, shall be provided with a **non-detachable** flexible cable or cord with protective earthing conductor and a plug with protective earthing contact.

If a **class I stationary transformer** is equipped with a **non-detachable** flexible cable or cord, the cable or cord shall have a protective earthing conductor and the plug shall have a protective earthing contact.

Compliance with the requirements of 19.16 to 19.19 is checked by inspection, by measurement, and by the tests of 17.1.

19.20 SELV- and PELV-circuit separation of live parts

Live parts of **SELV-** and **PELV-circuits** shall be electrically separated from each other and from other circuits. Taking the relevant **working voltage** into account the following requirements shall be met:

- **SELV output circuits** shall be electrically separated from all circuits other than **SELV** and **PELV** by **double** or **reinforced insulation**.
- **SELV output circuits** shall be electrically separated from other **SELV** and **PELV circuits** by **basic insulation**.

This requirement does not exclude the connection of **PELV circuits** to the protective earthing.

*Compliance is checked by compliance with 19.20.1 for **SELV-circuits** and 19.20.2 for **PELV-circuits***

19.20.1 Live parts of SELV-circuits shall not be connected to the protective earthing, to **live parts**, or protective earthing conductors forming part of other circuits.

Exposed **conductive parts** of **SELV-circuits** shall not be connected to:

- the protective earthing, or
- protective earthing conductors or exposed **conductive parts** of another circuit.

If the nominal voltage exceeds 25 V AC or 60 V ripple-free DC, protection against contact with live parts shall be provided by insulation capable of withstanding a test voltage for **double** or **reinforced insulation** according to Table 14.

If the nominal voltage does not exceed 25 V AC or 60 V ripple-free DC, protection against contact with live parts is generally unnecessary. However, it may be necessary under certain conditions of external influences (see relevant part of IEC 61558-2).

19.20.2 For **PELV-circuits**, the following requirements shall be fulfilled.

Protection against contact with live parts shall be ensured by insulation capable of withstanding a test voltage for **double** or **reinforced insulation** according to Table 14.

This requirement implies that **PELV-circuits** have to be insulated even for voltages below 25 V AC or 60 V ripple-free DC. Exempted are **live parts** directly connected to protective earthing.

19.21 Protection against contact for FELV-circuit

For **FELV-circuits**, the following requirements shall be fulfilled to ensure protection against both direct and indirect contact.

Such conditions may, for example, be ensured when the circuit contains equipment (such as **transformers**, relays, remote-control switches, contactors) insufficiently insulated with respect to circuits at higher voltages.

Protection against indirect contact shall be provided by insulation corresponding to the minimum test voltage required for the primary circuit.

19.22 Protective earthing regarding class II transformers

Class II transformers shall not be provided with means for protective earthing.

However, a **class II transformer** intended for looping-in may have an internal terminal for maintaining the electrical continuity of a protective earthing conductor not terminating in the **transformer**, provided that the terminal is insulated from the accessible **conductive parts** by class II insulation.

Compliance is checked by inspection.

19.23 Protective earthing regarding class III transformers

Class III transformers shall not be provided with means for protective earthing.

Compliance is checked by inspection.

20 Components

20.1 Components such as switches, plugs, fuses, lampholders, capacitors and flexible cables and cords shall comply with the relevant IEC standard as far as it reasonably applies.

Components incorporated in or supplied with the **transformers** are subjected to all tests of this document as part of the **transformer**.

Compliance with the IEC standard for the relevant component does not necessarily ensure compliance with the requirements of this document.

The testing of these components is, in general, carried out separately, according to the relevant standard, as follows:

- components marked with individual ratings are checked to establish that they suit the conditions which may occur in the **transformer**, including inrush current. The component is then tested in accordance with its marking, the number of specimens being that required by the relevant standard;
- components not marked with individual ratings are tested under the conditions occurring in the **transformer**, including inrush current, the number of specimens being, in general, that required by the relevant standard;
- where no IEC standard exists for the relevant component, or where the component is not marked, or where the component is not used in accordance with its marking, the component is tested under the conditions occurring in the **transformer**; the number of specimens being, in general, that required by a similar specification.

20.2 Appliance couplers for mains supply shall comply with IEC 60320 (all parts) for IPX0 **transformers** and IEC 60320-2-3 or IEC 60309 (all parts) for other **transformers**.

20.3 Automatic controls shall comply with IEC 60730 (all parts) and the appropriate parts of IEC 61558-2 unless they are tested with the **transformer**.

20.4 Thermal-links shall comply with IEC 60691 as far as reasonable.

20.5 Switches forming part of the **transformer** assembly shall comply with Annex F.

In addition, switches intended to disconnect the **transformer** from the supply shall disconnect all poles and shall provide full disconnection under the relevant overvoltage category. The requirements with regard to all-pole disconnection and full disconnection do not apply to **transformers** intended to be connected to the supply by means of a flexible cable or cord and a plug, or to **transformers** accompanied by an instruction sheet stating that such means for disconnection shall be incorporated in the fixed wiring.

Compliance is checked by inspection.

20.6 There shall be no unsafe compatibility between the socket-outlets in the **output circuit** and a plug intended for direct connection to a socket-outlet which could be used for the **input circuit** in relation to installation rules, voltages, and frequencies.

Plugs and socket-outlets for **SELV** systems shall comply with the requirements of IEC 60906-3 and IEC 60884-2-4. However, plugs and socket-outlets for **SELV** systems with both a rated

current ≤ 3 A and a maximum voltage of 24 V AC or 60 V DC with a power not exceeding 72 W are allowed to comply only with the following requirements:

- it shall not be possible for plugs to enter socket-outlets of other standardised voltage systems;
- socket-outlets shall not accommodate plugs for other standardised voltage;
- socket-outlets shall not have a protective earthing contact.

As IEC 60906-3 covers only 6 V, 12 V, 24 V and 48 V, **transformers** with intermediate supply voltage should be able to withstand the nearest upper voltage. Other plugs and socket-outlet systems are allowed for **associated transformers** only.

Plugs and socket-outlets for **PELV** systems shall comply with the following requirements:

- it shall not be possible for plugs to enter socket-outlets of other standardized voltage systems;
- socket-outlets shall not accommodate plugs of other standardized voltage systems;
- socket-outlets shall not have a protective earthing contact.

This does not preclude the use of socket-outlets incorporating functional bonding contact.

Plugs and socket-outlets for **FELV** systems shall comply with the following requirements:

- It shall not be possible for plugs to enter socket-outlets of other standardized voltage systems; and
- socket-outlets shall not accommodate plugs of other standardised voltage systems.

Compliance is checked by inspection and by manual test.

20.7 Thermal cut-outs, thermal links, **overload relays**, fuses and other overload protective devices shall have adequate breaking capacity.

*Compliance of the breaking capacity of **thermal cut-outs** is checked by the relevant tests of 20.8 and 20.9.*

*Compliance of the breaking capacity of **thermal links** is checked by the relevant test of 20.9*

The breaking capacity of the fuse shall be in accordance with the relevant fuse standard.

Fuses according to IEC 60127 (all parts) and IEC 60269 (all parts) are allowed to be continuously loaded by a current not exceeding 1,1 times the rated value.

20.8 Thermal cut-outs shall meet the requirements of 20.8.1.1 and 20.8.2, or 20.8.1.2 and 20.8.2.

20.8.1 Requirements according to IEC 60730-1.

20.8.1.1 Thermal cut-outs when tested as separate components shall comply with the appropriate requirements and tests of IEC 60730-1.

For the purpose of this document the following applies.

- a) **Thermal cut-outs** shall be of type 1 or type 2 (see 6.4 of IEC 60730-1:2013)
- b) **Thermal cut-outs** shall have at least micro-interruption (type 1.C or 2.C) (see 6.4.3.3 and 6.9.3 of IEC 60730-1:2013), or micro-disconnection (type 1.B or 2.B) (see 6.4.3.2 and 6.9.2 of IEC 60730-1:2013).

- c) **Thermal cut-outs** with manual reset shall have a trip free mechanism with contacts that cannot be prevented from opening against continuation of a fault (type 1.E and 2.E) (see 6.4.3.5 of IEC 60730-1:2013).
- d) The number of cycles of automatic action shall be:
 - 3 000 cycles for **self-resetting thermal cut-outs**,
 - 300 cycles for **non-self-resetting thermal cut-outs** which can be reset by hand without the use of a **tool** (see 6.11.10 of IEC 60730-1:2013),
 - 300 cycles for **non-self-resetting thermal cut-outs** which can be reset when the **transformer** is disconnected (see 6.11.10 of IEC 60730-1:2013),
 - 30 cycles for **non-self-resetting thermal cut-outs** which can only be reset by the use of a **tool** (see 6.11.11 of IEC 60730-1:2013).
- e) **Thermal cut-outs** shall be designed to withstand electrical stresses across their insulating parts for a long period of time and shall be tested accordingly (see 6.14.2 of IEC 60730-1:2013).
- f) The characteristics of **thermal cut-outs** with regard to:
 - their ratings (see Clause 5 of IEC 60730-1:2013);
 - their classification according to:
 - 1) nature of supply (see 6.1 of IEC 60730-1:2013),
 - 2) type of load to be controlled (see 6.2 of IEC 60730-1:2013),
 - 3) degree of protection provided by **enclosures** against ingress of solid objects and dust (see 6.5.1 of IEC 60730-1:2013),
 - 4) degree of protection provided by **enclosures** against harmful ingress of water (see 6.5.2 of IEC 60730-1:2013),
 - 5) **pollution degree** (see 6.5.3 of IEC 60730-1:2013),
 - 6) their comparative tracking index (see 6.13 of IEC 60730-1:2013), and
 - 7) their maximum ambient temperature limit (see 6.7 of IEC 60730-1:2013),
 shall be appropriate for the application in the **transformer** under normal operating conditions and under fault conditions (e.g. short-circuit of the output terminals).

20.8.1.2 A thermal cut-out when tested as part of a **transformer** shall:

- have at least micro-interruption (type 1.C or type 2.C) or micro-disconnection (type 1.B or 2.B) according to IEC 60730-1:2013;
- be aged for 300 h at a temperature corresponding to the ambient temperature of the **thermal cut-out** when the **transformer** is operated under normal operating conditions at an ambient temperature of 35 °C or, where relevant, ($t_a + 10$) °C;
- be subjected to a number of cycles of automatic operation as specified under 20.8.1.1 for **thermal cut-outs** tested as a separate component, by establishing the relevant fault condition(s).

The tests are carried out on three samples.

NOTE A sample consists of a **transformer** with an incorporated **thermal cut-out**.

Compliance is checked by inspection and by the specified tests.

During the tests, no sustained arcing shall occur, and there shall be no damage from other causes.

*After the tests, there shall be no damage to the **thermal cut-out** and the **transformer** in the sense of this document, in particular, the **enclosure** shall not deteriorate, there shall be no reduction of **clearances** and **creepage distances**, and no loosening of electrical connections or mechanical securing means.*

20.8.2 Thermal cut-outs shall have adequate breaking capacity.

20.8.2.1 A **transformer** with a **non-self-resetting thermal cut-out** is supplied at 1,1 times **rated input voltage** and the output terminals are short-circuited until the **thermal cut-out** operates. Then the supply voltage is switched off until the **transformer** cools down to approximately the room temperature. The supply voltage is then switched on (the output terminals still short-circuited).

This cycle of operation is carried out:

- 3 times at a room temperature of $(25 \pm 10) ^\circ\text{C}$ for **transformers** without a t_{amin} marking;
- 3 times at minimum ambient temperature t_{amin} for **transformers** with a t_{amin} marking.

After the cycling test, the **transformer** is supplied at 1,1 times the **rated supply voltage** for 48 h with the output terminals short-circuited.

20.8.2.2 A **transformer** with a **self-resetting thermal cut-out** is supplied at 1,1 times the **rated input voltage** with the output terminals short-circuited.

This operation is carried out:

- 48 h at an ambient temperature of $(25 \pm 10) ^\circ\text{C}$ for **transformers** without a t_{amin} marking;
- 24 h at an ambient temperature of $(25 \pm 10) ^\circ\text{C}$ and 24 h at minimum ambient temperature t_{amin} for **transformers** with a t_{amin} marking.

Compliance is checked by inspection and by the specified tests in the given order.

During these tests, no sustained arcing shall occur.

After the test, the **transformer** shall:

- withstand the test of Clause 18,
- show no damage in the sense of this document, and
- be operational.

20.8.3 A PTC resistor of indirect heating type is considered to be a **non-self-resetting thermal cut-out** by this document.

Compliance is checked by the following test:

The **transformer** is supplied at 1,1 times the rated input voltage for 48 h (two days) with the output terminals short-circuited.

- After 48 h, the **transformer** shall be allowed to cool down to approximately ambient temperature; this test shall be repeated five times at the maximum ambient temperature declared by the **transformer manufacturer**.
- The same test cycles shall be repeated, except at 0,9 times the rated input voltage and the minimum ambient temperature declared by the **transformer manufacturer**.

During the part of the cycle where the **transformer** is under load, the PTC shall operate and stay in high impedance position until the supply is switched off. At the end of the test, the **transformer** shall withstand the test of Clause 18, shall show no damage, and shall be operational.

20.9 Thermal-links shall be tested in one of the following two ways.

20.9.1 The **thermal-links**, when tested as separate components, shall comply with the requirements and tests of IEC 60691.

When a **thermal link** is tested according to IEC 60691, the following applies:

- the electrical conditions (see 6.1 of IEC 60691:2015);
- the thermal conditions (see 6.2 of IEC 60691:2015);
- the ratings of the **thermal-link** (see 8 b) of IEC 60691:2015); and
- suitability of the sealing compounds, and impregnating fluids or cleaning solvents (see 8 c) of IEC 60691:2015)

shall be appropriate for the application under normal operating conditions, and short-circuit and overload conditions.

Compliance is checked according to the test specifications of IEC 60691, by inspection, and measurement.

20.9.2 The thermal-links when tested as part of a transformer,:

- shall be aged for 300 h at a temperature corresponding to the ambient temperature of the **thermal-link** when the **transformer** is operated under normal operating conditions at an ambient temperature of 35 °C or, when relevant, ($t_a + 10$) °C;
- shall be subjected to the **transformer** fault conditions which cause the **thermal-link** to operate. There shall be no sustained arcing during the tests, and no damage in the sense of this document; and
- shall be capable of withstanding 2 times the rated voltage across the disconnection, and have an insulation resistance of at least 0,2 MΩ when measured with a DC voltage equal to 2 times the rated voltage across the disconnection.

The test is conducted 3 times; no failure is allowed. This test is not applicable to **fail-safe transformers**.

The **thermal-link** is replaced, partially or completely, after each test.

Where the **thermal-link** is not replaceable, the test is conducted on three new specimens.

Compliance is checked by inspection and by specified tests in the given order.

20.10 Self-resetting thermal protective devices shall not be used unless no mechanical, electrical, or other hazards occur from their operation during and after the tests of this document.

Compliance is checked by inspection.

20.11 Thermal cut-outs intended to be reset by soldering operation shall not be used for overload protection.

Compliance is checked by inspection.

20.12 Overload protective devices shall not operate when the supply voltage is switched on.

Compliance is checked by carrying out the following test.

*The **transformer**, with no load, is supplied from a voltage source equal to 1,1 times the **rated supply voltage**. The supply voltage is then switched on and off 20 times at intervals of approximately 10 s or at a point on the voltage wave such that the inrush current is maximized.*

The switching -on and -off may be carried out only twice if a device is used to switch on at the most unfavourable electrical angle of the supply voltage.

The supply source shall be such that the voltage drop does not exceed 2 % as a result of the inrush current.

NOTE This is not required for associated transformers.

21 Internal wiring

21.1 Internal wiring and electrical connections between different parts of the **transformer** shall be adequately protected or enclosed.

Wire-ways shall be smooth and free from sharp edges, burrs, flashes, etc. which may damage the insulation of conductors.

21.2 Openings in sheet metal through which insulated wires pass shall have rounded edges with a radius not less than 1,5 mm, or the openings shall be provided with bushing of insulating material.

21.3 Uninsulated conductors shall be so fixed that their distance from one another and from the **enclosure** is adequately maintained.

Compliance with the requirements of 21.1 to 21.3 is checked by inspection.

21.4 Internal wiring shall not loosen up when external wires are connected to the input or output terminals.

Compliance is checked by inspection and by carrying out the test of 23.3.

21.5 Insulated conductors subject to temperatures exceeding the limitations in 14.1 under normal use shall be provided with heat-resistant and non-hygroscopic insulating materials.

Compliance is checked by inspection and, if necessary, by carrying out additional tests; the temperature is determined during the test described in 14.1.

22 Supply connection and other external flexible cables or cords

22.1 All cables, flexible cords and connecting means referred to in this clause shall have appropriate current and voltage ratings suitable for the ratings of the **transformers** to which they are connected.

Compliance is checked by inspection.

22.2 Separate entries shall be provided for the input and output wiring.

Inlet and outlet openings for external wiring shall be so designed that the protective covering of the cord can be introduced without risk of damage.

Inlet and outlet openings for flexible cables or cords shall be of insulating material, or be provided with bushing of insulating material which is substantially free from ageing effects under conditions expected in service. The openings of bushings shall be so shaped as to prevent damage to the cord.

Bushings for external wiring shall be reliably fixed, and shall be such that they are unlikely to be damaged by the material in which they are mounted.

Bushings shall not be of natural rubber unless they form part of a cord guard (see 22.9).

NOTE These requirements do not preclude the use of removable bushings.

Compliance is checked by inspection.

22.3 Fixed transformers shall be so designed that, after the **transformer** has been fixed to its support in the normal way, it shall be possible to connect the rigid or flexible conductors of the external wiring.

Transformers other than those intended to be permanently connected to the fixed wiring may be provided with an appliance inlet on the input side.

The space for the wires inside the **transformer** shall be adequate to allow the conductors to be easily introduced and connected, and the cover, if any, fitted without risk of damage to the conductors or their insulation.

It shall be possible to connect the external supply wires to terminals without their insulation coming into contact with **hazardous-live-parts** of a different polarity, including **live parts** of the **output circuits**.

Compliance is checked by inspection and by an installation test with conductors of the largest cross-sectional area corresponding to the rated connecting capacity of the terminals.

22.4 For **portable transformers** provided with **power supply cords**, the length of the cord shall:

- not exceed 2 m for cross-sectional area of 0,5 mm²;
- exceed 2 m for cross-sectional areas greater than 0,5 mm².

Compliance is checked by inspection.

22.5 Power supply cords incorporated into **transformers** both having a protection index of IP20 or higher and **transformers** for “indoor use only” with protection index of IP20 or higher shall be as follows:

- for **transformers** with a mass not exceeding 3 kg, the cable or cord shall be at least light polyvinyl chloride sheathed flexible cable or cords according to IEC 60227-5:2011 – type 60227 IEC 52 or ordinary tough rubber sheathed flexible cable or cords according to IEC 60245-4:2011 – type 60245 IEC 53;
- for **transformers** with a mass exceeding 3 kg, the cable or cord shall be at least ordinary polyvinyl chloride sheathed flexible cable or cords according to IEC 60227-5:2011 – type 60227 IEC 53 or ordinary tough rubber sheathed flexible cable or cords according to IEC 60245-4:2011 – type 60245 IEC 53.

Power supply cords of **transformers** with protection index higher than IPX0, except for **transformers** for “indoor use only”, shall be polychloroprene sheathed cord and shall be at least ordinary polychloroprene sheathed cord according to IEC 60245-4:2011 – type 60245 IEC 57.

22.6 Power supply cords may be cord sets fitted with appliance couplers in accordance with IEC 60320 (all parts), provided the **transformers** are single-phase **portable transformers** with input current not exceeding 16 A at the **rated output**.

22.7 The nominal cross-sectional area of **external flexible cables** or **cords** shall not be less than shown in Table 16.

Table 16 – Nominal cross-sectional areas of external flexible cables or cords

Input or output current at rated output A	Nominal cross-sectional areas mm ²
Up to and including 3 ^a	0,5
Over 3 up to and including 6	0,75
Over 6 up to and including 10	1
Over 10 up to and including 16	1,5
Over 16 up to and including 25	2,5
Over 25 up to and including 32	4
Over 32 up to and including 40	6
Over 40 up to and including 63	10
NOTE In Japan, cords having a nominal cross-sectional area of 0,5 mm ² are not allowed for external power supply cords .	
^a These cords may be used as power supply cords if their length does not exceed 2 m between the point where the cord or cord guard enters the transformer and the entry to the plug.	

Compliance is checked by inspection and by measurement.

22.8 Each **power supply cord** of **class I transformers** shall have a green/yellow coloured cord connected to the protective earthing terminal of the **transformer** and to the protective earthing contact of the plug, if any.

Power supply cords of single-phase **portable transformers** having an input current at **rated output** not exceeding 16 A shall be provided with plugs complying with IEC TR 60083 or IEC 60906-1. Other **portable transformers** may be provided with plugs complying with IEC 60309 (all parts).

Compliance is checked by inspection.

22.9 External flexible cables or cords shall be attached to the **transformer** by **type X, Y** or **Z attachments** unless otherwise specified in the relevant part of IEC 61558-2.

Compliance is checked by inspection and, if necessary, by manual test.

22.9.1 For **type Z attachments**, moulding the **enclosure** of the **transformer** and the **external flexible cable or cord** together shall not affect the insulation of the cord.

Compliance is checked by inspection.

22.9.2 Inlet openings shall be designed and shaped, or be provided with an inlet bushing such that the protective covering of the **external flexible cable or cord** can be introduced without risk of damage.

The insulation between the conductor and the **enclosure** shall consist of the insulation of the conductor and, in addition:

- for **class I transformers**, at least **basic insulation**; and
- for **class II transformers**, at least **double** or **reinforced insulation**.

The sheath of an **external flexible cable or cord** equivalent to at least that of a cord complying with IEC 60227 (all parts) or IEC 60245 (all parts) is regarded as **basic insulation**.

A lining or a bushing of insulating material in a metallic enclosure is only regarded as **supplementary insulation** if it complies with the relevant requirements.

An **enclosure** of insulating material is regarded as **reinforced insulation**, in which case, two separate insulations are not necessary.

Compliance is checked by inspection and by carrying out a manual test.

22.9.3 Inlet bushings shall:

- be so shaped as to prevent damage to the **external flexible cable or cord**;
- be reliably fixed;
- not be removable without the aid of a **tool**; and
- not be of natural rubber, except if it is an integral part of the rubber sheath of the **external flexible cable or cord** for **type X** with a special cord, **type Y** and **type Z attachments** for **class I transformers**.

Compliance is checked by inspection and by carrying out a manual test.

22.9.4 Transformers provided with cords which are moved while in operation shall be constructed so that the cord is adequately protected against excessive flexing where it enters the **transformer**. Cord guards, if any, shall be of insulating material and be fixed in a reliable manner.

Compliance is checked by carrying out the following test, which is conducted on an apparatus having an oscillating member as shown in Figure 12.

*The part of the **transformer** comprising the cord entry, the cord guard, if any, and the **external flexible cable or cord** is fixed to the oscillating member so that when the latter is at the middle of its travel, the axis of the cord where it enters the cord guard or inlet is vertical and passes through the axis of oscillation. The major axis of the section of flat cords shall be parallel to the axis of oscillation.*

The cord is loaded so that the force applied is:

- 10 N for cords having a cross-sectional area exceeding 0,75 mm²; and
- 5 N for other cords.

*The distance A shown in Figure 12, between the axis of oscillation and the point where the cord guard enters the **transformer**, is adjusted so that when the oscillating member moves over its full range, the cord and load make the minimum lateral movement.*

*The oscillating member is moved through an angle of 90° (45° on either side of the vertical), the number of flexings for **type Z attachments** shall be 20 000, and for other attachments 10 000. The rate of flexing shall be 60 / min.*

NOTE 1 A flexing is one movement of 90°.

The cord and its associated parts are turned through an angle of 90° after half the number of flexings, unless a flat cord is fitted.

During the test, the conductors are loaded with the maximum rated current of the circuit under test, and at the rated voltage.

NOTE 2 Current is not passed through the protective earthing conductor.

The test shall not result in:

- *a short circuit between the conductors;*
- *breakage of more than 10 % of the strands of any conductor;*
- *separation of the conductor from the terminal;*
- *loosening of any cord guard;*
- *damage, within the meaning of this document, to the cord or cord guard; and*
- *broken strands piercing the insulation and becoming accessible.*

NOTE 3 Conductors include protective earthing conductors.

NOTE 4 A short circuit between conductors of the cord is considered to occur if the current exceeds a value equal to twice the rated maximum current of the circuit in question.

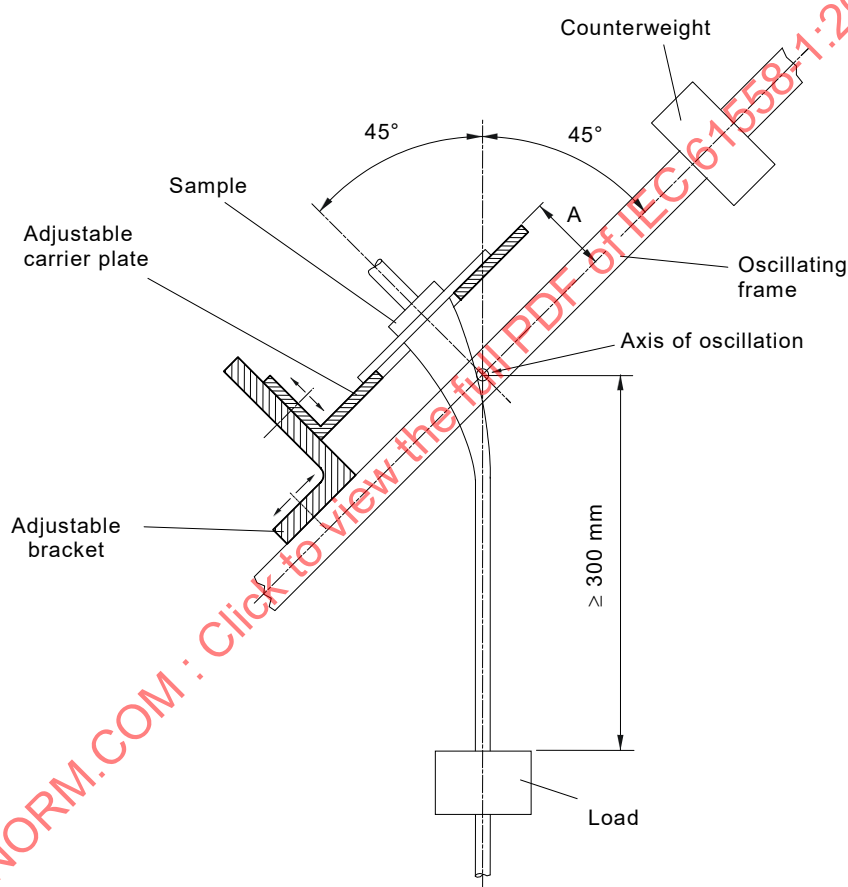


Figure 12 – Flexing test apparatus

22.9.5 Stationary transformers intended for use with **external flexible cables or cords** and **portable transformers** shall be provided with cord anchorages for strain relief including twisting where they are connected within the **transformer**, and for protection of the insulation of the conductors against abrasion.

For **type X attachments**, glands shall not be used as cord anchorages in **portable transformers** unless they have provisions for clamping all types and sizes of cables and cords which might be used as **external flexible cables or cords**. Production methods, such as, moulded-on designs, tying the cord into a knot or tying the ends with string, are not allowed; labyrinths or similar means are permitted, provided it is clear how the **external flexible cable or cord** is to be assembled.

For **type X attachments**, the cord anchorage shall be so designed or located that:

- replacement of the cord is easily possible;
- it is clear how strain relief and prevention of twisting are to be obtained;
- it is suitable for connection of different types of cords, unless the **transformer** is designed to accommodate only a specific type of cord;
- the entire flexible cable or cord with its covering, if any, is capable of being mounted into the cord anchorage;
- it does not damage the cord and is unlikely to be damaged when it is tightened or loosened in normal use; and
- the cord cannot touch the clamping screws of the cord anchorage if these screws are accessible or in contact with accessible **conductive parts**.

For **type X** with a special cord, and **type Y** and **Z attachments**, the cores of the **external flexible cable or cord** shall be insulated from accessible **conductive parts** by insulation complying with the requirements for **basic insulation** for **class I transformers**, and the requirements for **supplementary insulation** for **class II transformers**.

This insulation may consist of:

- a separate insulating barrier fixed to the cord anchorage;
- a special lining fixed to the cord; or
- for **class I transformers**, the sheath of a sheathed cord.

For **type X** with a special cord, and **type Y attachments**, the cord anchorage shall be so designed that:

- the replacement of the **external flexible cable or cord** does not impair compliance with this document;
- the entire flexible cable or cord with its covering, if any, is capable of being mounted into the cord anchorage;
- it does not damage the cord and is unlikely to be damaged when it is tightened or loosened in normal use; and
- the cord cannot touch the clamping screws of the cord anchorage if these screws are accessible or in contact with accessible conductive parts;

Compliance is checked by inspection and by the following tests.

*For **type X attachments**, except with a special cord, the **transformer** shall be fitted with a suitable **external flexible cable or cord**. The conductors shall be introduced into the terminals, and the terminal screws, if any, shall be tightened sufficiently to prevent the conductors from shifting position. The cord anchorage shall be used in the normal way, its clamping screws tightened with a torque equal to two-thirds of that specified in Table 18.*

*The tests are first conducted with the lightest permissible type of cord of the smallest cross-sectional area specified in Table 16 and then with the next heavier type of cord of the largest cross-sectional area specified, unless the **transformer** is designed to accommodate only a specific type of cord.*

*For **type X** with a special cord, and **type Y** and **Z attachments**, the **transformer** is tested with the cord in place.*

*It shall not be possible to push the cord into the **transformer** to the extent that the cord or internal parts of the **transformer**, could be damaged.*

The cord shall then be subjected 25 times to a pull force of the value shown in Table 17. The pull force shall be applied in the most unfavourable direction without a jerking motion, each time for 1 s.

Immediately after the pull tests, the cord is subjected for 1 min to a torque of the value shown in Table 17.

Table 17 – Pull and torque to be applied to external flexible cables or cords fixed to stationary and portable transformers

Mass of transformer kg	Pull N	Torque Nm
Up to and including 1	30	0,1
Over 1 up to and including 4	60	0,25
Over 4	100	0,35

The cord shall not be damaged during the tests.

After the tests, the cord shall not be longitudinally displaced by more than 2 mm, and the conductors shall not shift over a distance of more than 1 mm in the terminals, nor shall there be appreciable strain at the connection.

Creepage distances and clearances shall not be reduced below the values specified in Clause 26.

For the measurement of the longitudinal displacement, a mark is made on the cord at a distance of approximately 20 mm from the cord anchorage or other suitable point before starting the tests.

After the tests, the displacement of the mark on the cord in relation to the cord anchorage or other point is measured, while the cord is still under the pull force.

22.9.6 The space for the supply cables or the **external flexible cable or cord** provided inside for the connection

- a) to fixed wiring and for **type X** and **Y attachments** shall be designed to:
 - permit checking the proper connection and positioning of the conductors prior to fitting of cover, if any;
 - ensure the covers, if any, can be fitted without risk of damage to the conductors or their insulation;
 - prevent, for **portable transformers**, the un-insulated end of the conductor, should it pull free from the terminal, from coming into contact with accessible **conductive parts**, unless, for **type X** and **Y attachments**, the cord is provided with terminations that are unlikely to pull free from the conductor; and
- b) to fixed wiring and for **type X attachments**, in addition shall be:
 - adequate to allow the conductors to be easily introduced and connected; and
 - designed such that covers, if any, giving access to terminals for external conductors can only be removed with the aid of a **tool**.

Compliance is checked by inspection and by manual tests.

23 Terminals for external conductors

23.1 Transformers intended to be permanently connected to fixed wiring, and **transformers** other than those provided with external flexible cords with **type Y** or **Z attachments** shall be provided with terminals in which connection is made by means of screws, nuts or equally effective devices.

*Terminals that are an integral part of the **transformer** shall comply with IEC 60999-1 under the conditions prevailing in the **transformer**.*

Other terminals shall be:

- *either separately checked according to IEC 60998-2-1, IEC 60998-2-2 or IEC 60947-7-1, and used in accordance with their marking, or*
- *checked according to IEC 60999-1 under the conditions prevailing in the **transformer**.*

For **transformers** with **type X attachment**, soldered connections may be used for external conductors, provided that the conductor is so positioned or fixed that reliance is not placed upon soldering alone to maintain the conductor in position, unless barriers are provided so that **creepage distances** and **clearances** between **hazardous-live-parts** and other conductive parts cannot be reduced to less than 50 % of the values specified in Clause 26, should the conductor break away at the soldered joint.

For **transformers** with **type Y** and **Z attachments**, soldered, welded, crimped and similar connections may be used for external conductors.

For **class II transformers**, the conductor shall be so positioned or fixed that reliance is not placed upon soldering, crimping, or welding alone to maintain the conductor in position, unless barriers are provided so that **creepage distances** and **clearances** between **hazardous-live-parts** and other **conductive parts** cannot be reduced to less than 50 % of the values specified in Clause 26, should the conductor break away at the soldered or welded joint, or slip out of the crimped connections.

NOTE In general, hooking-in before soldering is considered to be a suitable method for retaining the conductor of a flexible cable or cord in position, provided the hole through which the conductor is passed is not unduly large.

23.2 Terminals for **type X** attachment with a special cord, and **types Y** and **Z attachments** shall be suitable for their purpose.

Compliance with the requirements of 23.1 and 23.2 is checked by inspection and by applying a pull force of 5 N to the connection immediately before carrying out the test of 14.1.

23.3 Terminals, other than those with **type Y** or **Z attachments**, shall be so fixed that when the clamping means is tightened or loosened, the terminal does not loosen up, internal wiring is not subjected to stress, and **creepage distances** and **clearances** are not reduced below the values specified in Clause 26.

23.4 Terminals, other than those with **type Y** or **Z attachments**, shall be so designed that they clamp the conductor between metallic surfaces with sufficient contact pressure, and without damage to the conductor.

Compliance with the requirements of 23.3 and 23.4 is checked by inspection and by measurement after fastening and loosening 10 times a conductor of the largest cross-sectional area corresponding to the rated connecting capacity of the terminal, and the torque applied shall be equal to two-thirds of the torque specified in Clause 25.

Securing with sealing compounds without other means of clamping is not considered sufficient. However, self-hardening resins may be used to secure terminals that are not subject to torsion in normal use.

23.5 Terminals provided for connection to fixed wiring, and terminals with **type X attachment** shall be located near their associated terminals of different polarities and the protective earthing terminal, if any.

Compliance is checked by inspection.

23.6 Terminal blocks and similar devices shall not be accessible without the aid of a **tool**, even if their **hazardous-live-parts** are not accessible.

Compliance is checked by inspection and by carrying out a manual test.

23.7 Terminals or terminations of **transformers** with **type X attachment** shall be so located or shielded that, should a strand of wire from a stranded conductor pull out when the conductors are fitted, there shall be no risk of accidental connection between **live parts** and accessible **conductive parts**, and in case of **class II transformers**, between **live parts** and **conductive parts** separated from accessible **conductive parts** by **supplementary insulation** only.

Compliance is checked by inspection and by carrying out the following test.

An 8-mm length of insulation is removed from the end of a flexible conductor having a nominal cross-sectional area as specified in Clause 22. One strand of wire from the stranded conductor is left free, and the other strands are fully inserted into the terminal and clamped in.

*The free strand of wire is bent in every possible direction without making sharp bends round barriers and without tearing the insulation back. The free strand of wire connected to a live terminal shall not touch any accessible conductive parts. For **class II transformers**, it shall also not touch any conductive part separated from accessible conductive parts by **basic** or **supplementary insulation** only. The free strand of wire from a conductor connected to an earthing terminal shall not touch any **hazardous-live-part**.*

23.8 Terminals without pressure plate shall be provided with at least two clamping screws if the current exceeds 25 A.

Compliance is checked by inspection.

23.9 Terminal screws other than screws of terminals for the connection of protective earthing conductors shall not come into contact with any accessible **conductive parts**. For **class II transformers**, they shall also not touch any conductive parts separated from accessible conductive parts only by **basic** or **supplementary insulation** when the screws are loosened up as far as possible.

Compliance is checked by inspection during the test of 23.2.

24 Provisions for protective earthing

24.1 Accessible conductive parts of **class I transformers** which may become live in the event of an insulation fault shall be permanently and reliably connected to a protective earthing terminal within the **transformer**.

Class II transformers shall have no provisions for protective earthing the **transformer** except for functional purposes.

Compliance is checked by inspection.

NOTE If accessible **conductive parts** are separated from **hazardous-live-parts** by a conductive screen connected to the protective earthing terminal, or if they are separated from **hazardous-live-parts** by **double**

insulation or **reinforced insulation**, they are not, for the purpose of this requirement, regarded as likely to become live in the event of an insulation fault.

24.2 Protective earthing terminals for connection to fixed wiring, and protective earthing terminals with **type X attachment** shall comply with the requirements of Clause 23. Their clamping means shall be adequately locked against accidental loosening, and it shall not be possible to loosen them without the aid of a **tool**.

Compliance is checked by inspection, by manual test and by the tests of Clause 23.

NOTE Some terminals, especially, the pillar types, can require special provisions, such as an adequately resilient part not likely to be removed inadvertently.

24.3 All parts of the protective earthing terminal shall be such that there is no risk of corrosion resulting from contact between these parts and the copper of the protective earthing conductor, or any other metal that is in contact with these parts.

If the **body** of the protective earthing terminal is part of a frame or **enclosure** of aluminium or aluminium alloy, precautions shall be taken to avoid the risk of corrosion resulting from contact between copper and aluminium or its alloys.

Compliance is checked by inspection.

The **body** of the protective earthing terminal shall be of brass or other metal not less resistant to corrosion, unless it is a part of the metal frame or **enclosure**, in which case, the screw or nut shall be of brass or other metal equally resistant to corrosion.

24.4 The connection between the protective earthing terminal and parts required to be connected thereto shall be of low resistance.

Compliance is checked by the following test.

*A current derived from an AC source, having a no-load voltage not exceeding 12 V and equal to 1,5 times the rated input current or to 25 A, whichever is greater, is passed for 1 min between the protective earthing terminal and each of the **accessible conductive parts** in turn.*

NOTE 1 Rated input current is determined as the quotient of the **rated output** by the **rated supply voltage**, or for polyphase **transformers**, by $\sqrt{n}$ times the **rated supply voltage**, n being the number of phases.

*The voltage drop between the protective earthing terminal and the **accessible conductive part** is measured and the resistance calculated from the current and this voltage drop.*

In no case shall the resistance exceed 0,1 Ω .

In case of doubt, after 1 min, the test shall be conducted until steady-state conditions are established.

NOTE 2 Care is taken to ensure that the contact resistance between the tip of the measuring probe and the conductive part under test does not affect the test results.

NOTE 3 The resistance of the supply's flexible cable or cord, if used for convenience in the test, is not included in the resistance measurement.

NOTE 4 The cores of IP00 **transformers** are considered to be not accessible.

24.5 For **class I transformers** with **external flexible cables or cords**, the arrangement of the terminals, or the length of the conductors between the cord anchorage and the terminals, shall be such that the current-carrying conductors are stretched before the protective earthing conductor if the cord pulls out of the cord anchorage.

25 Screws and connections

25.1 Screwed connections, electrical or otherwise, shall withstand the mechanical stresses occurring in normal use.

Screws transmitting contact pressure, and screws which are likely to be tightened by the user and have a nominal diameter less than 2,8 mm, shall screw into metal.

Screws shall not be of soft metal liable to creep, such as, zinc or aluminium.

Screws of insulating material shall not be used for any electrical connection.

Screws shall not be of insulating material if their replacement by a metal screw could impair **basic insulation** between **input** and **output circuit**, **supplementary insulation**, or **reinforced insulation**, and the screws which may be removed when replacing a **power supply cord** shall not be of insulating material if their replacement by a metal screw could impair **basic insulation**.

Compliance is checked by inspection and, for screws and nuts transmitting contact pressure or which are likely to be tightened by the user, by the following test.

The screws or nuts are tightened and loosened:

- 10 times for a screw in engagement with the threads of insulating material, and
- 5 times for nuts and other screws.

Screws in engagement with the threads of insulating material are completely removed and re-inserted each time.

When testing terminal screws and nuts, a flexible cable or cord of the largest cross-sectional area specified in Table 16 is placed in the terminal and it is repositioned before each tightening.

The test is conducted by means of a suitable test screwdriver, spanner or key, applying a torque as shown in Table 18, the appropriate column shall be:

- a) *for metal screws without heads, if the tightened screw does not protrude from the hole I*
- b) *for other metal screws and for nuts II*
- c) *for screws of insulating material:*
 - *having a hexagonal head with the dimension across flats exceeding the overall thread diameter, or*
 - *with a cylindrical head and a socket for a key, the socket having a dimension across flats not less than 0,83 times the overall thread diameter, or*
 - *with a head having a slot or cross slots, the length of which exceeds 1,5 times the overall thread diameter II*
- d) *for other screws of insulating material III*

Table 18 – Torque to be applied to screws and connections

Nominal diameter of screw mm	Torque Nm		
	I	II	III
Up to and including 2,8	0,2	0,4	0,4
Over 2,8 up to and including 3,0	0,25	0,5	0,5
Over 3,0 up to and including 3,2	0,3	0,6	0,6
Over 3,2 up to and including 3,6	0,4	0,8	0,6
Over 3,6 up to and including 4,1	0,7	1,2	0,6
Over 4,1 up to and including 4,7	0,8	1,8	0,9
Over 4,7 up to and including 5,3	0,8	2,0	1,0
Over 5,3 up to and including 6,0	–	2,5	1,25

The conductor is withdrawn and inserted each time the fastener is loosened.

During the test, no damage impairing further use of the screwed connections shall occur.

NOTE Screws or nuts likely to be tightened by the user include screws intended to be operated when replacing power supply cords with type X attachment.

The blade of the test screwdriver shall fit the head of the screw to be tested. The screws and nuts should be tightened without jerking motion.

25.2 Screws in engagement with a thread of insulating material shall have a length of engagement of at least 3 mm plus one-third of the nominal screw diameter or 8 mm, whichever is shorter.

Proper introduction of the screw into the screw hole or nut shall be ensured.

Compliance is checked by inspection and by carrying out the test of 25.1, and the torque applied shall be increased to 1,2 times the torque specified.

The requirement for the proper introduction is met if introduction of the screw in a slanting manner is prevented (e.g., by guiding the screw using the part to be fixed, by a recess in the female thread, or by the use of a screw with the leading thread removed).

25.3 Electrical connections shall be designed so that contact pressure is not transmitted through insulating material other than ceramic or pure mica, except if the insulation material fulfills the tests according to 14.3, unless there is sufficient resiliency in the metallic parts to compensate for any possible shrinkage or distortion of the insulating material.

25.4 Thread-forming screws (sheet metal screws) shall not be used for the connection of current-carrying parts, unless they clamp these parts directly in contact with each other, and are provided with suitable locking means.

Thread-cutting (self-tapping) screws shall not be used for the connection of current-carrying parts unless they generate a full form standard machine screw thread. Such screws shall not, however, be used if they are likely to be operated by the user or installer unless the thread is formed in a length of material previously obtained by a swaging action.

Thread-cutting and thread-forming screws, when used to provide protective earthing continuity, shall be such that it is not necessary to disturb the connection in normal use, and at least two screws are used for each connection.

Compliance with the requirements of 25.3 and 25.4 is checked by inspection.

25.5 Screws making mechanical connections between different parts of the **transformer** shall be locked against loosening if the connection carries current or forms part of the protective earthing circuit.

Rivets used for current-carrying connections shall be locked against loosening if these connections are subject to torsion in normal use.

Compliance is checked by inspection and by carrying out a manual test.

NOTE 1 Spring washers and the like can provide satisfactory locking.

NOTE 2 For rivets, a non-circular shank or an appropriate notch can be sufficient.

NOTE 3 Sealing compounds softening due to heat provide satisfactory locking only for screw connections not subjected to torsion in normal use.

25.6 Screwed glands shall comply with the following test:

Screwed glands shall be fitted with a cylindrical metal rod having a diameter equal to the nearest whole number of millimetres below the internal diameter of the packing. The glands shall then be tightened by means of a suitable spanner, and the force shown in Table 19 shall be applied to the spanner for 1 min at a point 250 mm from the axis of the gland.

Table 19 – Torque test on glands

Diameter of test rod mm	Force	
	Metal glands N	Glands of moulded material N
Up to and including 14	25	15
Over 14 up to and including 20	30	20
Over 20	40	30

*After the test, the **transformer** and the glands shall show no damage.*

26 Creepage distances, clearances and distances through insulation

26.1 General

Creepage distances (CR), clearances (CL) and distances through insulation shall not be less than the values shown in the relevant Table 20, Table 21 and Table 22 for the relevant insulating material (see IEC 60664-1).

Compliance is checked by measurements under the provisions of 26.2 and 26.3.

NOTE 1 Table 20, Table 21 and Table 22 are only applicable for frequencies up to and including 30 kHz.

Creepage distances and **clearances** are measured, using the supply cable and cords for connection to fixed wiring and those for **type X attachment** with maximum and minimum size conductors corresponding to the rated connecting capacity of the terminal. For **type X** with a special cord, **Y** or **Z attachments**, the supply cable and cords as delivered are used.

Where layers of serrated tapes are used, the value for **creepage distances** and **clearances** are determined as if the layers of serration coincided with one another.

NOTE 2 Diagrams showing some examples of the methods of measurement of **creepage distances** and **clearances** are found in Annex A.

NOTE 3 Diagrams showing some examples of points of measurement of **creepage distances** and **clearances** are given in Annex P.

NOTE 4 Details of the tests necessary to determine the separation of material groups are given in Annex G.

Values for printed wiring boards where failure may cause a hazard in the sense of this document, shall be the same as unreduced values for **live parts** as in Table 20 and Table 21, except if the printed wiring board complies with the requirements of IEC 60664-3.

If the **pollution** results in high and persistent conductivity caused, for instance, by conductive dust, rain or snow, the **creepage distances** and **clearances**, as given for **pollution degree 3**, shall be further increased with a minimum **clearance** of 1,6 mm and a value of **X** in Annex A of 4,0 mm.

26.2 Creepage distances and clearances

26.2.1 General

The **creepage distance** and **clearance** values are shown in Table 20 and Table 21.

26.2.2 Windings covered with adhesive tape

For windings covered with an adhesive bonding tape adhering to the flanges of a coil former, the values of creepage path are considered along the bonded surface of the adhesive bonding tape. Reduced values are those stated for **pollution degree 1** (P1), provided:

- all insulating materials are classified according to IEC 60085 and IEC 60216 (all parts);
- the impulse voltage dielectric test of 6.1.2.2.1 of IEC 60664-1:2007 is fulfilled; and
- the test A of 26.2.4 is fulfilled.

NOTE An explanation of the application of 6.1.2.2.1 of IEC 60664-1:2007 can be found in Annex R.

Clearance values are not required.

26.2.3 Uncemented insulating parts

Where an insulation barrier consisting of an uncemented snap-on partition wall is used, **creepage distances** and **clearance** are measured through the joint. If the joint is covered by adhesive bonding tape in accordance with IEC 60454 (all parts), one layer of adhesive bonding tape is required on each side of the wall in order to reduce the risk of tape folding over during production.

The materials used shall be classified according to IEC 60085 and IEC 60216 (all parts).

The values stated for **pollution degree 1** (P1) do not apply.

26.2.4 Cemented insulating parts

For **transformers** with cemented parts or parts adhered together, no minimum **creepage distance** and **clearance** are required through the joint. Only the values for distance through insulation (DTI) apply. In this case, the impulse voltage dielectric test of 6.1.2.2.1 of IEC 60664-1:2007 shall also be fulfilled.

NOTE An explanation of the application of 6.1.2.2.1 of IEC 60664-1:2007 can be found in Annex R.

The materials used shall be classified according to IEC 60085 and IEC 60216 (all parts).

In order to check whether the parts are adequately cemented or adhered, the following tests are performed as appropriate:

- **Test A**

*Three specially prepared specimens with winding wires replaced by uninsulated wires without any impregnation or potting are required. The windings shall be constructed such that there is no possible flashover between **input** and **output windings** anywhere other than in the cemented joint to be tested.*

The specimens shall be subjected 10 times to the following sequence of temperature cycles:

68 h at the highest winding temperature ± 2 °C measured in normal use plus 10 K with a minimum of 85 °C;

1 h at (25 ± 2) °C;

2 h at (0 ± 2) °C;

1 h at (25 ± 2) °C.

Two of the three specimens shall then be subjected to the humidity treatment of 17.2 (48 h treatment) and the relevant dielectric strength test of 18.3, except the test voltage is multiplied by 1,35.

One of the three specimens shall be subjected to the relevant dielectric strength test of 18.3 immediately after the last period at the highest temperature during the thermal cycling test, but with a test voltage multiplied by 1,35.

NOTE The test voltage applied to the specimens for cemented parts is higher than the normal test voltage in order to ensure that a breakdown occurs if the surfaces are not cemented together.

26.2.5 Enclosed parts (e.g. by impregnation or potting)

26.2.5.1 For **transformers** with parts enclosed or hermetically sealed against ingress of dust and moisture, and satisfying the following tests, the minimum required **creepage distances** may be the reduced values as stated for **pollution degree 1** (P1). In this case, the impulse voltage dielectric test of 6.1.2.2.1 of IEC 60664-1:2007 shall also be fulfilled.

NOTE An explanation of the application of 6.1.2.2.1 of IEC 60664-1:2007 can be found in Annex R.

No clearance values are required.

The materials used shall be classified according to IEC 60085 and IEC 60216 (all parts).

In order to check whether the parts are adequately potted or impregnated, the following tests are performed as appropriate:

- **Test B**

To test the potting or the impregnation, three prepared specimens shall be used as follows. For components where potting or impregnation is used, the reliability of the joint is checked by subjecting the samples to the dielectric strength test applied only directly to the joint.

The specimens shall be subjected 10 times to the following sequence of temperature cycles:

68 h at the highest winding temperature ± 2 °C measured in normal use plus 10 K with a minimum of 85 °C;

1 h at (25 ± 2) °C;

2 h at (0 ± 2) °C;

1 h at (25 ± 2) °C.

During each thermal cycling test, a test voltage of 500 V or the working voltage, whichever is the higher value, at 50 Hz or 60 Hz shall be applied to the specimens between the windings where the reduced values apply.

Two of the three specimens shall then be subjected to the humidity treatment of 17.2 (48 h treatment) and the relevant dielectric strength test of 18.3 conducted at a voltage multiplied by 1,25.

One of the three specimens shall be subjected to the relevant dielectric strength test of 18.3 immediately at the end of the last period at the highest temperature during the thermal cycling test conducted at a voltage multiplied by 1,25.

26.2.5.2 For **transformers** with parts enclosed or hermetically sealed against ingress of dust and moisture, and satisfying the following tests, no minimum creepage distances and clearances are required. Only the values for distance through insulation (DTI) apply. In this case, the impulse voltage dielectric test of 6.1.2.2.1 of IEC 60664-1:2007 shall also be fulfilled.

NOTE An explanation of the application of 6.1.2.2.1 of IEC 60664-1:2007 can be found in Annex R.

In order to check whether the parts are adequately potted or impregnated, the following tests shall be performed as appropriate:

- **Test C**

To test the potting or the impregnation three specimens shall be used.

*For components where insulating compound forms solid insulation between **conductive parts**, finished components shall be tested. There shall be neither cracks nor voids in the insulating compounds.*

The specimens shall be subjected 10 times to the following sequence of temperature cycles:

68 h at the highest winding temperature ± 2 °C measured in normal use plus 10 K with a minimum of 85 °C;

1 h at (25 ± 2) °C;

2 h at (0 ± 2) °C;

1 h at (25 ± 2) °C.

During each thermal cycling test, a test voltage of 500 V or the working voltage, whichever is the higher value, at 50 Hz or 60 Hz shall be applied to the specimens between the windings where the reduced values apply.

Two of the three specimens are then subjected to the humidity treatment of 17.2 (48 h treatment) and the relevant dielectric strength test of 18.3 conducted at a voltage multiplied by 1,35.

One of the three specimens shall be subjected to the relevant dielectric strength test of 18.3 immediately at the end of the last period at highest temperature during the thermal cycling test conducted at a voltage multiplied by 1,35.

26.3 Distance through insulation

26.3.1 The distances through insulation (DTI) are required for **supplementary, double or reinforced** insulation only as shown in Table 22.

The insulation shall fulfil either the material classification as given in IEC 60085 and IEC 60216 (all parts) or the test of 14.3.

NOTE The material is considered as having adequate mechanical strength and resistance to ageing if it fulfils the test of 14.3.

The requirements concerning distance through insulation (DTI) do not imply that the prescribed distance shall be through solid or thin sheet insulation only. It may consist of the thickness of solid or thin sheet insulation plus a specified clearance distance.

26.3.2 In case of solid insulation, the required values are specified in the Table 22. For classified materials in accordance to IEC 60085 and IEC 60216 (all parts), distances through

insulation multiplied by 0,4 with a minimum of 0,2 mm for **reinforced insulation** and of 0,1 mm for **supplementary insulation** for **working voltage** above 25 V may be used if the test of 14.3 is fulfilled.

26.3.3 In the case of insulation constructed of thin sheets of insulated material, the insulation shall be such that at every place, there is at least the required number of layers and the DTI as follows:

- if the layers are non separable (glued together):
 - 3 layers are required;
 - the entire composite sheet shall fulfil the mandrel test of 26.3.4 with a pull force of (150 ± 10) N;
 - the required values for DTI of thin layers in Table 22;
- if the layers are separated:
 - 2 layers are required; for separated serrated layers, one additional layer is required (serrated tape) plus one layer without serration fixed (e.g. adhesive);
 - each layer shall fulfil the mandrel test of 26.3.4 with a pull force of (50 ± 5) N;
 - the required values for DTI of thin layers in Table 22;
- if the layers are separated (alternative):
 - at least 3 layers are required; for separated serrated layers, one additional layer is required (serrated tape) plus one layer without serration fixed (e.g. adhesive);
 - two-thirds of the number of layers shall fulfil the mandrel test of 26.3.4 with a pull force of (100 ± 5) N;
 - the required values for DTI of thin layers in Table 22.

Additional layers are required in case of use of serrated layers because it is assumed that different layers of serration can coincide with one another.

For classified materials in accordance to IEC 60085 and IEC 60216 (all parts), no requirements for distances through insulation are required if the test of 14.3 is fulfilled.

The required values of Table 22 for thin layers shall be used as follows:

- for **transformers** having a **rated output** greater than 100 VA, the values for thin layers apply;
- for **transformers** having a **rated output** of 25 VA up to and including 100 VA, the values for thin layers may be reduced to two-thirds of their value;
- for **transformers** having a **rated output** of less than 25 VA, the figures in values for thin layers may be reduced to one-third of their value.

26.3.4 For the mandrel test, three separate test specimens of thin sheets $(70 \pm 0,5)$ mm in width shall be supplied by the manufacturer.

The test shall be performed by fixing the specimens of thin sheets on a mandrel made of nickel plated steel or brass with smooth surface finish as shown in Figure 13.

A metal foil (aluminium or copper) $0,035 \text{ mm} \pm 0,005 \text{ mm}$ thick shall be placed closely to the surface of the specimen and subjected to a pull force of $(1 \pm 0,1)$ N. The metal foil shall be so positioned that its borders are 20 mm away from the borders of the specimen, and when the mandrel is in its final position, it covers the edges upon which the specimen is lying by at least 10 mm.

The specimen is held in place at its free end by an appropriate clamping device and subjected to:

- a pull force of (150 ± 10) N for a specimen consisting of several non separable layers;
- a pull force of (100 ± 5) N for a specimen consisting of $2/3$ the number of separated layers (serrated or not); and
- a pull force of (50 ± 5) N for a specimen consisting of a single layer (serrated or not).

The mandrel shall be slowly rotated forwards and backwards 3 times for 230° without jerking motion. If the specimen breaks at the clamping device during the rotation, the test shall be repeated. If one or more specimens break at any other place, the test is not fulfilled. While the mandrel is in its final position, within a minute following the final positioning, a dielectric strength test voltage shall be applied for 1 min as described in 18.3 between the mandrel and the metal foil as follows:

- a test voltage of at least 5 kV or the applicable test voltage of 18.3 multiplied by 1,35 for a specimen consisting of several non separable layers (at least 3 layers), whichever is greater;
- a test voltage of at least 5 kV or the applicable test voltage of 18.3 multiplied by 1,25 for a specimen consisting of $2/3$ of the number of at least 3 separated layers, whichever is greater;
- a test voltage of at least 5 kV or the applicable test voltage of 18.3 multiplied by 1,25 for a specimen consisting of one layer of the number of 2 separated layers, whichever is greater.

No flashover or breakdown shall occur during the test, and corona effects and similar phenomena shall be disregarded.

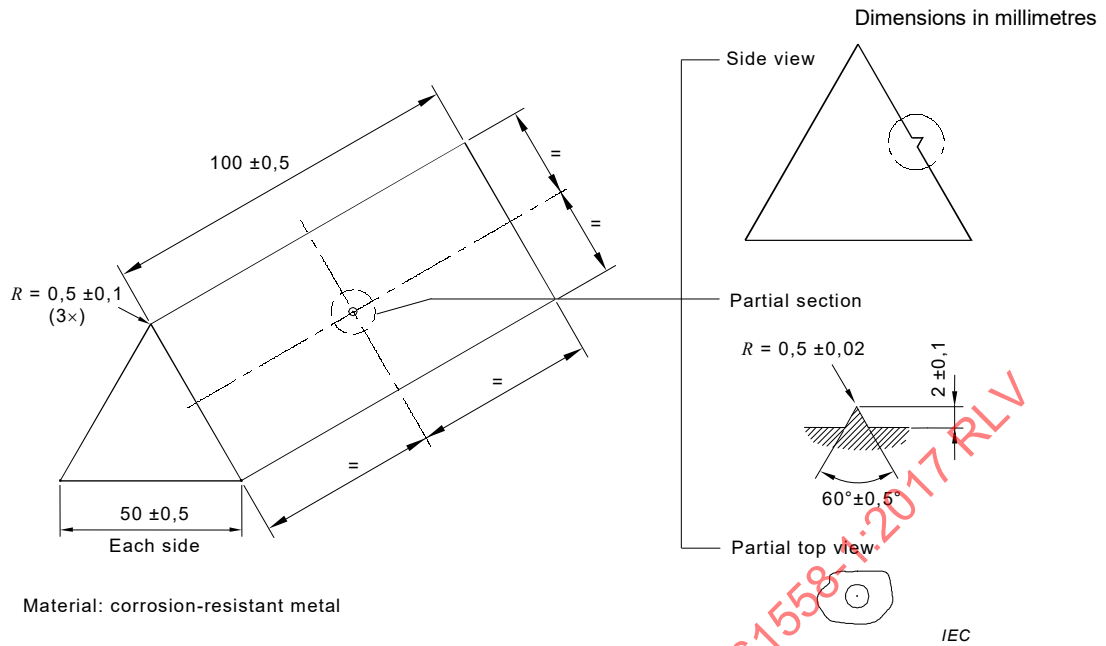


Figure 13a – Mandrel

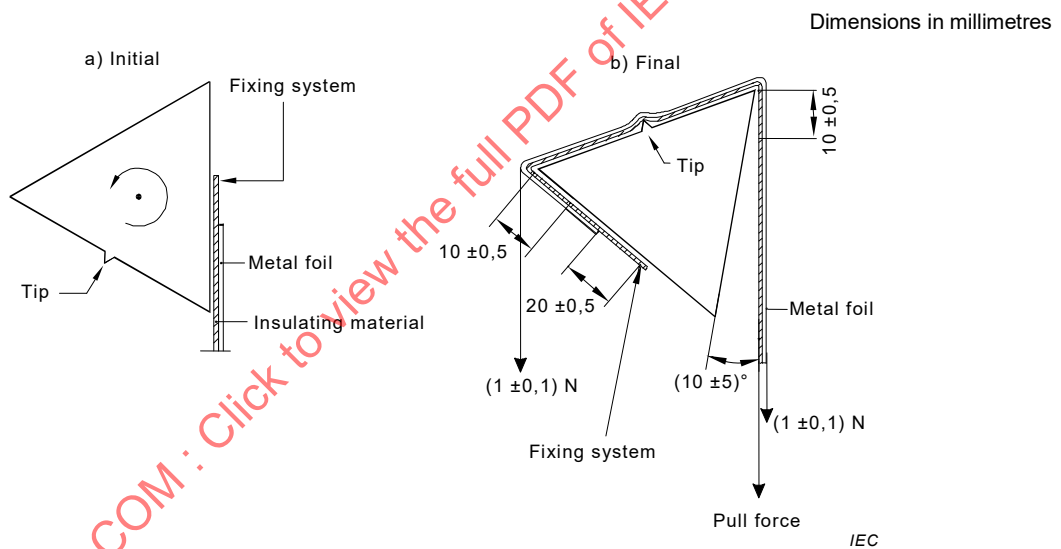


Figure 13b – Position of mandrel

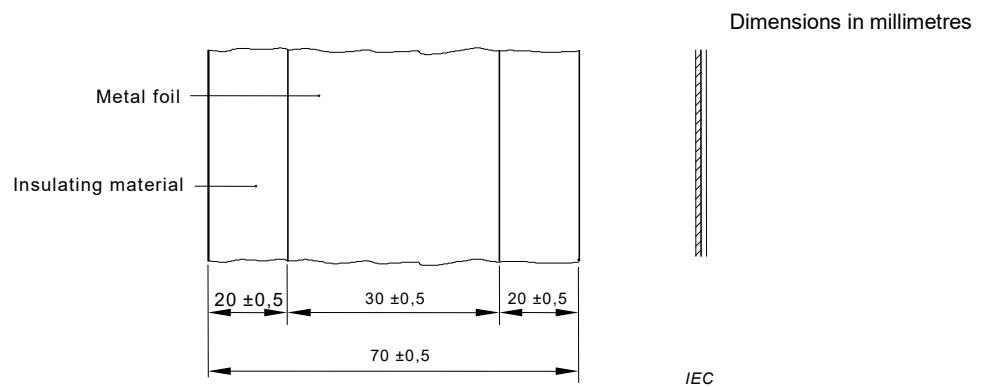


Figure 13c – Position of metal foil on paper

Figure 13 – Test arrangement for checking mechanical withstanding of insulating materials in thin sheet layers

Table 20 – Clearances in mm

Overvoltage category	Insulation of the conductive part	Pollution degree	Working voltage [V]					
			≥ 25 ≤ 50	100	150	300	600	1 000
OVC I	Basic insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,2	0,5	1,5	3,0
		P3	0,8	0,8	0,8	0,8	1,5	3,0
	Supplementary insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,2	0,5	1,5	3,0
		P3	0,8	0,8	0,8	0,8	1,5	3,0
	Double or reinforced insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,5	1,5	3,0	5,5
		P3	0,8	0,8	0,8	1,5	3,0	5,5
OVC II	Basic insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,5	1,5	3,0	5,5
		P3	0,8	0,8	0,8	1,5	3,0	5,5
	Supplementary insulation	P1	-	-	-	-	-	-
		P2	0,2	0,2	0,5	1,5	3,0	5,5
		P3	0,8	0,8	0,8	1,5	3,0	5,5
	Double or reinforced insulation	P1	-	-	-	-	-	-
		P2	0,2	0,5	1,5	3,0	5,5	8,0
		P3	0,8	0,8	1,5	3,0	5,5	8,0
OVC III	Basic insulation	P1	-	-	-	-	-	-
		P2	0,2	0,5	1,5	3,0	5,5	8,0
		P3	0,8	0,8	1,5	3,0	5,5	8,0
	Supplementary insulation	P1	-	-	-	-	-	-
		P2	0,2	0,5	1,5	3,0	5,5	8,0
		P3	0,8	0,8	1,5	3,0	5,5	8,0
	Double or reinforced insulation	P1	-	-	-	-	-	-
		P2	0,5	1,5	3,0	5,5	8,0	14,0
		P3	0,8	1,5	3,0	5,5	8,0	14,0
OVC IV	Basic insulation	P1	-	-	-	-	-	-
		P2	0,5	1,5	3,0	5,5	8,0	14,0
		P3	0,8	1,5	3,0	5,5	8,0	14,0
	Supplementary insulation	P1	-	-	-	-	-	-
		P2	0,5	1,5	3,0	5,5	8,0	14,0
		P3	0,8	1,5	3,0	5,5	8,0	14,0
	Double or reinforced insulation	P1	-	-	-	-	-	-
		P2	1,5	3,0	5,5	8,0	14,0	25,0
		P3	1,5	3,0	5,5	8,0	14,0	25,0

For **functional insulation** no **clearances** are required

Values of **clearances** may not be interpolated between the values in the table.

No values for **clearances** are required for **working voltages** below 25 V AC or 60 V DC as the dielectric strength test of Table 14 is considered sufficient.

These values do not apply:

- inside each winding or between groups of windings intended to be permanently connected together, provided that the termination of windings to be connected together are at the same potential,
- where the **working voltage** does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317 (all parts), if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 115 / 230 V).

For insulation between **SELV circuits** and adjacent **circuits** other than **SELV** or **PELV**, the insulation shall fulfil the requirements of **double** or **reinforced insulation** (according to 19.1).

NOTE 1 When a numeric figure is replaced by a dash in a column of the table it means that no value is required

NOTE 2 P1 = **pollution degree** 1; P2 = **pollution degree** 2; P3 = **pollution degree** 3.

NOTE 3 The minimum values for **clearances** in this table are applicable in air up to 2 000 m above sea level. For higher values use IEC 60664-1:2007 Table A.2

Table 21 – Creepage distances in mm

Material group (CTI-value)	Insulation of the conductive part	Pollution degree	Working voltage [V]					
			≥ 25 ≤ 50	100	150	300	600	1 000
I (CTI ≥ 600)	Basic insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	0,6	0,7	0,8	1,5	3,0	5,5
		P3	1,5	1,8	2,0	3,9	7,7	12,5
	Supplementary insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	0,6	0,7	0,8	1,5	3,0	5,5
		P3	1,5	1,8	2,0	3,9	7,7	12,5
	Double or reinforced insulation	P1	0,25	0,4	0,7	1,7	4,0	7,5
		P2	0,7	1,0	1,6	3,0	6,0	10,0
		P3	1,8	2,5	4,2	7,7	16,0	25,0
II ($400 \leq \text{CTI} < 600$)	Basic insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	0,9	1,0	1,1	2,1	4,3	7,1
		P3	1,7	2,0	2,2	4,2	8,6	14,0
	Supplementary insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	0,9	1,0	1,1	2,1	4,3	7,1
		P3	1,7	2,0	2,2	4,2	8,6	14,0
	Double or reinforced insulation	P1	0,25	0,4	0,7	1,7	4,0	7,5
		P2	1,0	1,4	2,0	4,3	8,6	14,0
		P3	2,0	2,8	4,2	8,6	17,2	28,0
IIIa ($175 \leq \text{CTI} < 400$)	Basic insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	1,2	1,4	1,6	3,0	6,0	10,0
		P3	1,9	2,2	2,5	4,7	9,5	16,0
	Supplementary insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	1,2	1,4	1,6	3,0	6,0	10,0
		P3	1,9	2,2	2,5	4,7	9,5	16,0
	Double or reinforced insulation	P1	0,25	0,4	0,7	1,7	4,0	7,5
		P2	1,4	2,0	3,0	6,0	12,0	20,0
		P3	2,2	3,0	4,7	9,5	19,2	32,0
IIIb ($100 \leq \text{CTI} < 175$)	Basic insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	1,2	1,4	1,6	3,0	6,0	10,0
		P3	1,9	2,2	2,5	4,7	9,5	16,0
	Supplementary insulation	P1	0,18	0,25	0,3	0,7	1,7	3,2
		P2	1,2	1,4	1,6	3,0	6,0	10,0
		P3	1,9	2,2	2,5	4,7	9,5	16,0
	Double or reinforced insulation	P1	0,36	0,5	0,7	1,7	4,0	7,5
		P2	2,4	2,8	3,2	6,0	12,0	20,0
		P3	3,8	4,4	5,0	9,5	19,2	32,0

For **functional insulation** no **creepage distance** values are required.

Values of **creepage distances** may be found for intermediate values of **working voltages** by linear interpolation between the values in the table.

No values for **creepage distances** are required for **working voltages** below 25 V AC or 60 V DC as the dielectric strength test of Table 14 is considered sufficient.

These values do not apply:

- inside each winding or between groups of windings intended to be permanently connected together, provided that the termination of windings to be connected together are at the same potential,
- where the **working voltage** does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317 (all parts), if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 115 / 230 V).

For insulation between **SELV circuits** and adjacent **circuits** other than **SELV** or **PELV**, the insulation shall fulfil the requirements of **double** or **reinforced insulation** (according to 19.1).

NOTE 1 When a numeric figure is replaced by a dash in a column of the table it means that no value is required.

NOTE 2 P1 = **pollution degree 1** P2 = **pollution degree 2** P3 = **pollution degree 3**.

Creepage distances shall not become less than the **clearances**.

Material group IIIb ($100 \leq \text{CTI} < 175$) is not recommended for application in **pollution degree 3** above 630 V

An explanation for the determination of the comparative tracking indices (CTI) defined in IEC 60112 is given in Annex G.

Table 22 – Distance through insulation in mm

Insulation of the conductive part		Working voltage [V]					
		≥ 25 ≤ 50	100	150	300	600	1 000
Basic insulation	solid	-	-	-	-	-	-
	thin layers	-	-	-	-	-	-
Supplementary insulation	solid	0,1	0,15	0,25	0,5	0,75	1,0
	thin layers	0,05	0,05	0,08	0,15	0,2	0,25
Double or reinforced insulation	solid	0,2	0,3	0,5	1,0	1,5	2,0
	thin layers	0,1	0,1	0,15	0,3	0,4	0,5

For **functional insulation** no distance through insulation (DTI) is required.

Values of distance through insulation (DTI) may be found for intermediate values of **working voltages** by linear interpolation between the values in the table.

No values for distances through insulation are required for **working voltages** below 25 V AC or 60 V DC as the dielectric strength test of Table 14 is considered sufficient.

These values do not apply:

- inside each winding or between groups of windings intended to be permanently connected together, provided that determination of windings to be connected together are at the same potential,
- where the **working voltage** does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317 (all parts), if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 115 / 230 V).

For insulation between **SELV circuits** and adjacent **circuits** other than **SELV** or **PELV**, the insulation shall fulfil the requirements of **double** or **reinforced insulation** (according to 19.1).

NOTE 1 When a numeric figure is replaced by a dash in a column of the table it means that no value is required

When **double insulation** is required between **input** and **output windings**, the total thickness through insulation shall be measured directly or via metals parts, with the exception of insulated wires (see 19.12).

NOTE 2 In case of a physical breakdown of the **basic insulation** or **supplementary insulation**, the thickness of the insulation is added to the **clearance**.

A reduction of these values is allowed in the case of different layers according to clause 26.3.3.

Table 23 – Creepage distances and clearance between terminals for external connection

	Current values [A]	Working voltage [V]					
		≥ 25 ≤ 50	100	150	300	600	1 000
Creepage distances and clearance between terminals or the connection of external cables and cords excluding those between screw terminals for input and for output	≤ 6	3,0	3,6	4,0	6,0	9,0	12,5
	> 6 and ≤ 16	5,0	6,0	7,0	10,0	13,0	16,0
	> 16	10,0	11,0	12,0	14,0	17,0	20,0
NOTE 1 Values of clearances and creepage distances may be found for intermediate values of working voltages by linear interpolation between the values in the table. NOTE 2 No values for clearances are required for working voltages below 25 V AC or 60 V DC as the dielectric strength test of Table 14 is considered sufficient. These values do not apply: – inside each winding or between groups of windings intended to be permanently connected together, provided that the termination of windings to be connected together are at the same potential. – where the working voltage does not exceed 300 V and the winding wires comply at least with grade 1 of IEC 60317 (all parts), if only the windings are intended to be connected in a series or parallel arrangement (e.g. input voltage 115 / 230 V). For insulation between SELV circuits and adjacent circuits other than SELV or PELV, the insulation shall fulfil the requirements of double or reinforced insulation (according to 19.1).							

26.3.5 For transformers with FIW wires the following test is required:

To test the FIW-winding at the final transformer, three specimens shall be used. The specimens shall be subjected 10 times to the following sequence of temperature cycles:

68 h at the highest winding temperature ± 2 °C measured in normal use plus 10 K with a minimum of 85 °C;

1 h at (25 ± 2) °C;

2 h at (0 ± 2) °C;

1 h at (25 ± 2) °C.

During each thermal cycling test, a test voltage of 500 V or the working voltage, whichever is the higher value, at 50 Hz or 60 Hz shall be applied to the specimens between the windings where the reduced values apply.

Two of the three specimens are then subjected to the humidity treatment of 17.2 (48 h treatment) and the relevant dielectric strength test of 18.3.

One of the three specimens shall be subjected to the relevant dielectric strength test of 18.3 immediately at the end of the last period at highest temperature during the thermal cycling test.

The partial discharge test shall be done at the end of the cycling test at normal room temperature as performed in 18.3.1.

NOTE The minimal value depends on the of diameter increase at the temperature of 180°C. The voltage values are valid for all diameters of the FIW grade. The specimen has to withstand the dielectric strength test voltage for at least 60 s.

The values of allowed voltage strength for other **FIW** dimensions than defined in Table 24 are calculated according following formula:

$$U_s = (d_o - d_{Cu}) \times U_b \times 0,85 \times 10^3 \quad (6)$$

where

d_o is the minimum overall diameter [mm];

d_{Cu} is the nominal conductor diameter (copper diameter) [mm];

U_b is the minimum characteristic breakdown voltage [V/μm];

U_s is the allowed dielectric strength voltage for FIW [V] (duration of 60 s).

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Table 24 – Values of FIW wires with minimum overall diameter and minimum test voltages according to the total enamel increase

Nominal conductor diameter d_{Cu} [mm]	Minimum specific breakdown voltage ^a U_b [V/μm]	Minimum overall FIW diameter d_o [mm]								Minimum dielectric strength test voltage values per wire for basic or reinforced insulation at overall diameter U_s [V] (duration of 60 s)							
		Grade of FIW 3	Grade of FIW 4	Grade of FIW 5	Grade of FIW 6	Grade of FIW 7	Grade of FIW 8	Grade of FIW 9	Grade of FIW 3	Grade of FIW 4	Grade of FIW 5 of FIW 5	Grade of FIW 6	Grade of FIW 7	Grade of FIW 8	Grade of FIW 9		
0,04	56	0,055	0,059	0,070	0,080	0,090	0,100		714	904	1 428	1 904	2 380	2 856			
0,045	56	0,062	0,067	0,079	0,090	0,101	0,112		809	1 047	1 618	2 142	2 666	3 189			
0,05	56	0,067	0,073	0,084	0,095	0,106	0,117		809	1 095	1 618	2 142	2 666	3 189			
0,056	56	0,075	0,082	0,093	0,105	0,117	0,129		904	1 238	1 761	2 332	2 904	3 475			
0,063	56	0,084	0,090	0,103	0,116	0,129	0,142		1 000	1 285	1 904	2 523	3 142	3 760			
0,071	56	0,092	0,098	0,111	0,124	0,137	0,150	0,163	1 000	1 285	1 904	2 523	3 142	3 760	4 379		
0,08	56	0,102	0,109	0,123	0,137	0,151	0,165	0,179	1 047	1 380	2 047	2 713	3 380	4 046	4 712		
0,09	56	0,114	0,121	0,135	0,149	0,163	0,177	0,191	1 142	1 476	2 142	2 808	3 475	4 141	4 808		
0,1	56	0,126	0,133	0,149	0,165	0,181	0,197	0,213	1 238	1 571	2 332	3 094	3 856	4 617	5 379		
0,112	53	0,140	0,148	0,165	0,182	0,199	0,216	0,233	1 261	1 622	2 388	3 154	3 919	4 685	5 451		
0,125	53	0,155	0,164	0,182	0,200	0,218	0,236	0,254	1 352	1 757	2 568	3 379	4 190	5 001	5 811		
0,14	53	0,172	0,182	0,202	0,222	0,242	0,262	0,282	1 442	1 892	2 793	3 694	4 595	5 496	6 397		
0,16	53	0,195	0,206	0,228	0,250	0,272	0,294	0,316	1 577	2 072	3 063	4 055	5 046	6 037	7 028		
0,18	53	0,218	0,230	0,254	0,278	0,302	0,326	0,350	1 712	2 253	3 334	4 415	5 496	6 577	7 659		
0,2	53	0,240	0,253	0,278	0,303	0,328	0,353	0,378	1 802	2 388	3 514	4 640	5 766	6 893	8 019		
0,224	53	0,267	0,281	0,308	0,335	0,362	0,389	0,416	1 937	2 568	3 784	5 001	6 217	7 433	8 650		
0,25	53	0,298	0,313	0,343	0,373	0,403	0,433	0,463	2 162	2 838	4 190	5 541	6 893	8 244	9 596		
0,28	53	0,330	0,346	0,377	0,408	0,439	0,470	0,501	2 253	2 973	4 370	5 766	7 163	8 560	9 956		
0,315	53	0,368	0,385	0,416	0,447	0,478	0,509	0,540	2 388	3 154	4 550	5 947	7 343	8 740	10 136		
0,355	53	0,412	0,429	0,460	0,491	0,522	0,553	0,584	2 568	3 334	4 730	6 127	7 523	8 920	10 316		
0,4	49	0,460	0,479	0,510	0,541	0,572	0,603		2 499	3 290	4 582	5 873	7 164	8 455			
0,45	49	0,514	0,534	0,565	0,596	0,627	0,658		2 666	3 499	4 790	6 081	7 372				
0,5	49	0,567	0,588	0,629	0,670	0,711			2 791	3 665	5 373	7 081	8 788				

Nominal conductor diameter d_{Cu} [mm]	Minimum specific breakdown voltage ^a U_b [V/ μ m]	Minimum overall FIW diameter d_o [mm]							Minimum dielectric strength test voltage values per wire for basic or reinforced insulation at overall diameter U_g [V] (duration of 60 s)						
		Grade of FIW 3	Grade of FIW 4	Grade of FIW 5	Grade of FIW 6	Grade of FIW 7	Grade of FIW 8	Grade of FIW 9	Grade of FIW 3	Grade of FIW 4	Grade of FIW 5	Grade of FIW 6	Grade of FIW 7	Grade of FIW 8	Grade of FIW 9
0,56	37	0,631	0,654	0,695	0,736	0,777			2 233	2 956	4 246	5 535	6 825		
0,63	37	0,705	0,729	0,770	0,811	0,852			2 359	3 114	4 403	5 692	6 982		
0,71	37	0,790	0,815	0,856	0,897	0,938			2 516	3 302	4 592	5 881	7 171		
0,8	37	0,885	0,912	0,963	1,014				2 673	3 522	5 126	6 730			
0,9	37	0,990	1,019	1,070	1,121				2 831	3 743	5 347	6 950			
1	37	1,095	1,125	1,176	1,227				2 988	3 931	5 535	7 139			
1,12	33	1,218	1,249	1,310					2 749	3 618	5 330				
1,25	33	1,350	1,382	1,443					2 805	3 703	5 414				
1,4	33	1,503	1,536	1,597					2 889	3 815	5 526				
1,6	33	1,707	1,741	1,802					3 001	3 955	5 666				

^a Value according to Table 7 of IEC 60317-0-7:2012

^a Value according to Table 7 of IEC 60317-0-7:2012

27 Resistance to heat, fire and tracking

27.1 General

For components previously tested in accordance with their relevant IEC standards, the requirements and tests having the same level of severity as the requirements and tests of this document, the following tests may be omitted.

27.2 Resistance to heat

27.2.1 General

All parts of the **transformer** made of insulating material shall be resistant to heat.

The following tests do not apply to parts made of natural or synthetic rubber that shall be tested according to 19.9. Additionally the tests do not apply to parts made of ceramic material.

Compliance is checked by subjecting parts made of insulating materials to a ball-pressure test according to 27.2.2 and 27.2.3 as appropriate by means of the apparatus shown in Figure 14.

The test is not carried out for cables and small connectors with a rated current ≤ 3 A and a rated voltage ≤ 24 V AC or ≤ 60 V DC and a power not exceeding 72 W.

The test shall be performed in a heating cabinet at a temperature specified below.

NOTE Details of the ball pressure test procedure are described in IEC 60695-10-2.

The surface of the part to be tested shall be placed in a horizontal position and a steel ball of $(5 \pm 0,05)$ mm diameter shall be pressed against the surface with a force of $(20 \pm 0,2)$ N.

After 1 h, the ball is removed from the specimen, and the specimen is cooled down, within 10 s, to approximately ambient temperature by immersion in cold water. The diameter of the impression caused by the ball is measured and shall not exceed 2 mm.

Dimensions in millimetres

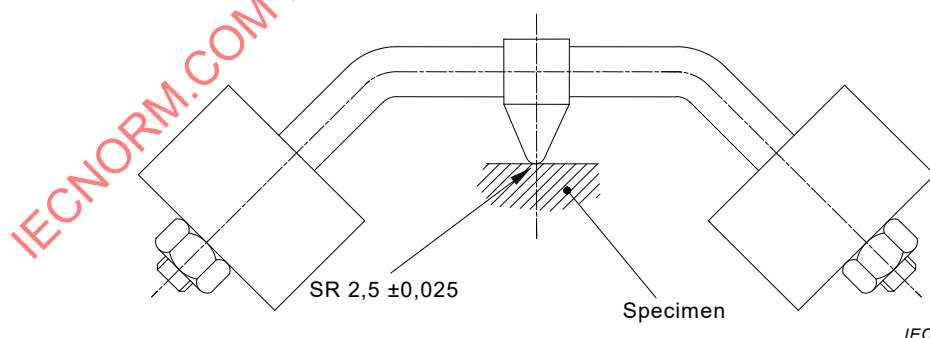


Figure 14 – Ball-pressure apparatus

27.2.2 External accessible parts

External accessible parts of insulating materials shall be resistant to heat.

Compliance is checked by the following test.

The test is carried out at a temperature of (70 ± 2) °C, or at a temperature of $(T + 15 \pm 2)$ °C where T is the temperature of the relevant part during the test of 14.1, whichever is higher.

*The temperature of the relevant part shall be measured at the hottest point, normally, occurring inside the **enclosure**.*

NOTE The constant 15 °C is the safety margin.

27.2.3 Internal parts

Internal parts of insulating material retaining current carrying parts in position shall be resistant to heat.

Compliance is checked by the following test.

The test shall be performed at a temperature of (125 ± 2) °C, or at a temperature of $(T + 15 \pm 2)$ °C where T is the temperature of the relevant part during the test of 14.1, whichever is higher.

NOTE 1 The constant 15 °C is the safety margin.

NOTE 2 The test is not conducted on parts of ceramic material, bobbins, or glass.

27.3 Resistance to abnormal heat under fault conditions

27.3.1 Transformers with protection index IP20 or higher, under fault conditions, shall not act as a source of ignition, and the insulation between the windings shall not result in breakdown; moreover, **hazardous-live-parts** shall not be accessible.

*Compliance is checked by the tests of 27.3.2 and 27.3.3. This test is not required on **fail-safe transformers** as they are covered by 15.5.*

For this test, one or two additional specially prepared specimens is (are) required. A short-circuit in the winding(s) shall either be built in, or made possible by short-circuiting the leads connected to the winding(s) provided by the manufacturer.

If the **transformer** is provided with a thermal protective device in the **input circuit**, the short-circuit shall be introduced in the **output winding** and vice versa.

If the **transformer** is provided with a thermal protective device in both the **input** and **output circuits**, the short-circuit shall be introduced in each winding in two separate specimens.

The short-circuit shall be made in the middle of the winding. In case of more than two windings, the short-circuit shall be introduced in the winding being thermally farthest away from the thermal control.

The percentage of turns to be short-circuited shall be approximately equal to the **short-circuit voltage** expressed as a percentage of the **rated supply voltage**. The specimen with the short-circuit shall then be checked as follows.

*The unloaded **transformer** shall be supplied at 1,1 times the **rated input voltage** at ambient temperature and the input power (W) measured shall be equal to the value of the **rated output** with a tolerance of ± 20 %. During the measurement, no adjustments shall be made.*

27.3.2 Portable transformers shall be placed on a dull black painted plywood support as described in 14.1.1.

Stationary transformers, not designed to be built in, shall be mounted in the most unfavourable position under normal use to a dull black painted plywood support as described in 14.1.1. When the most unfavourable position of use is vertical or on the ceiling, the **stationary transformer** and the support are placed in this position (200 ± 5) mm above a

piece of white pinewood board, approximately 10 mm thick, covered with a single layer of tissue paper.

For this test, the **input circuit** shall be protected by a fuse or circuit-breaker with a rated current 10 times the rated current of the **transformer**, but at least 16 A.

The **transformer**, with its protective devices when applicable, shall be tested as specified above for 15 days but without load. The result shall be a definitive interruption in the circuit. If no definitive interruption occurs after this period, the supply is switched off.

For **transformers** with self-resettable protective devices, all the protective devices are short-circuited.

If the non-self-resettable or replaceable protective device, if any, interrupts the circuit, the supply shall be switched off and the **transformer** shall be left to cool down for 2 h. Then the protective device shall be reset or replaced, and the supply shall be switched on until the device interrupts the circuit or an interruption in the **transformer** occurs. If no interruption in the **transformer** occurs, 30 cycles shall be conducted in the case of resettable protective devices, or 10 cycles in the case of replaceable devices. Each cycle consists of supplying the **transformer** until the protective device interrupts the circuit and the power remains switched off for 2 h.

During the test, no flames shall occur, and the **transformer** shall not act as a source of ignition for the surroundings. The temperature of the support shall not exceed 125 °C. If **stationary transformers** are placed in a vertical position or on the ceiling, burning drops, if any, shall not ignite the tissue paper or scorch the pinewood board.

27.3.3 After the test of 27.3.2 and after cooling down to ambient temperature, the following applies.

- a) **Transformers** where a definitive interruption in the **input circuit** has occurred shall withstand a dielectric strength test, the test voltage being 35 % of the values according to Table 14 of Clause 18.
- b) **Transformers** where no definitive interruption has occurred after the cycling test shall withstand the test voltages according to Table 14 of Clause 18.

Transformers with protection index IP20 and higher shall not allow the standard test finger to touch **hazardous-live-parts** without appreciable force. In case of doubt, contact with **hazardous-live-parts** is shown by means of an electrical contact indicator, the voltage being not less than 40 V. If one specimen does not pass the test, the complete test has failed.

27.4 Resistance to fire

27.4.1 General

All parts of the **transformer** made of insulating material shall be resistant to ignition and spread of fire.

This requirement does not apply to decorative trims, knobs and other parts not likely to be ignited or to propagate flames originating from inside the **transformer**.

Compliance is checked by subjecting parts made of insulating materials to the glow-wire test, specified in IEC 60695-2-10 and amended in Annex E of this document.

The test shall be performed on a complete **transformer**. If this is not possible, a suitable specimen of the part to be tested shall be used.

*If necessary, parts of an **enclosure** can be removed or a suitable specimen can be cut off to perform the test. However, care shall be taken to ensure that the standard test conditions are not significantly different from those occurring in normal use, with regard to shape, ventilation, effects of thermal stresses and of possible flames, burning droplets or glowing particles falling in the vicinity of the specimen.*

Any flame or glowing of the specimen shall extinguish within 30 s of withdrawing the glow-wire. Burning or molten drops, if any, shall not ignite the tissue paper, as specified in IEC 60695-2-10:2013 (ISO 4046-4:2016), spread out horizontally as a single layer (200 ± 5) mm below the specimen.

Only one specimen shall be tested. In case of inconclusive results, the test is repeated on two additional specimens and both shall pass the test.

27.4.2 External accessible parts

External parts of insulating materials shall be resistant to ignition and spread of fire.

*Compliance is checked by subjecting **enclosures** and other external **accessible parts** to the glow-wire test with the temperature of the glow wire as follows:*

- 650 °C for **enclosures**;
- 650 °C for parts retaining current carrying (keeping in position) parts in position and terminals for external conductors which carry a current up to 0,2 A during normal operation;
- 750 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors with fixed connection (e.g., soldering) which carry a current exceeding 0,2 A during normal operation;
- 850 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors with non-fixed connection which carry a current exceeding 0,2 A during normal operation.

No glow wire tests are required for foils in thin sheet form with a thickness of up to 0,2 mm.

27.4.3 Internal parts

Parts of insulating materials retaining (keeping in position) current carrying parts in position shall be resistant to ignition and spread of fire.

Compliance is checked by subjecting the parts of insulating materials to the glow-wire test with the temperature of the glow wire as follows:

- 550 °C for internal insulating material not retaining (not keeping in position) current carrying parts in position;
- 650 °C for coil formers (bobbins);
- 650 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors which carry a current up to 0,2 A during normal operation;
- 750 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors with fixed connection (e.g., soldering) which carry a current exceeding 0,2 A during normal operation;
- 850 °C for parts retaining (keeping in position) current carrying parts in position and terminals for external conductors with non fixed connection which carry a current exceeding 0,2 A during normal operation.

No glow wire tests are required for foils in thin sheet form with a thickness of up to 0,2 mm.

27.5 Resistance to tracking

For **transformers** with an IP rating other than IPX0, insulating parts retaining current carrying parts in position shall have resistance to tracking corresponding to at least material group IIIb if they are exposed to pollution degree 3.

Material group IIIb ($100 \leq \text{CTI} < 175$) is not recommended for application in pollution degree 3 above 630 V

For materials other than ceramics, compliance is checked by the tests of Annex G.

No flashover or breakdown between electrodes shall occur before a total of 50 drops has fallen.

28 Resistance to rusting

Ferrous parts, the rusting of which might cause the **transformer** to become unsafe, shall be adequately protected against rusting.

This requirement applies to the outer surfaces of iron cores, in which case, protection by a coating of varnish is deemed to be adequate.

Compliance is checked by inspection and, in case of doubt, by the following test.

All grease shall be removed from the parts to be tested by immersion in trichloroethane for 10 min. The parts shall then be immersed for 10 min in a 10 % solution of ammonium chloride in water at a temperature of $(20 \pm 5) ^\circ\text{C}$. Without drying, but after shaking off any drops, the parts shall be placed for 10 min in a box containing air saturated with moisture at a temperature of $(20 \pm 5) ^\circ\text{C}$.

After all the parts have been dried for 10 min in a heating cabinet at a temperature of $(100 \pm 5) ^\circ\text{C}$; their surfaces shall show no signs of rust.

NOTE Traces of rust on sharp edges and any yellowish film removable by rubbing are ignored.

Annex A (normative)

Measurement of creepage distances and clearances

The widths X of grooves specified in Figure A.1 to Figure A.8 apply to all examples as a function of the **pollution degree** as follows:

Table A.1 – Width of groove values depending on the pollution degree

Pollution degree	Width X of grooves' minimum values mm
1	0,25
2	1,0
3	1,5

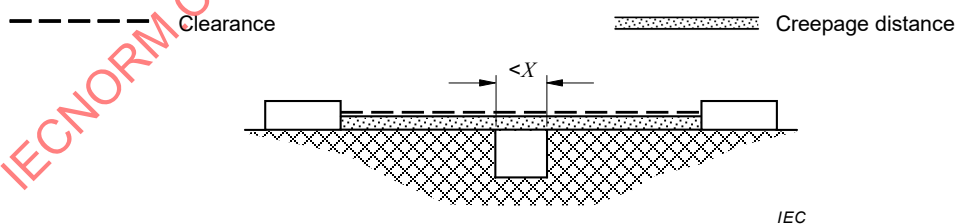
NOTE If the associated **clearance** is less than 3 mm, the minimum groove width can be reduced to one-third of this distance.

The dimension X , specified in the examples A.1 to A.8 has a minimum value depending on the pollution degree according to Table A.1.

The methods of measuring **creepage distances** and **clearances** are indicated in Figure A.1 to Figure A.8. These cases do not differentiate between gaps and grooves or between types of insulation.

The following assumptions are made:

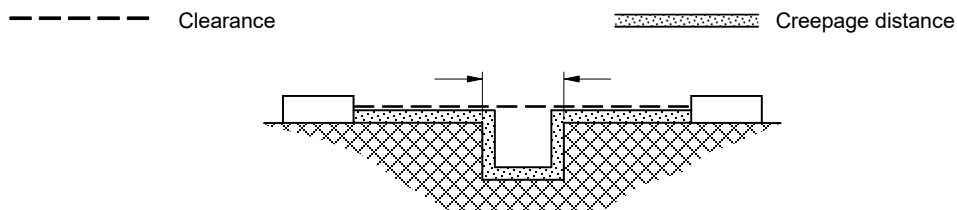
- any recess is assumed to be bridged with an insulating link having a length equal to the specified width X and being placed in the most unfavourable position (see Figure A.3);
- where the distance across a groove is equal to or larger than the specified width X , the **creepage distance** is measured along the contours of the groove (see Figure A.2);
- **creepage distances** and **clearances**, measured between parts which can assume different positions in relation to each other, are measured when these parts are in their most unfavourable position.



Condition: Path under consideration includes a parallel or converging sided groove of any depth with a width of less than X mm.

Rule: **Creepage distance** and **clearance** are measured directly across the groove as shown above.

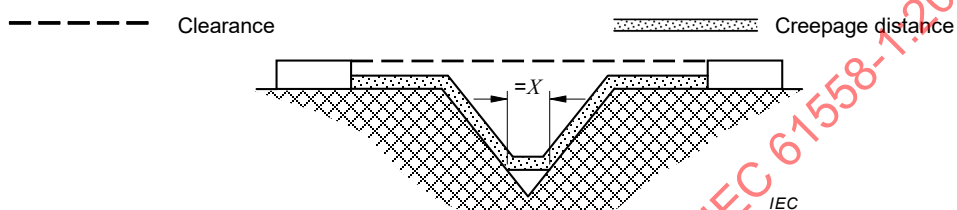
Figure A.1 – Example 1



Condition: Path under consideration includes a parallel sided groove of any depth and equal to or more than X mm wide.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove.

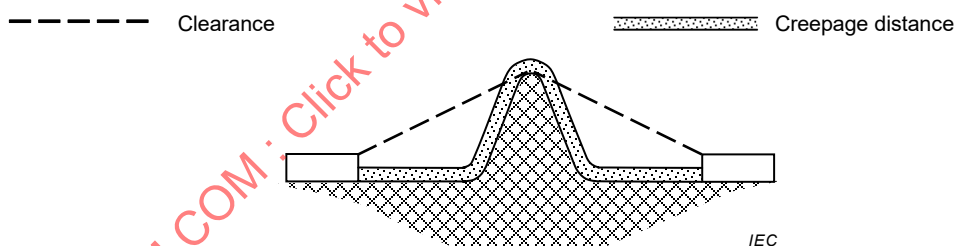
Figure A.2 – Example 2



Condition: Path under consideration includes a V-shaped groove with an internal angle of less than 80° and 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 a length of X mm.

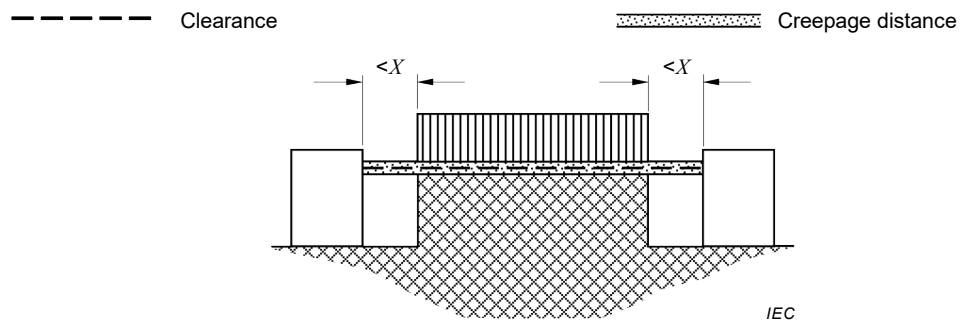
Figure A.3 – Example 3



Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib.

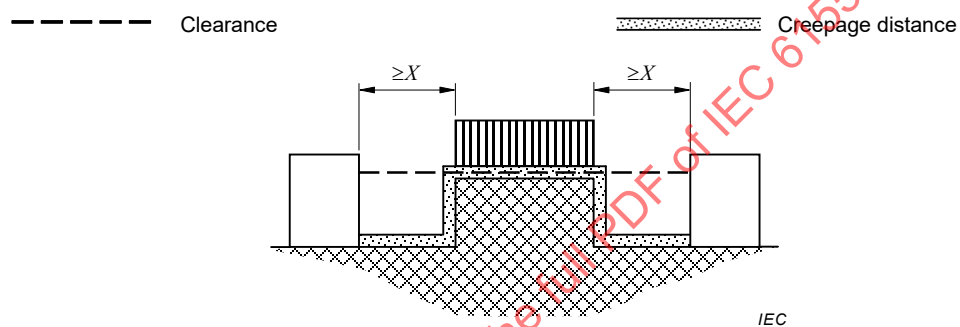
Figure A.4 – Example 4



Condition: Path under consideration includes an uncemented joint with grooves less than X mm wide on either side.

Rule: Creepage distance and clearance path is the "line of sight" distance shown.

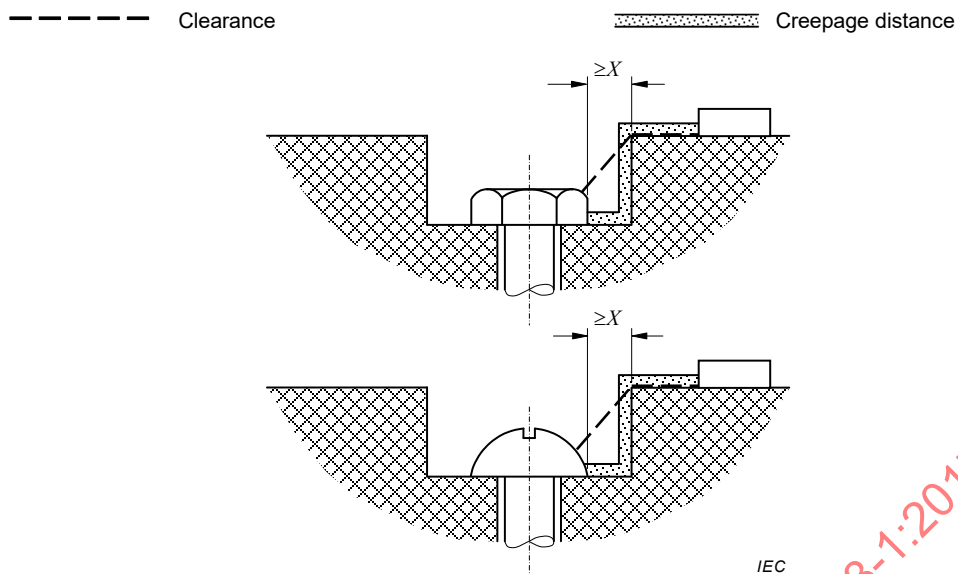
Figure A.5 – Example 5



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm wide on each side.

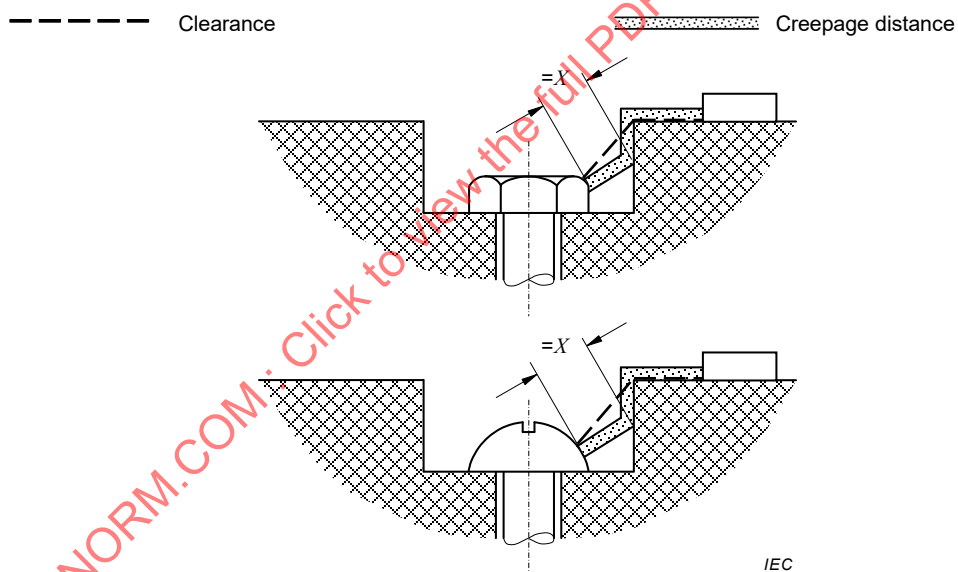
Rule: Clearance path is the "line of sight" distance. Creepage follows the contour of the groove.

Figure A.6 – Example 6



Gap between head of screw and wall of recess wide enough to be taken into account.

Figure A.7 – Example 7



Gap between head of screw and wall of recess too narrow to be taken into account.

Figure A.8 – Example 8

Annex B (normative)

Testing a series of transformers

B.1 General

The requirements of this annex are intended to facilitate the testing of a series of **transformers**.

If a series of **transformers** is to be tested, the number of samples to be tested may be reduced.

Transformers can be considered as a series if:

- a) they are of the same family, this meaning that they are covered by the same part of IEC 61558-2;
- b) they are of the same construction, implying that:
 - 1) they have lamination or core from the same pattern range and made of the same material,
 - 2) the same type of winding technology has been used (for example concentric or two chambers, same insulation system),
 - 3) the same assembling technology has been used (for example open type, enclosed type, encapsulated type, impregnated, potted, etc.),
 - 4) the same type of protection against overload has been used (for example fuses, **thermal cut-out**, etc.),
 - 5) they are of the same frequency range;
- c) they are designed for the same minimum and maximum ambient temperatures.

Variations in the following parameters are permitted, provided that the **transformers** comply in all other respects with the rules detailed above:

- input voltage range;
- output voltage range;
- number of tapping and/or windings;
- supply frequency in the declared frequency range;
- **rated output**.

B.2 Requirements

The number of samples needed in case of testing a series of **transformers** as defined above shall be:

- a) for parameters 1) 2) and 3): two samples minimum and not more than four, chosen in order to be sure that they represent the most unfavourable situation in the family to be tested;

The samples should be chosen according to the following rules:

- one of the lowest rated output, with the highest voltages and the lowest number of tappings;
- one of the highest rated output, with the lowest voltages and the lowest number of tappings;

- one of the lowest rated output, with the highest number of tapplings with the highest voltage difference between adjacent windings;
- one of the medium rated output, with medium voltages and medium number of tapplings;
- one of the highest rated output, with the lowest voltages and the highest number of windings.

When only two samples are chosen the first two alternatives should be used.

- b) for parameter 4): one sample of the lowest supply frequency and, in case of doubt, one sample of the highest supply frequency within the range;

If possible, the sample may be the second sample chosen for parameters 1), 2) and 3).

- c) for parameter 5): two samples minimum, taken from the extremities of the range.

The samples should be chosen according to the following rules:

- one of the lowest rated output, with the highest difference in percentage between the value of the current of the transformer and the value of the current of the relevant protective device, if any;
- one of the highest rated output, with the highest difference in percentage between the value of the current of the transformer and the value of the current of the relevant protective device, if any;
- one sample representing the most unfavourable condition of the temperature of winding and core;
- one sample representing the most unfavourable condition of the temperature rise of the enclosure.

To be sure that in any case the most unfavourable situation is covered, the manufacturer shall declare the type in the series having the maximum losses in normal condition; this type shall be chosen as one of the samples to be tested.

The conditions above may be covered by a minimum of two samples.

The number of specimens for each sample shall be in accordance with 5.2, except for:

- the test of 14.3 where only two samples of three specimens in total are needed for the series, the samples being the two first of parameter 5;
- the test of 15.5 where only two samples of three specimens in total are needed for the series, the samples being the two first of parameter 5;
- the test of 16.4 where only three specimens in total are needed for the series, the heaviest type being chosen.

B.3 Constructional inspection

At least one specimen of each lamination or core size shall be provided for constructional clearances, mechanical strength, etc.

The samples required in B.3 shall include the samples used in B.2.

Annex C

(void)

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Annex D

(void)

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Annex E (normative)

Glow-wire test

E.1 General

The glow-wire test is carried out in accordance with IEC 60695-2-10 and IEC 60695-2-11.

For the purpose of this document, the following applies with reference to the relevant clauses and subclauses of IEC 60695-2-11.

E.2 Severity

The requirements of 8.2, “Test temperatures” of IEC 60695-2-11:2014 apply, except that the temperature of the tip of the glow-wire is that stated in 27.4 of this document.

E.3 Conditioning

The requirements of Clause 7, “Conditioning”, of IEC 60695-2-11:2014 apply, but preconditioning is required.

E.4 Test procedure

The requirements of Clause 8, “Test procedure”, of IEC 60695-2-11:2014 apply with the following addition to 8.1:

“If possible, the tip of the glow-wire is applied to flat surfaces and not to grooves, knock-outs, narrow recesses or sharp edges.”

Annex F (normative)

Requirements for manually operated switches which are parts of transformers assembly

F.1 General

The tests on switches being either integrated or incorporated in the **transformers** are carried out in accordance with IEC 61058-1 as stated in F.2 or F.3.

Manually operated mechanical switches shall comply with the requirements of F.2 or F.3.

F.2 Switches tested as a separate component

The switch, tested as a separate component, shall comply with the requirements and tests of IEC 61058-1:2016, modified as follows:

- 7.9: the switch shall be suitable for use in the relevant **pollution degree** situation;
- 7.11.3: the switch shall be resistant to 850 °C glow wire temperature regarding the resistance to heat and fire.

In addition, the characteristics of the switches as described in IEC 61058-1:2016 shall be appropriate for the function of the switches under normal operating conditions with regard to:

- a) Clause 6: the rating of the switches;
- b) The classification of the switches according to:
 - 7.1: nature of supply;
 - 7.2: type of load to be controlled by the switches;
 - 7.3: ambient air temperature.

If the switch energises or de-energises the socket-outlet(s) in the **secondary circuit**, the rated output current and the rated peak surge current of the socket-outlet(s) of Table F.1 shall be taken into account as specified in F.3.3.

Compliance is checked by inspection and by measurements according to test specifications of IEC 61058-1.

F.3 Switches tested as part of the transformer

F.3.1 The switch, tested as part of the apparatus **transformer** working under normal operating conditions, shall meet the requirements of F.3.2, F.3.3 and F.3.4.

F.3.2 The switch shall withstand without excessive wear or other harmful effects the electrical, thermal and mechanical stresses that occur in normal use, and shall have a mechanism complying with Clause 13 of IEC 61058-1:2016 for switches.

Compliance is checked according to Clause 13 of IEC 61058-1:2016 and by the following endurance test:

The switch is subjected to 10 000 cycles of operation with a sequence according to 17.1.2 of IEC 61058-1-1:2016, except the increased voltage test at accelerated speed specified in 17.5.1 of IEC 61058-1-1:2016, and under electrical and thermal conditions given by the normal operating conditions of the apparatus.

The test is carried out on three specimens, no failure is allowed.

F.3.3 If the switch energises or de-energises the socket-outlet(s) in the **secondary circuit**, the endurance test is carried out with an additional load connected to the socket-outlet(s), consisting of the circuit shown in Figure 8 of IEC 61058-1:2016, taking into account Figure 10 of IEC 61058-1:2016.

The rated current I of the additional load shall correspond to the marking of the socket outlet(s) (see item d) of 8.1). The peak surge current of the additional load shall have a value as shown in Table F.1.

Table F.1 – Peak surge current of additional loads

Rated current I of the socket-outlet(s) A	Peak surge current A
$I \leq 0,5$	20
$0,5 < I \leq 1,0$	50
$1,0 < I$	100

If the socket-outlet(s) is/are marked with the current which may be drawn, this/these value(s) is/are chosen for the rated current I of the socket-outlet(s).

If the socket-outlet(s) is/are marked with the power which may be drawn, the rated current of the socket-outlet(s) is calculated from this/these value(s).

After the test, the switch shall show no damage in the sense of this document. In particular, it shall show no deterioration of its **enclosure**, no reduction of **clearances** and **creepage distances** and no loosening of electrical connections with mechanical fixing.

Compliance is checked by inspection and by the tests specified in F.3.4 and F.3.5, respectively, in the given order.

F.3.4 The switch shall be so constructed that it does not attain excessive temperatures in normal use. The materials used shall be such that the performance of the switch is (are) not adversely affected by the operation in normal use in the conditions given by the apparatus. In particular, the material and design of the contacts and terminals shall be such that the operation and the performance of the switch are not adversely affected by its oxidation or other deterioration.

Compliance is checked in the "ON" position under normal operating conditions and according to 16.4 e) and q) of IEC 61058-1:2016, taking into account the rated current of the socket-outlet(s), if any, including the peak surge current according to Clause F.3.

F.3.5 The switch shall have adequate dielectric strength.

Compliance is checked by the following tests:

The switch shall withstand a dielectric strength test as specified in 18.3, without being previously subjected to the humidity treatment, the test voltage being decreased to 75 % of the corresponding test voltage specified in that subclause, but not less than 500 V RMS (700 V peak).

- *The test voltage is applied in the "ON" position between **hazardous-live-parts** and accessible conductive parts, and, in addition, between the poles in case of a multipole switch.*

- *The test voltage is applied in the "OFF" position across each contact gap. During the test, resistors and capacitors in parallel to a contact gap may be disconnected.*

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Annex G (normative)

Tracking test

G.1 General

The tracking tests on the **transformers** are carried out in accordance with IEC 60112 as follows.

For the purpose of this document, materials are classified into four groups by their comparative tracking index (CTI) values, as follows:

- material group I $600 \leq (\text{CTI})$;
- material group II $400 \leq (\text{CTI}) < 600$;
- material group IIIa $175 \leq (\text{CTI}) < 400$;
- material group IIIb $100 \leq (\text{CTI}) < 175$.

Separation of the material groups is (are) determined by compliance with the comparative tracking index test made in accordance with IEC 60112.

The test is made on three separate specimens or on three pieces cut from the relevant component, care being taken that the electrodes are clean, correctly shaped and correctly positioned before each test is started. In case of doubt, the test is repeated, if necessary, on a new specimen.

For the purpose of this document, the following applies with reference to the clauses and subclauses of IEC 60112.

G.2 Test specimen

The requirements of Clause 5 “Test specimen”, of IEC 60112:2003 apply except the thickness requirement of at least 3 mm.

G.3 Test apparatus

The requirements of Clause 7 “Test apparatus”, with the test solution A as described in 7.3 of IEC 60112:2003 shall be used.

G.4 Procedure

The requirements of Clause 8 “Basic test procedure”, of IEC 60112:2003 applies except that:

- *for the CTI test of Clause 11, the Note 3 and last paragraph of Clause 5 also applies;*
- *Clause 10 does not apply.*

Annex H (normative)

Electronic circuits

H.1 General

For **transformers** including **electronic circuits**, the following requirements apply additionally to Clauses 5, 15, 26.

This annex is not required for associated transformers.

H.2 General notes on tests (addition to Clause 5)

H.2.1 All clauses of this document, as modified in this annex, and in the Parts of IEC 61558-2 for the specific **transformers**, apply to electronic circuits.

H.2.2 The accumulation of stress resulting from successive tests is to be avoided. It may be necessary to replace components or to use additional samples.

The number of additional samples should be kept to a minimum by an evaluation of the relevant circuits.

H.3 Short circuit and overload protection (addition to Clause 15)

H.3.1 Electronic circuits shall be so designed and applied that a fault condition will not render the **transformer** unsafe with regard to electric shock, fire hazard or dangerous malfunction.

Compliance is checked by evaluation of the fault conditions specified in H.3.3 for all circuits or parts of circuits, unless they comply with the conditions specified in H.3.2.

*If the safety of the **transformer** under any of the fault conditions depends on the operation of a fuse-link, the test of H.3.4 is made.*

*During and after each test, the temperatures shall not exceed the values specified in Table 5 and the **transformer** shall comply with the conditions specified in 15.1.*

If a conductor of a printed circuit board becomes open-circuited, the **transformer** is considered to have withstood the particular test, provided that all six of the following conditions are met:

- the printed circuit board complies with the requirements of FV1;
- the interrupted conductors have not peeled by more than 2 mm on each side;
- the interruption is in a low-power circuit as described in H.3.2, and in addition the voltage over the interruption shall not exceed 50 V;
- the **transformer** complies with the requirements of this subclause with the interrupted conductors bridged;
- no other conductor has been loosened over a length of more than 5 mm;
- any peeled or loosened conductor does not reduce the **creepage distances** and **clearances** between **hazardous-live-parts** and **accessible parts** below the values specified in Clause 26.

Unless it is necessary to replace components after any of the tests, the dielectric strength test of 18.3 need only be carried out after the final test on the **electronic circuit**.

In general, examination of the **transformer** and its circuit diagram will reveal the fault conditions which have to be simulated, so that testing can be limited to those cases which may be expected to give the most unfavourable result.

H.3.2 Fault conditions a) to f) specified in H.3.3 are not applied to circuits or parts of circuits where both of the following conditions are met:

- the **electronic circuit** is a low-power circuit as described below;
- the protection against electric shock, fire hazard, mechanical hazards or dangerous malfunction in other parts of the **transformer** does not rely on the correct functioning of the **electronic circuit**.

A low-power circuit is determined as follows (an example is given in Figure H.1):

*The **transformer** is operated at rated voltage and a variable resistor, adjusted to its maximum resistance, is connected between the point to be investigated and the opposite pole of the supply source to the electronic circuit.*

The resistance is then decreased until the power consumed by the resistor reaches a maximum. Any point nearest to the supply at which the maximum power delivered to this resistor does not exceed 15 W at the end of 5 s is called a low-power point. The part of the circuit which is further from the supply source than a low-power point is considered to be a low-power circuit.

The measurements are made from only one pole of the supply source to the electronic circuit, preferably the one that gives the fewest low power points.

When determining the low power points, it is recommended to start with points close to the supply source.

NOTE The power consumed by the variable resistor is measured by a wattmeter.

H.3.3 The following fault conditions are considered and, if necessary, applied one at a time. Consequential faults are taken into consideration.

- a) Short circuit of **creepage distances** and **clearances** between **live parts** of different polarity, if these distances are less than those specified in Clause 26.
- b) Open circuit at the terminals of any component.
- c) Short circuit of capacitors, unless they comply with IEC 60384-14.
- d) Short circuit of any two terminals of an electronic component, other than integrated circuits. This fault condition is not applied between the two circuits of an optocoupler.
- e) Open circuit or short circuit inside an integrated circuit. In that case, the possible hazardous situations of the **transformer** are assessed to ensure that safety does not rely on the correct functioning of such a component.

All possible output signals of the integrated circuit are considered in the result. If it can be shown that a particular output signal is unlikely to occur, then the relevant fault is not considered.

Microprocessors are tested as integrated circuits.

Semiconductor components such as thyristors and triacs are subjected to fault conditions b) and d).

- f) In addition, each low-power circuit is short-circuited by connecting the low power point to the pole of the supply from which the measurements were taken.

For simulation of the fault conditions, the **transformer** is operated at any supply voltage between 0,9 times and 1,1 times the **rated supply voltage**.

Where any of the fault conditions are simulated, the test is continued until steady-state conditions are established.

In each case, the test is ended if interruption of the supply occurs within the **transformer**.

If the **transformer** incorporates an electronic circuit which operates to ensure compliance with Clause 15, the relevant test is repeated with a single fault simulated, as indicated in a) to e) above.

Fault condition e) is applied to encapsulated and similar components if the circuit cannot be assessed by other methods.

Positive temperature coefficient resistors (PTCs) and negative temperature coefficient resistors (NTCs) are not short-circuited if they are used within their manufacturer's declared specification.

H.3.4 If, for any of the fault conditions specified in H.3.3, the safety of the **transformer** depends on the operation of a fuse-link, the test is repeated but with the fuse-link replaced by an ammeter.

In case of doubt, the maximum resistance of the fuse-link has to be taken into account when determining the current.

For miniature fuse-links complying with IEC 60127-3 the following applies.

If the current measured does not exceed 2,1 times the rated current of the fuse-link, the circuit is not considered to be adequately protected, and the test is carried out with the fuse-link short-circuited.

If the current is at least 2,75 times the rated current of the fuse-link, the circuit is considered to be adequately protected.

If the current measured exceeds 2,1 times the rated current of the fuse-link, but less than 2,75 times the rated current, the fuse-link is short-circuited and the test is carried out:

- for quick acting fuse-links for the relevant period, or for 30 min, whichever is the shorter;
- for time lag fuse-links, for the relevant period, or for 2 min, whichever is the shorter.

The verification whether the fuse-link acts as a protective device is based on the fusing characteristics specified in IEC 60127-3, which also gives the information necessary to calculate the maximum resistance of the fuse-link.

For fuses other than those complying with IEC 60127-3, the test is carried out as specified in 15.3.2 to 15.3.5.

H.4 Creepage distances, clearances and distances through insulation (addition to Clause 26)

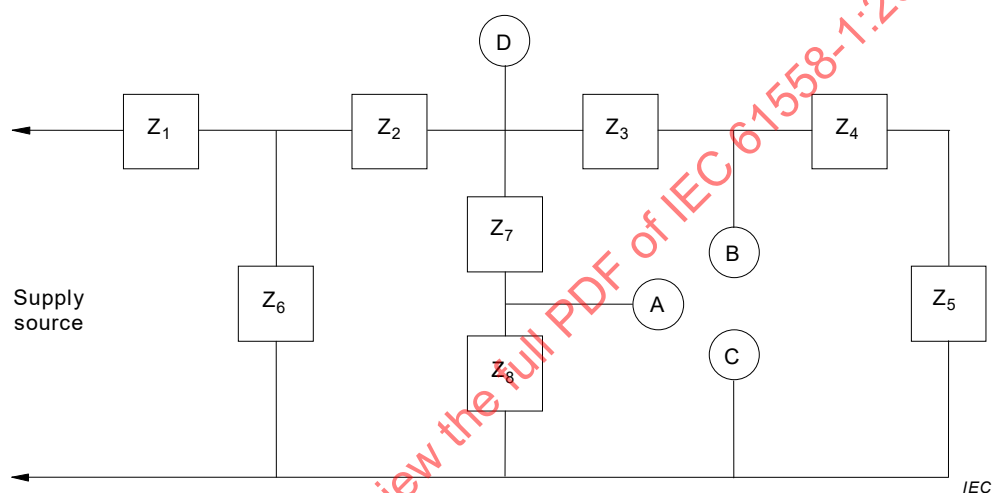
H.4.1 For live parts of different polarity separated by **basic insulation** only, **creepage distances** and **clearances** smaller than those specified in Clause 26 are allowed, provided the requirements of Clause H.3 are met if these **creepage distances** and **clearances** are short-circuited in turn.

Creepage distances and **clearances** within optocouplers are not measured if the individual insulation is adequately sealed, and if air is excluded between individual layers of the material.

If coatings are used on printed circuit boards to protect the micro-environment or to provide **basic insulation**, Annex W applies. Smaller distances as required in Clause 4 of IEC 60664-3:2016, are applicable (Type 1 protection: P1 value; Type 2 protection distances to insulation).

For cycling tests for potted **transformers** see 26.2.

H.4.2 For optocouplers, the conditioning procedure is carried out at a temperature of 50 K in excess of the maximum temperature measured on the surface of the optocoupler during the tests of Clause 14 or Clause 15, the optocoupler being operated under the most unfavourable conditions which occur during these tests.



D is a point furthest from the supply source where the maximum power delivered to external load exceeds 15 W.

A and B are points closest to the supply source where the maximum power delivered to external load does not exceed 15 W. These are low-power points.

Points A and B are separately short-circuited to C.

The fault conditions a) to e) specified in H.3.3 are applied individually to Z_1 , Z_2 , Z_3 , Z_6 , and Z_7 .

Figure H.1 – Example of an electronic circuit with low-power points

Annex I (informative)

Dimensions for rectangular cross-section connectors of transformers, basic dimensions and coordination

If the dimension A in the Table I.1 is not higher than 400 mm, the size of the rectangular cut surface cross-section shall be at least 50 % of the cross-section value for the winding wire or foil.

When the size A in the Table I.1 is higher than 400 mm, the dimension parameters shall be according to DIN 43671 for copper rectangular cross-section connectors, DIN 43670 for aluminium rectangular cross-section connectors and DIN 43670 part 2 for copper cladding aluminium cross-section connectors or at least equal to the cross-section value for the winding wire or foil.

The current-density of the rectangular cross-section connector shall not exceed 4,0 A/mm². The dimensions and mounting holes of the attachment surface shall conform with the values stated in Table I.1.

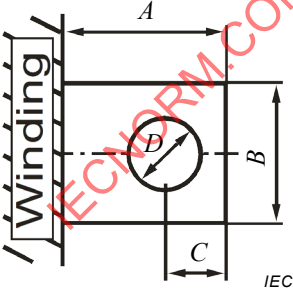
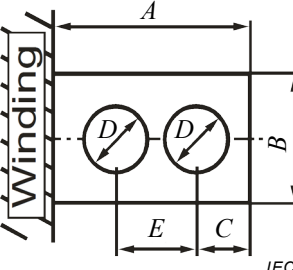
For higher current values or by constructional reasons, rectangular cross-section connectors can be used in parallel connection if the same value of the cross-section dimension is met.

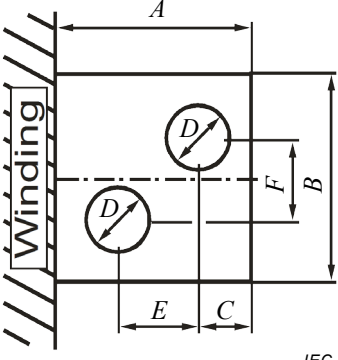
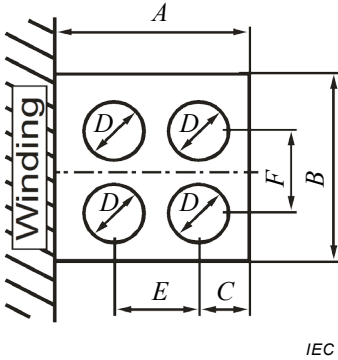
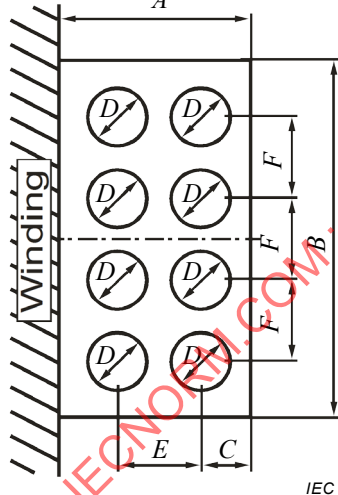
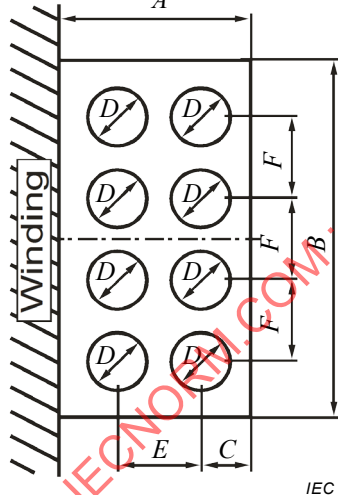
NOTE These values can be reduced when the rectangular cross-section connectors are cooled by additional methods and the attachment is ensured. Methods are for example liquid cooling.

The rectangular cross-section connectors shall have sufficient mechanical strength to avoid contortion or breaking away caused, for example, by high short-circuit currents and the connection with a bunched conductor.

Table I.1 is only necessary to ensure the connection with busbars.

Table I.1 – Dimensions of rectangular copper connectors

Dimensions	Current A	A mm	B mm	C mm	D mm	E mm	F mm	Mounting Screws
	≤ 145	15	12	6	5,5	/	/	M5
	≤ 215	18	15	7,5	6,6			M6
	≤ 365	23	20	10	9			M8
	≤ 430	28	25	12,5	11			M10
	≤ 760	35	30	15	11			M10
	≤ 950	45	40	20	13,5			M12
	≤ 1 130	85	50	20	13,5	40	/	M12

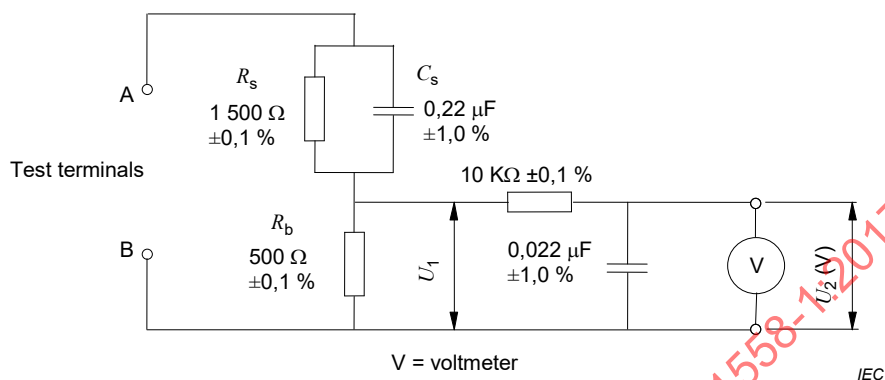
Dimensions	Current [A]	A [mm]	B [mm]	C [mm]	D [mm]	E [mm]	F [mm]	Mounting Screws
	≤ 1 305	65	60	17	13,5	26	26	M12
	≤ 1 645	85	80	20	13,5	40	40	M12
	≤ 1 975	85	100	20	13,5	40	50	M12
	≤ 2 305	85	120	20	13,5	40	60	M12
	≤ 2 940	85	160	20	13,5	40	40	M12
	≤ 3 565	85	200	20	13,5	40	50	M12

NOTE 1 For aluminium rectangular cross-section connectors, the value for the current can be reduced to 78 % of the specified value.

NOTE 2 For copper cladding aluminium rectangular cross-section connectors the value for the current can be reduced to 83 % of the specified value.

Annex J (normative)

Measuring network for touch-currents



Source: Figure 4 of IEC 60990:2016.

True RMS reading

Input capacitance:

≤ 200 pF

Uncertainty: $\leq 2 \%$

Supply frequency range:

15 Hz to 1 MHz

Input resistance: 0,1 M Ω

Figure J.1 – Measuring network for touch-current

Annex K (normative)

Insulated winding wires

K.1 General

This annex specifies the winding wires of the insulation that may be used to provide basic insulation, supplementary insulation, double insulation or reinforced insulation in wound components. For details of the construction, see 19.12.3.

This annex applies to solid circular winding wires and stranded winding wires having diameters between 0,05 mm and 5,0 mm and solid square and solid rectangular (flatwise bending) winding wires with equivalent cross-sectional areas (0,002 mm² to 19,6 mm²).

If the wire is insulated with two or more spirally wrapped layers of tape, the overlap of layers shall be adequate to ensure continued overlap during manufacture of the wound component. The layers of spirally wrapped wire insulation shall be sufficiently secured to maintain the amount of overlap.

K.2 Type tests

K.2.1 General

The winding wire shall pass the following type tests, carried out at a temperature between 15 °C and 35 °C and a relative humidity between 25 % and 75 %, unless otherwise specified.

K.2.2 Dielectric strength test

K.2.2.1 Solid circular winding wires and stranded winding wires

The test sample is prepared according to 4.4.1 of IEC 60851-5:2008 (twisted pair). The sample is then subjected to the dielectric strength test of 18.3 in this document with a test voltage standard, with a minimum of:

- 6 kV RMS for reinforced insulation, or
- 3 kV RMS for basic insulation or supplementary insulation.

K.2.2.2 Square or rectangular wires

The test sample is prepared according to 4.7.1 of IEC 60851-5:2008 (single conductor surrounded by metal shots). The sample is then subjected to the dielectric strength test of 18.3, with a minimum test voltage of:

- 5,5 kV RMS for reinforced insulation, or
- 2,75 kV RMS for basic insulation or supplementary insulation.

K.2.3 Flexibility and adherence

The mandrel winding test 5.1 (in Test 8) of IEC 60851-3:2009 shall be used, with the mandrel diameters of Table K.1. The test voltage is applied between the wire and the mandrel.

The test sample is then examined in accordance with 5.1.1.4 of IEC 60851-3:2009, followed by the dielectric strength test of 18.3, with minimum test voltage of:

- 5,5 kV RMS for reinforced insulation, or
- 2,75 kV RMS for basic insulation or supplementary insulation.

The test voltage is applied between the wire and the mandrel.

Table K.1 – Mandrel diameter

Nominal conductor diameter or thickness ^a mm	Mandrel diameter mm
< 0,35	4,0 ± 0,2
< 0,50	6,0 ± 0,2
< 0,75	8,0 ± 0,2
< 2,50	10,0 ± 0,2
< 5,00	4 times the conductor diameter or thickness ^b
^a Up to but excluding this value.	
^b In accordance with IEC 60317-43.	

The tension to be applied to the wire during winding on the mandrel is calculated from the wire diameter to be equivalent to 118 MPa, with a relative tolerance of ±10 %, (118 N/mm², with a relative tolerance of ±10 %).

Edgewise bending on the smaller dimension side (width) is not required for rectangular wire. For mandrel winding test of the square and rectangular wire, two adjacent turns do not need to contact each other.

K.2.4 Heat shock

The test sample shall be prepared in accordance with 3.2.1 (in Test 9) of IEC 60851-6:2012, followed by the dielectric strength test of 18.3, with a minimum test voltage of:

- 5,5 kV RMS or for reinforced insulation, or
- 2,75 kV RMS for basic insulation or supplementary insulation.

The test voltage is applied between the wire and the mandrel. The oven temperature is the relevant temperature of the thermal class of insulation in Table K.2. The mandrel diameter and tension applied to the wire during winding on the mandrel are as in Table K.1. The test voltage is applied between the wire and the mandrel.

The dielectric strength test is conducted at room temperature after removal from the oven.

Table K.2 – Oven temperature

Thermal class	Class 105 (A)	Class 120 (E)	Class 130 (B)	Class 155 (F)	Class 180 (H)
Oven temperature °C	200	215	225	250	275

Edgewise bending on the smaller dimension side (width) is not required for rectangular wire.

NOTE 3.2.2 in Test 9 of IEC 60851-6:2012 is not used for solid square and solid rectangular winding wires.

K.2.5 Retention of dielectric strength after bending

Five samples are prepared as in K.2.3 and tested as follows. Each sample is removed from the mandrel, placed in a container and positioned so that it can be surrounded by at least 5 mm of metal shot. The ends of the conductor in the sample shall be sufficiently long to avoid flash over. The shot shall be not more than 2 mm in diameter and shall consist of balls of

stainless steel, nickel or nickel plated iron. The shot is gently poured into the container until the sample under test is covered by at least 5 mm of shot. The shot shall be cleaned periodically with a suitable solvent.

NOTE The above test procedure is reproduced from 4.6.1 c) of IEC 60851-5:1988 but is not included in the fourth edition (2008) of that standard.

The samples shall be subjected to the dielectric strength test of 18.3, with a minimum test voltage of:

- *5,5 kV RMS for reinforced insulation, or*
- *2,75 kV RMS for basic insulation or supplementary insulation.*

The mandrel diameter and tension applied to the wire during winding on the mandrel are as in Clause K.2.3.

K.3 Testing during manufacturing

K.3.1 General

The wire shall be subjected by the wire manufacturer to dielectric strength tests during manufacture as specified in K.3.2 and K.3.3.

K.3.2 Routine test

The test voltage for routine test shall be in accordance with the dielectric strength test of 18.3, with a minimum of:

- *4,2 kV RMS for reinforced insulation, or*
- *2,1 kV RMS for basic insulation or supplementary insulation.*

K.3.3 Sampling test

K.3.3.1 Solid circular winding wires and stranded winding wires

Twisted pair samples shall be tested in accordance with 4.4.1 of IEC 60851-5:2008. The test voltage shall be in accordance with the dielectric strength test of 18.3, with a minimum of:

- *6 kV RMS for reinforced insulation, or*
- *3 kV RMS for basic insulation or supplementary insulation.*

K.3.3.2 Square or rectangular wire

The test sample is prepared according to 4.7.1 of IEC 60851-5:2008. The sample is then subjected to the dielectric strength test of 18.3. The test voltage shall be in accordance with the dielectric strength test of 18.3, with a minimum of:

- *5,5 kV RMS for reinforced insulation, or*
- *3 kV RMS for basic insulation or supplementary insulation.*

Annex L (normative)

Routine tests (production tests)

L.1 General

The tests specified in this annex are intended to reveal, as far as safety is concerned, unacceptable variations in material or manufacture. These tests are intended not to impair the properties and the reliability of the **transformer**, and shall be made by the manufacturer on each **transformer** after production. The inspection is to check that the following is ascertained on 100 % of the products by the manufacturer production system.

These tests should be carried out at the temperature of the production line.

Further tests may have to be made to ensure that every **transformer** is conform with the specimens that withstood the tests of this document, depending on the experience gained by the manufacturer.

The routine tests shall in principle be carried out at the end of the production. However they may be carried out at an earlier stage if it can be shown that the procedure provides the same degree of safety.

L.2 Protective earthing continuity test

For **class I transformers**, a current of at least 10 A, derived from a source with a no-load voltage not exceeding 12 V, is passed in turn between the protective earthing terminal and each of accessible conductive parts which have to be earthed for safety reasons.

During this test, no interruption of the connections or substantial decrease of the current shall occur between the protective earthing terminal and the relevant accessible metal part conductive parts.

L.3 Checking of no-load output voltage

The **no-load output voltage** shall comply with the declared value and tolerance stated by the manufacturer and shall in addition not exceed the maximum **no-load output voltage** required by the relevant part of IEC 61558-2.

L.4 Dielectric strength test

The test is made in accordance with Table 14 at ambient temperature and without the humidity treatment of 17.2.

The specified test voltage is applied for 1 s.

The tests are made between:

- a) **live parts** of the **input circuits** and accessible conductive parts of the **transformer**;
- b) **input circuits** and **output circuits**.

No flashover or breakdown shall occur during the test.

Additional tests may be required for high insulation level **transformers** and **separating transformers** with **working voltage** above 1 000 V.

L.5 Checking of protective devices mounting

The operation of a protection device, if any, shall not be prevented by incorrect mounting of the device in the **transformer**.

Compliance is checked by inspection.

L.6 Visual inspection

Visual inspection shall ensure that all required and relevant markings are provided.

L.7 Repetition test after routine dielectric strength test

Any repetitions test for the dielectric strength test shall be 80 % according to Table 14 of the required test voltage value.

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Examples to be used as a guide for 19.1

The examples of Figure M.1, Figure M.2, Figure M.3, Figure M.4 and Figure M.5 can be used as a guide for 19.1.

R*	One piece of specified thickness or at least three layers of tape.	CR	creepage distance
R**	One piece of specified thickness plus an adhesive tape or an insulation insert or at least three layers of tape plus, for example, an adhesive tape or at least four layers of serrated tape	CL	clearance
		B	basic insulation
1	A tube of a specified thickness for supplementary insulation or at least three layers of tape (see Clause 26).	S	supplementary insulation
2	Formed part of thickness as specified for supplementary insulation in Clause 26	R	reinforced insulation or double insulation
3	Last turn of winding prevented from being displaced. For example, adhesive bonding tape or a bonding agent.	I	input or first winding
		O	output or second winding

M.2.1 Concentric type

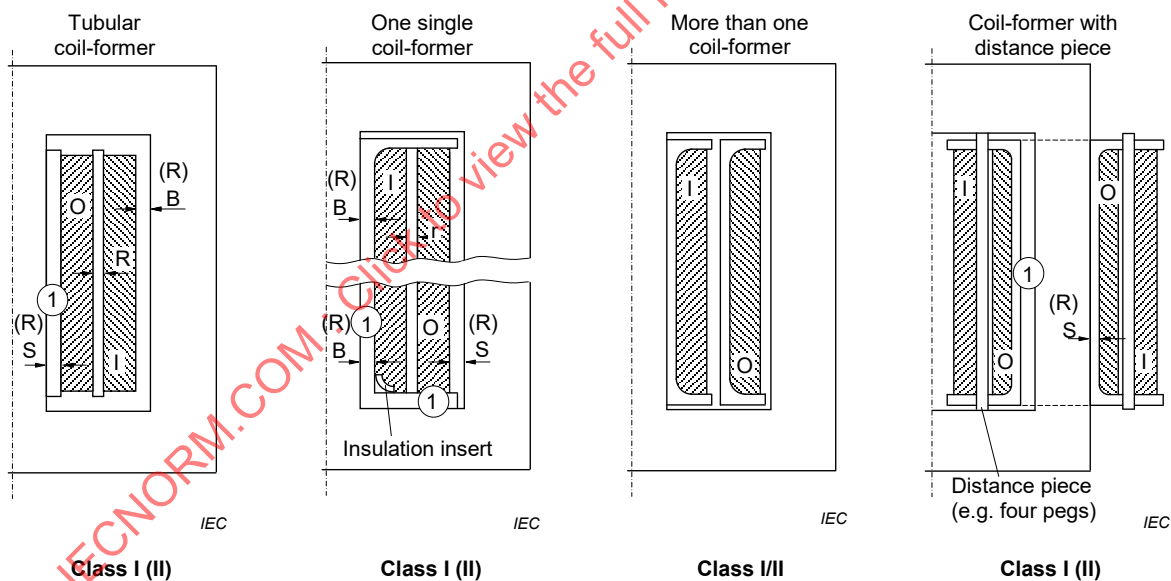


Figure M.1 – Examples for concentric type constructions

M.2.2 Side-by-side type

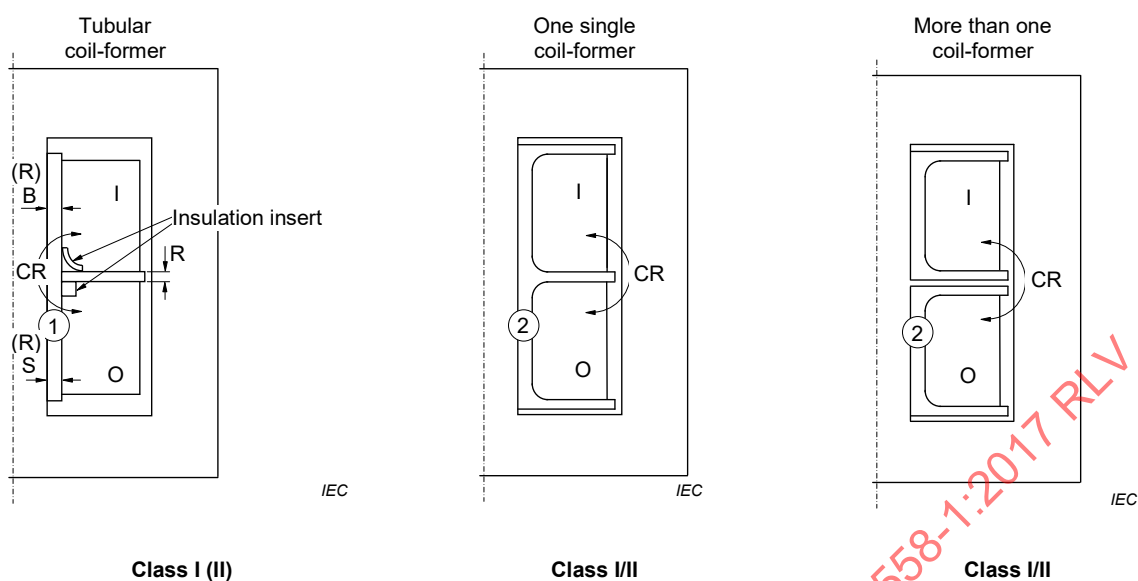


Figure M.2 – Examples for side-by-side type constructions

M.3 Windings

M.3.1 Without screen

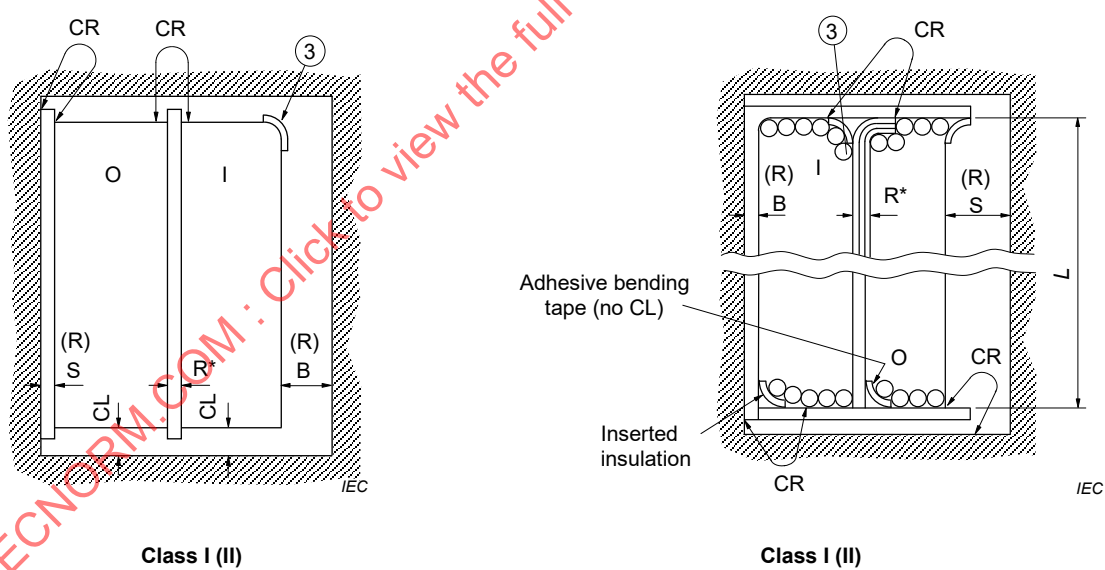
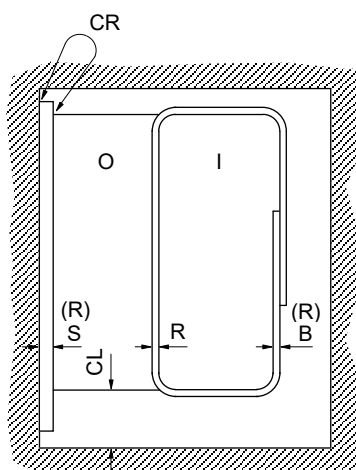


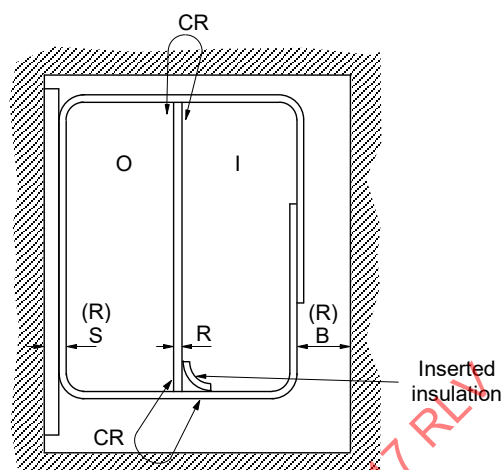
Figure M.3 – Examples for winding constructions without screen



Input or output winding wrapped with insulating material

IEC

Class I (II)



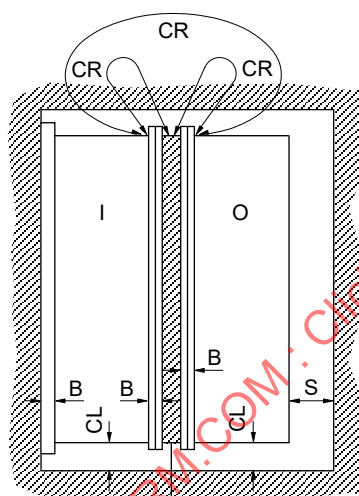
Input and output winding wrapped with insulating material (no CR)

IEC

Class I (II)

Figure M.4 – Examples for wrapped winding constructions

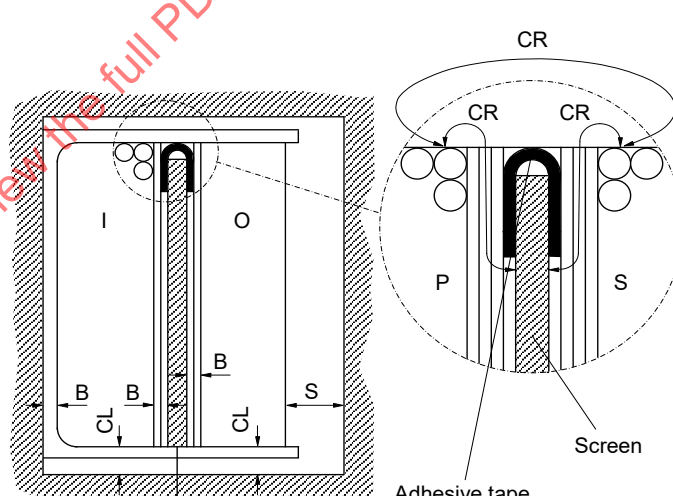
M.3.2 With screen



Earthing

IEC

Class I



Earthing

IEC

Class I

Figure M.5 – Examples for winding constructions with screen

NOTE For class II constructions the abbreviations are given in brackets.

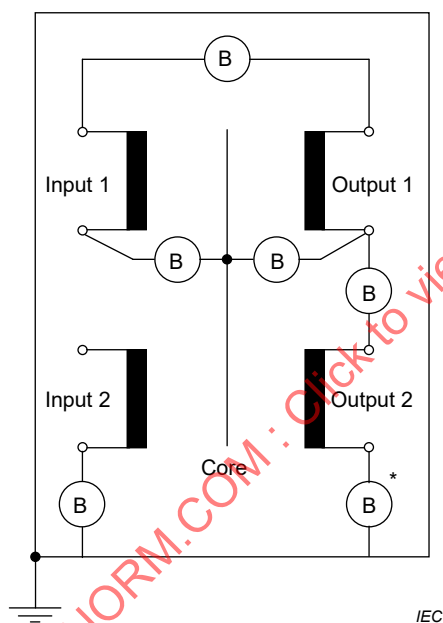
Annex N (informative)

Examples for checking points of dielectric strength test voltages

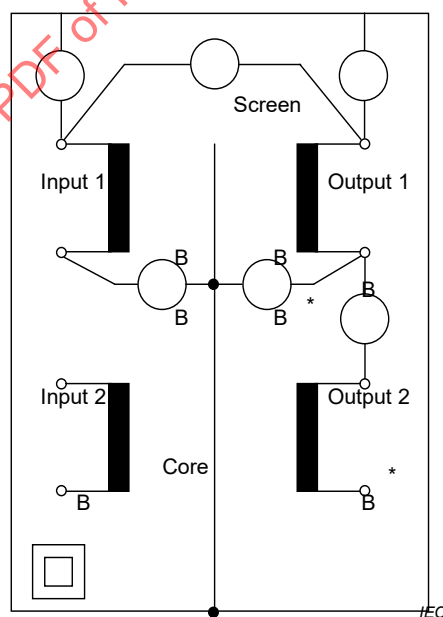
Figure N.1, Figure N.2 and Figure N.3 are specified for a separating transformer according to IEC 61558-2-1.

Explanation of test voltage value requirements for different types of insulation using the example of a separating transformer (see 19.1.3):

- (F) functional insulation (e.g. for polyfilar windings according to Table 20, Table 21 and Table 22)
- (B) basic insulation
- (B)* basic insulation (for the level of the applied voltage to the output winding)
- (S) supplementary insulation
- (D) double or reinforced insulation



a) Transformer of class I construction



b) Transformer of class I construction
with earthed metal screen

Figure N.1 – Transformer of class I construction with metal enclosure

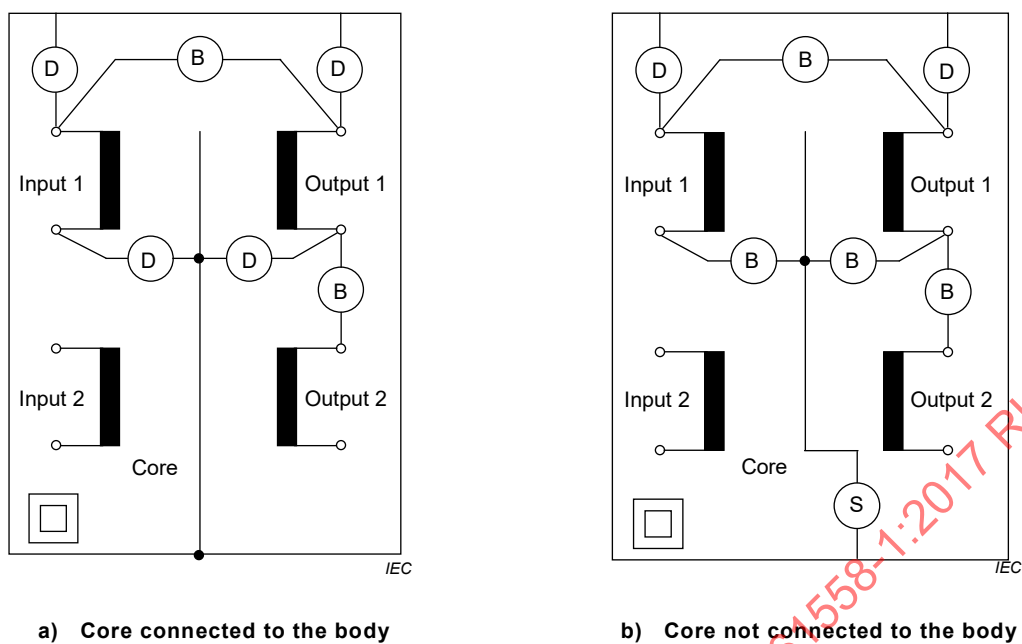


Figure N.2 – Transformer of class II construction with metal enclosure

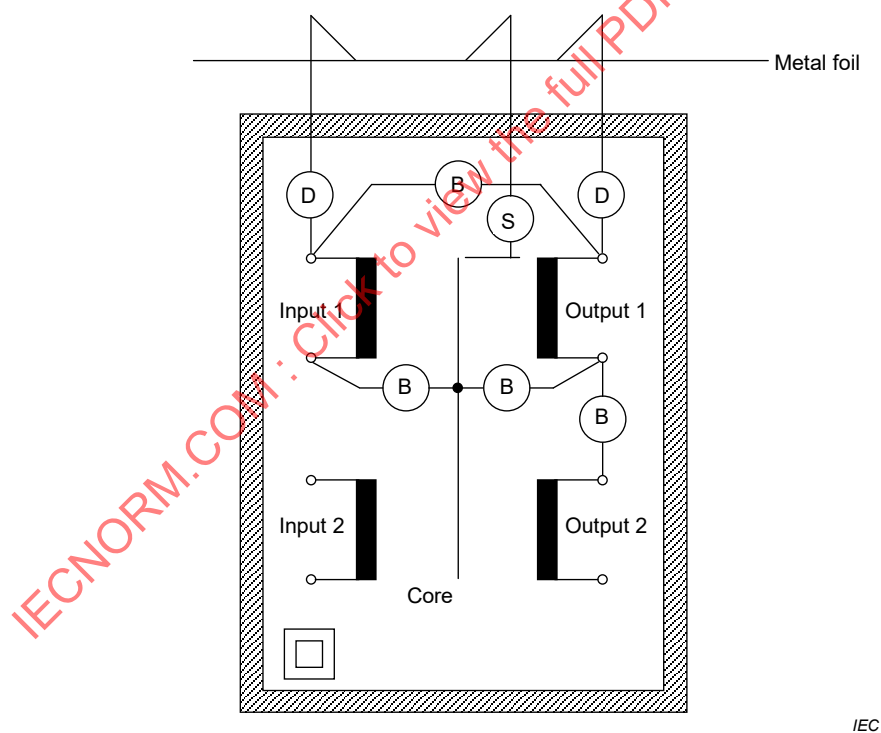


Figure N.3 – Transformer of class II construction with enclosure of insulating material

Annex O

(void)

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Annex P (informative)

Examples for measurement points of creepage distances and clearances

Figure P.1, Figure P.2, Figure P.3 and Figure P.4 are specified for a separating transformer according to IEC 61558-2-1.

Explanation using the example of an separating transformer where each insulation is required (see 19.1.3):

- (F) functional insulation (e.g. for polyfilar windings according to Table 20, Table 21 and Table 22)
- (B) basic insulation
- (B)* basic insulation (for the level of the applied voltage to the output winding)
- (S) supplementary insulation
- (D) double or reinforced insulation
- (C) between terminals for the connections (see Table 23)

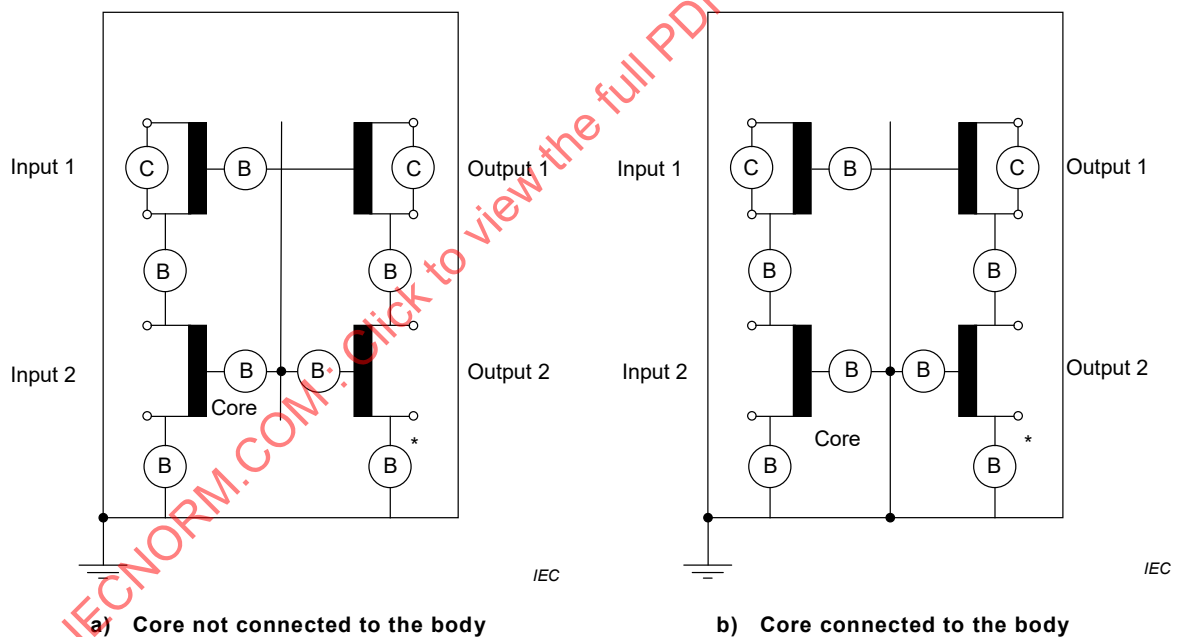


Figure P.1 – Transformer of class I construction

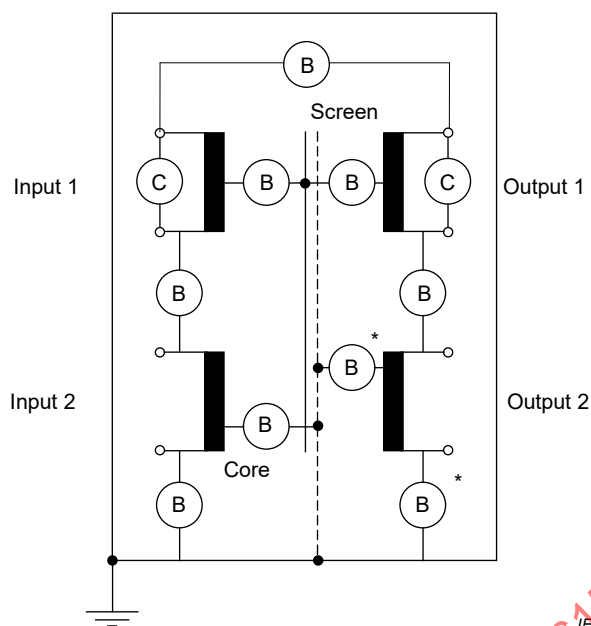


Figure P.2 – Transformer of class I construction with earthed metal screen

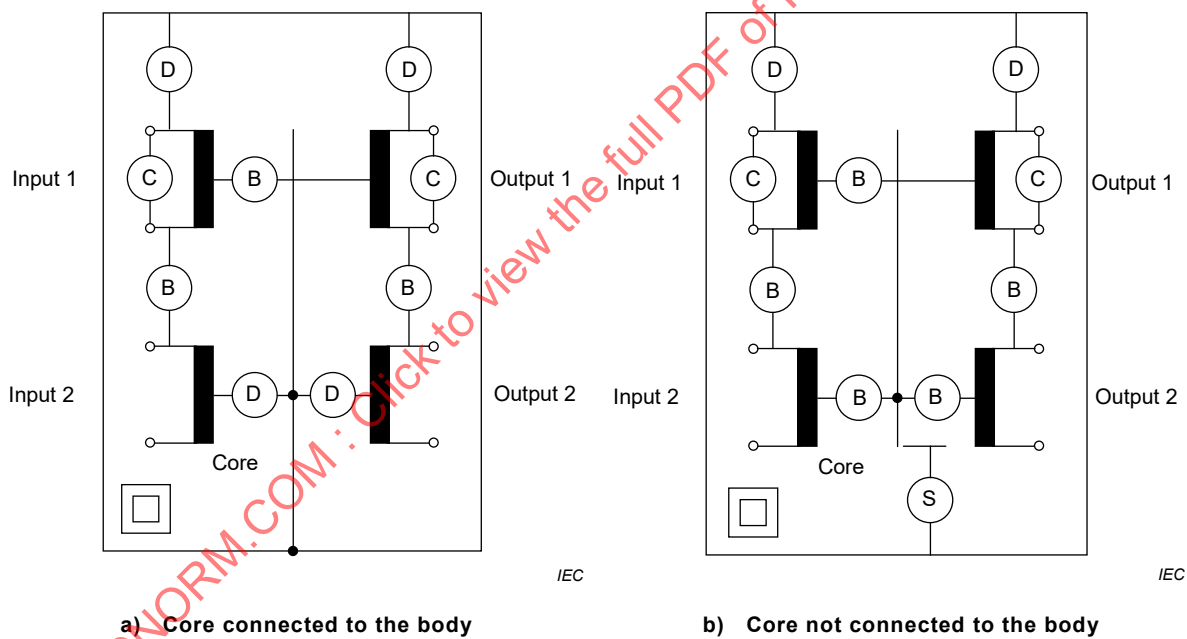


Figure P.3 – Transformer of class II construction with metal enclosure

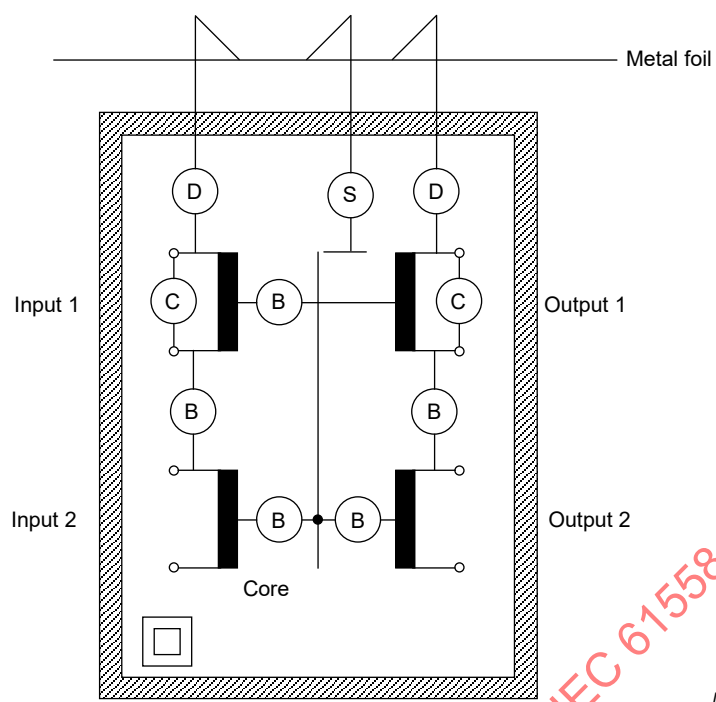


Figure P.4 – Transformer of class II construction with enclosure of insulating material

Annex Q (informative)

Explanation of IP numbers for degrees of protection

Q.1 General

For full details see IEC 60529 from which the following is an extract.

The designation indicating the degrees of protection consists of the characteristic letters IP followed by two numerals (the "characteristic numerals") indicating conformity with the conditions stated in Table Q.1, Table Q.2 and Table Q.3 respectively. The first numeral indicates the degree of protection described under item Q.2 a) and b) and the second numeral the degree of protection described under item Q.3.

An additional letter (optional) may be used to indicate the degree of protection against the access to hazardous parts more detailed (see IEC 60529:1989, Clause 7).

A supplementary letter (optional) may be used for supplementary information (see IEC 60529:1989, Clause 8).

Q.2 Degrees of protection against access to hazardous parts and against solid foreign objects

The type of protection covered by this system of classification is as follows:

- a) protection of persons against contacts with, or approach to, **live parts** and against contact with moving parts (other than smooth rotating shafts and the like) inside the **enclosure**;
- b) protection of the equipment against ingress of solid foreign objects.

Table Q.1 – Degrees of protection against access to hazardous parts indicated by the first characteristic numeral

First characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non-protected	-
1	Protected against access to hazardous parts with the back of a hand	The access probe, sphere of 50 mm Ø, shall have adequate clearance from hazardous parts.
2	Protected against access to hazardous parts with a finger	The jointed test finger of 12 mm Ø, 80 mm length, shall have adequate clearance from hazardous parts
3	Protected against access to hazardous parts with a tool	The access probe of 2,5 mm Ø shall not penetrate.
4	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm Ø shall not penetrate.
5	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm Ø shall not penetrate.
6	Protected against access to hazardous parts with a wire	The access probe of 1,0 mm Ø shall not penetrate.
Due to the simultaneous requirement specified in Table Q.2, the definition "shall not penetrate" is given in Table Q.2		
NOTE In case of the first characteristic numerals 3,4,5 and 6, protection against access to hazardous-live-parts is satisfied if adequate clearance is kept.		

Table Q.2 – Degrees of protection against solid foreign objects indicated by the first characteristic numeral

First characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non-protected	-
1	Protected against solid foreign objects of 50 mm Ø and greater	The object probe, sphere of 50 mm Ø, shall not fully penetrate ¹⁾
2	Protected against solid foreign objects of 12,5 mm Ø and greater	The object probe, sphere of 12,5 mm Ø, shall not fully penetrate ¹⁾
3	Protected against solid foreign objects of 2,5 mm Ø and greater	The object probe of 2,5 mm Ø, shall not penetrate at all. ¹⁾
4	Protected against solid foreign objects of 1,0 mm Ø and greater	The object probe of 1,0 mm Ø, shall not penetrate at all. ¹⁾
5	Dust-protected	Ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the apparatus or to impair safety
6	Dust-tight	No ingress of dust
¹⁾ The full diameter of the object probe shall not pass through an opening of the enclosure.		

Q.3 Degrees of protection against ingress of water

Protection of the equipment inside the **enclosure** against harmful ingress of water.

Table Q.3 – Degrees of protection indicated by the second characteristic numeral

Second characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non-protected	-
1	Protected against vertically falling water drops	Vertically falling drops shall have no harmful effects
2	Protected against vertically falling water drops when enclosure tilted up to 15°	Vertically falling drops shall have no harmful effects when the enclosure is tilted at any angle up to 15° on either side of the vertical
3	Protected against spraying water	Water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effects
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effects
5	Protected against water jets	Water projected in jets against the enclosure from any direction shall have no harmful effects
6	Protected against powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effects
7	Protected against the effects of temporary immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under standardized conditions of pressure and time
8	Protected against the effects of continuous immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is continuously immersed in water under conditions which shall be agreed between manufacturer and user but which are more severe than for numeral 7
9	Protected against high pressure and temperature water jets	Water projected at high pressure and high temperature against the enclosure from any direction shall not have harmful effects

Annex R (normative)

Explanations of the application of 6.1.2.2.1 of IEC 60664-1:2007

R.1 Impulse dielectric test

- wave-form: 1,2 / 50 μ s
- three impulses of each polarity
- interval between impulses at least 1 s
- impulse voltage according to Table F.5 of IEC 60664-1:2007
- rated impulse voltage according to **working voltage** and overvoltage category of Table F.1 of IEC 60664-1:2007
- for **double** or **reinforced insulation** the next higher value according to 4.2.3 of IEC 60664-1:2007 is to be used (see 5.1.6 of IEC 60664-1:2007). With this value the applicable impulse voltage in Table F.5 of IEC 60664-1:2007 can be found.
- An abstract of the impulse test voltage according to 6.1.2.2.1 of IEC 60664-1:2007 can be found in Table R.1.

R.2 Example

Working voltage: 300 V (r.m.s.) OVC III

- ⇒ according to Table F.1: 4 000 V (rated impulse voltage)
- ⇒ **double insulation** ⇒ 6 000 V (next higher value according to 4.2.3 rated impulse voltage)
- ⇒ according to Table F.5 (6 000 V) = 7,385 kV (impulse test voltage at sea level)

Table R.1 – Impulse test voltage according to 6.1.2.2.1 of IEC 60664-1:2007

	Overvoltage category IV		Overvoltage category III		Overvoltage category II		Overvoltage category I	
Working voltage	Double or reinforced insulation	Basic insulation	Double or reinforced insulation	Basic insulation	Double or reinforced insulation	Basic insulation	Double or reinforced insulation	Basic insulation
V AC	V AC	V AC	V AC	V AC	V AC	V AC	V AC	V AC
50	2 920	1 751	1 751	934	934	541	541	357
100	4 923	2 920	2 920	1 751	1 751	934	934	541
150	7 385	4 923	4 923	2 920	2 920	1 751	1 751	934
300	9 847	7 385	7 385	4 923	4 923	2 920	2 920	1 751
600	14 770	9 847	9 847	7 385	7 385	4 923	4 923	2 920
1 000	n.a.	14 770	14 770	9 847	9 847	7 385	7 385	4 923

Values of test voltage for intermediate values of **working voltage** are found by interpolation between tabulated values.

Example:

AC 230 V	8 698 V	6 236 V	6 236 V	3 989 V	3 989 V	2 375 V	2 375 V	1 370 V

NOTE Definitions of **overvoltage categories** are given in 4.3.3.2 of IEC 60664-1:2007.

Transformers for general use are in **overvoltage category III** or higher.

Transformers e.g. for use in household appliances or audio/video, information and communication technology equipment are in **overvoltage category II** or higher.

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Annex S

(void)

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Annex T

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Annex U

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Annex V (informative)

Symbols to be used for thermal cut-outs

V.1 General

The purpose of this annex is to give information to the equipment manufacturer and the end user on the way to proceed for resetting the **transformer** after operation of the thermal cut-out.

When the symbols are used, they are intended for information. In the future, when they are known and recognized, the intention is to make them mandatory.

The symbols, when used, are placed on the **transformer**. They apply to both **independent** and **associated transformers**.

Figure V.1, Figure V.2, Figure V.3 and Figure V.4 should be used.

NOTE θ is the symbol used to show that the device is operated by temperature.

V.2 Non-self-resetting thermal cut-out (see 3.3.4)

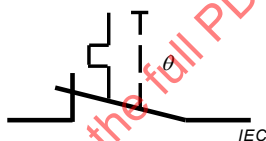


Figure V.1 – Restored by manual operation

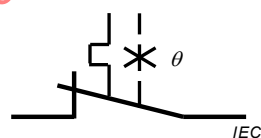


Figure V.2 – Restored by disconnection of the supply

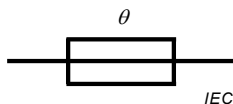


Figure V.3 – Thermal link (see 3.3.5)

V.3 Self-resetting thermal cut-out (see 3.3.3)

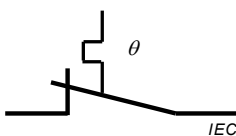


Figure V.4 – Self-resetting thermal cut-out

Annex W (normative)

Coated printed circuit boards

W.1 Preamble

The testing of protective coatings of printed circuit boards is carried out in accordance with IEC 60664-3 with the modifications described in W.2 to W.5.

W.2 General

The requirements of 5.1 of IEC 60664-3:2016 apply, but when production samples are used, three samples of the printed circuit board are tested.

W.3 Cold

The test of 5.7.2 of IEC 60664-3:2016 is carried out at –25 °C.

W.4 Rapid change of temperature

In the requirement of 5.7.4 of IEC 60664-3:2016, severity 1 is specified.

W.5 Additional tests

The requirements of 5.9 of IEC 60664-3:2016 are not applicable.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

**SÉCURITÉ DES TRANSFORMATEURS, BOBINES D'INDUCTANCE,
BLOCS D'ALIMENTATION ET DES COMBINAISONS DE CES ÉLÉMENTS –****Partie 1: Exigences générales et essais****AVANT-PROPOS**

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La Norme internationale IEC 61558-1 a été établie par le comité d'études 96 de l'IEC: Transformateurs, bobines d'inductance, blocs d'alimentations et combinaison de ces éléments.

Cette troisième édition annule et remplace la deuxième édition parue en 2005 et l'Amendement 1:2009. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) fils de bobinage totalement isolés (FIW), nouveaux tableaux et essais de vieillissement pour les constructions avec fils FIW,
- b) les catégories de surtensions 1, 2, 3 et 4 pour les distances d'isolement et les essais de rigidité diélectrique (nouveaux tableaux) sont incluses,

- c) développement de nouveaux symboles pour les différentes catégories de surtensions,
- d) symbole pour les altitudes maximales, si elles sont supérieures à 2 000 m,
- e) symbole pour les blocs d'alimentation enfichables, si les broches sont endommagées (essai au tambour tournant),
- f) symbole pour la température minimale (même durant le transport),
- g) variante de mesure de la température, méthode de charge simulée et d'essai en opposition conformément à l'IEC 60076-11,
- h) protection contre les courts-circuits et les surcharges, méthode de charge simulée et d'essai en opposition conformément à l'IEC 60076-11,
- i) ajustement des températures dans le Tableau 2 conformément au Guide CENELEC 29,
- j) établissement de l'essai de décharge partielle au-dessus de 750 V pour les constructions avec fils FIW,
- k) exigences pour noyaux toroïdaux, division pour l'isolation principale et pour l'isolation supplémentaire,
- l) modification des indices de protection pour les enveloppes (code IP),
- m) dimensionnement des connecteurs de section rectangulaire pour transformateurs,
- n) essai de répétition, 80 % de la tension d'essai de rigidité diélectrique requise dans le Tableau 14,
- o) essai de vibrations pour les véhicules et les applications ferroviaires,
- p) deux condensateurs Y1 pour des tensions locales supérieures à 250 V et ne dépassant pas 500 V avec la catégorie de surtension 3.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
96/466/FDIS	96/468/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Elle a le statut d'une publication groupée de sécurité conformément au Guide IEC 104.

Une liste de toutes les parties de la série IEC 61558, publiées sous le titre général *Sécurité des transformateurs, bobines d'inductance, blocs d'alimentation et des combinaisons de ces éléments*, peut être consultée sur le site web de l'IEC.

Les futures normes de cette série porteront dorénavant le nouveau titre général cité ci-dessus. Le titre des normes existant déjà dans cette série sera mis à jour lors de la prochaine édition.

Dans la présente norme, les caractères d'imprimerie suivants sont employés:

- exigences proprement dites: caractères romains;
- *modalités d'essais: caractères italiques;*
- commentaires: petits caractères romains.

Dans le texte de la norme, les mots en **gras** sont définis à l'Article 3.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "<http://webstore.iec.ch>" dans les données relatives à la publication recherchée. A cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

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INTRODUCTION

Le présent document couvre les exigences de sécurité pour les **transformateurs**. Lorsque le terme «**transformateur**» est utilisé, il couvre soit le **transformateur**, soit la **bobine d'inductance**, soit le **bloc d'alimentation**, suivant les cas.

Lors de l'élaboration de ce document, les exigences de l'IEC 60364 (toutes les parties) ont été prises en compte autant que possible, de sorte qu'un **transformateur** puisse être installé conformément aux règles d'installation qu'elle contient. Cependant les règles d'installation nationales peuvent différer.

Ce document couvre les niveaux de protection acceptés internationalement contre les risques tels que les risques électriques, mécaniques et liés au feu, qui peuvent être induits par les **transformateurs** durant leur fonctionnement en utilisation normale et selon les instructions du constructeur. Il couvre aussi les situations anormales qui peuvent se produire dans la pratique.

Un **transformateur** conforme à ce document ne sera pas nécessairement jugé conforme aux principes de sécurité de ce document si, lorsqu'il est examiné et soumis à essai, il apparaît avoir d'autres caractéristiques qui compromettent le niveau de sécurité couvert par les exigences du présent document.

Un **transformateur** utilisant des matériaux ou ayant des formes de construction qui diffèrent des données détaillées dans ce document peut être examiné et soumis à essai en tenant compte des objectifs de ces exigences. S'il est jugé pratiquement équivalent, il peut être considéré conforme aux exigences de sécurité de ce document.

La norme traitant des aspects non relatifs à la sécurité de la compatibilité électromagnétique (CEM) des **transformateurs** est l'IEC 62041. Cependant, cette dernière fait également mention d'essais qui peuvent soumettre le **transformateur** à des conditions impliquant des aspects relatifs à la sécurité.

L'objectif de l'IEC 61558-1 est de fournir un ensemble d'exigences et d'essais qui sont considérés comme généralement applicables à la plupart des types de **transformateurs** et qui peuvent être mentionnés le cas échéant par la partie appropriée de l'IEC 61558-2. Par conséquent, l'IEC 61558-1 ne doit pas être considérée en soi comme une spécification pour un type donné de **transformateur**, et ses dispositions s'appliquent uniquement à des types particuliers de **transformateurs** dans la limite déterminée par la partie appropriée de l'IEC 61558-2. L'IEC 61558-1 comporte également des essais individuels de série normatifs.

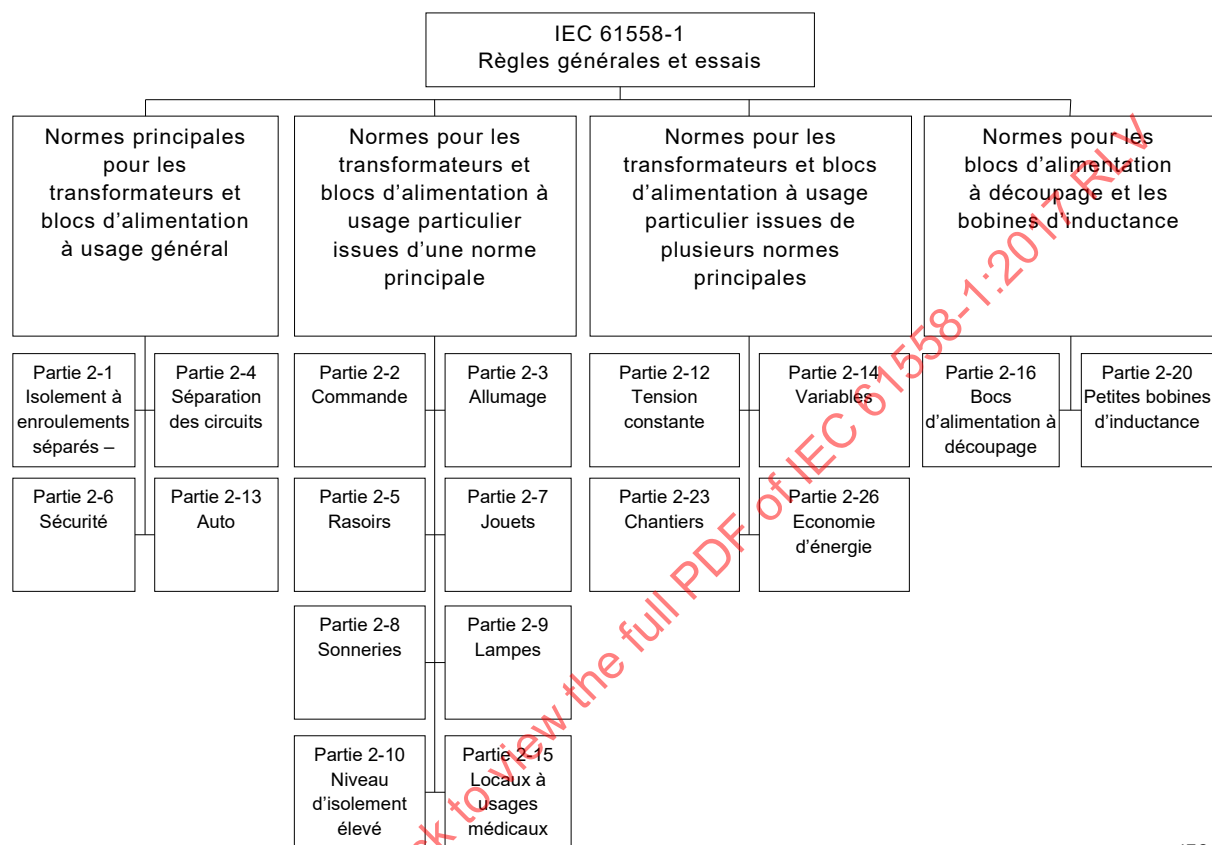
Chaque partie de l'IEC 61558-2, conjointement avec ce document, comprend toutes les exigences nécessaires pour le **transformateur** considéré et par conséquent ne fait pas référence à une autre partie de l'IEC 61558-2. Pour les **transformateurs** ayant un indice de protection IP00 et les **transformateurs** associés, il est possible d'avoir, dans la même construction, plusieurs circuits conformes à différentes parties de l'IEC 61558-2 (par exemple, un circuit secondaire TBTS conforme à l'IEC 61558-2-6 et un circuit secondaire 230 V conforme à l'IEC 61558-2-4). Cependant, lorsque différentes parties de l'IEC 61558-2 s'appliquent à un **transformateur**, la partie appropriée de l'IEC 61558-2 sera appliquée séparément à chaque fonction/application dans la mesure du possible. L'influence d'une fonction sur l'autre sera prise en compte le cas échéant.

Si une partie appropriée de l'IEC 61558-2 pour un type particulier de **transformateur** ou pour un groupe de **transformateurs** n'existe pas, la partie applicable la plus proche peut être utilisée comme un guide pour les exigences et les essais.

Certains pays toutefois peuvent souhaiter considérer l'application du présent document, dans la mesure du possible, à des transformateurs qui ne sont pas mentionnés dans la série IEC 61558-2 ainsi qu'à des transformateurs conçus suivant de nouveaux principes.

Lorsque dans une des parties de l'IEC 61558-2 il est fait référence à l'un des articles de l'IEC 61558-1 par la phrase «L'article de la Partie 1 est applicable», cette phrase signifie que toutes les exigences de cet article de l'IEC 61558-1 s'appliquent, à l'exception de celles qui sont clairement inapplicables pour le type particulier de **transformateurs** couvert par cette partie de l'IEC 61558-2.

Le principe de la préparation des différentes parties de l'IEC 61558-2 est décrit Figure 1.



IEC

Figure 1 – Principe de l'IEC 61558

Les articles du présent document (par exemple, les articles traitant de l'essai d'endurance thermique pour enroulements) s'appliquent aussi aux **transformateurs** faisant partie intégrante d'un appareil et ne pouvant pas être soumis à essai séparément.

L'IEC 61558 comprend les parties suivantes, présentées sous le titre général *Sécurité des transformateurs, bobines d'inductance, blocs d'alimentation et des combinaisons de ces éléments*:¹

- Partie 1: Exigences générales et essais
- Partie 2-1: Règles particulières et essais pour les transformateurs d'isolement à enroulements séparés pour applications générales
- Partie 2-2: Règles particulières et essais pour les transformateurs de commande
- Partie 2-3: Règles particulières et essais pour les transformateurs d'allumage pour brûleurs à gaz et combustibles liquides

¹ Certaines parties, publiées antérieurement, portent le titre général de *Sécurité des transformateurs, blocs d'alimentation, bobines d'inductance et produits analogues*, celui de *Sécurité des transformateurs, blocs d'alimentation et analogues* ou celui de *Sécurité des transformateurs, blocs d'alimentation et dispositifs similaires*. Leur titre sera mis à jour lors d'une prochaine édition.

- Partie 2-4: Règles particulières et essais pour les transformateurs de séparation des circuits
- Partie 2-5: Règles particulières et essais pour les transformateurs et les blocs d'alimentation pour rasoirs
- Partie 2-6: Règles particulières et essais pour les transformateurs de sécurité
- Partie 2-7: Règles particulières et essais pour transformateurs pour jouets
- Partie 2-8: Règles particulières et essais pour les transformateurs pour sonneries
- Partie 2-9: Règles particulières et essais pour les transformateurs pour baladeuses de classe III pour lampe à filament de tungstène
- Partie 2-10: Règles particulières et essais pour les transformateurs d'isolement à enroulements séparés à niveau d'isolement élevé et pour les transformateurs d'isolement à enroulements séparés à tensions secondaires supérieures à 1 000 V
- Partie 2-12: Règles particulières et essais pour les transformateurs à tension constante
- Partie 2-13: Règles particulières et essais pour les autotransformateurs
- Partie 2-14: Règles particulières et essais pour les transformateurs variables
- Partie 2-15: Règles particulières pour les transformateurs de séparation de circuits pour locaux à usages médicaux
- Partie 2-16: Règles particulières et essais pour les blocs d'alimentations à découpage et les transformateurs pour blocs d'alimentation à découpage
- Partie 2-20: Règles particulières et essais pour les petites bobines d'inductance
- Partie 2-23: Règles particulières et essais pour les transformateurs et les blocs d'alimentation pour chantiers
- Partie 2-26: Règles particulières et essais pour les transformateurs et les blocs d'alimentation entièrement destinés à l'économie d'énergie et à d'autres fins

D'autres parties sont actuellement à l'étude.

SÉCURITÉ DES TRANSFORMATEURS, BOBINES D'INDUCTANCE, BLOCS D'ALIMENTATION ET DES COMBINAISONS DE CES ÉLÉMENTS –

Partie 1: Exigences générales et essais

1 Domaine d'application

La présente partie de l'IEC 61558 traite des aspects relatifs à la sécurité des **transformateurs**, bobines d'inductance, blocs d'alimentation et des combinaisons de ces éléments, tels que la sécurité électrique, la sécurité thermique et la sécurité mécanique.

Le présent document couvre les **transformateurs de type sec**, les **blocs d'alimentation**, y compris les **blocs d'alimentation à découpage**, les **bobines d'inductance** et les combinaisons de ces éléments, de type **indépendant** ou **associé**, fixe ou mobile, dans le domaine de la sécurité. Les enroulements peuvent être enrobés ou non enrobés. Ils ne constituent pas une partie du réseau de distribution.

NOTE 1 La distinction entre transformateurs, blocs d'alimentation, et blocs d'alimentation à découpage s'établit de la manière suivante:

- pour les **transformateurs**, il n'y a pas de changement de fréquence. Cependant, des **transformateurs** (par exemple les **transformateurs** à tension constante peuvent avoir des fréquences de résonance interne ne dépassant pas 30 kHz;
- pour les **blocs d'alimentation**, la **fréquence de fonctionnement interne** et la forme d'onde sont différentes de la **fréquence d'alimentation** et de la forme d'onde du réseau et la **fréquence de fonctionnement interne** n'excède pas 500 Hz (voir définition 3.1.19);
- pour les **blocs d'alimentation à découpage**, la **fréquence de fonctionnement interne** et la forme d'onde sont différentes de la **fréquence d'alimentation** et de la forme d'onde et la **fréquence de fonctionnement interne** est comprise entre 500 Hz et 100 MHz.

Voir la ou les parties de l'IEC 61558-2 qui s'appliquent dans la liste fournie dans l'avant-propos de ce document.

a) **Transformateurs de séparation des circuits et transformateurs de sécurité, associés ou indépendants**, fixes ou mobiles, à refroidissement par air (circulation naturelle ou forcée), monophasés ou polyphasés, présentant les caractéristiques suivantes:

- **tension primaire assignée** ne dépassant pas 1 000 V en courant alternatif;
- **fréquence d'alimentation assignée** ne dépassant pas 500 Hz;

et respectant les limites suivantes sauf spécification contraire dans la partie appropriée de l'IEC 61558-2:

- pour les **transformateurs de séparation des circuits**:
 - une puissance assignée pour les **transformateurs** monophasés n'excédant pas 25 kVA, et pour les **transformateurs** polyphasés n'excédant pas 40 kVA;
 - une **tension secondaire à vide** et une **tension secondaire assignée** excédant 50 V en courant alternatif et n'excédant pas 500 V en courant alternatif ou 1 000 V en courant alternatif, conformément aux règles nationales d'installation ou pour des applications spéciales.
- pour les **transformateurs de sécurité**:
 - une **puissance assignée** pour les **transformateurs** monophasés n'excédant pas 10 kVA, et pour les **transformateurs** polyphasés n'excédant pas 16 kVA;
 - une **tension secondaire à vide** et une **tension secondaire assignée** n'excédant pas 50 V en courant alternatif entre conducteurs, ou entre n'importe quel conducteur et la terre de protection.

NOTE 2 Les **transformateurs de séparation des circuits** et les **transformateurs de sécurité** sont utilisés lorsque la **double isolation** ou l'**isolation renforcée** est requise entre les circuits par les règles d'installation ou par la spécification de l'appareil d'utilisation (par exemple: jouets, sonneries, **outils** portatifs, baladeuses).

b) **Transformateurs à enroulements séparés, autotransformateurs, transformateurs variables** et petites **bobines d'inductance, associés ou indépendants**, à refroidissement par air (circulation naturelle ou forcée), **fixes ou mobiles**, monophasés ou polyphasés, présentant les caractéristiques suivantes:

- **tension primaire assignée** ne dépassant pas 1 000 V en courant alternatif;
- **fréquence d'alimentation assignée** ne dépassant pas 500 Hz;

et respectant les limites suivantes sauf spécification contraire dans la partie appropriée de l'IEC 61558-2:

- une tension secondaire à vide ou une tension secondaire assignée pour les **transformateurs** associés ou indépendants n'excédant pas 15 kV en courant alternatif et pour les **transformateurs** indépendants une tension secondaire assignée excédant 50 V en courant alternatif;
- une **puissance assignée** n'excédant pas les valeurs suivantes:
 - 1 kVA pour les **transformateurs** monophasés;
 - 2 kVAR pour les **bobines d'inductance** monophasées;
 - 5 kVA pour les **transformateurs** polyphasés;
 - 10 kVAR pour les **bobines d'inductance** polyphasées.

NOTE 3 Les **transformateurs à enroulements séparés** sont utilisés lorsque la **double isolation** ou l'**isolation renforcée** n'est pas exigée entre les circuits par les règles d'installation ou la spécification de l'appareil d'utilisation.

NOTE 4 Normalement, les **transformateurs** du type b) sont destinés à être associés à un équipement pour lui fournir des tensions différentes de la tension d'alimentation pour des raisons fonctionnelles. La protection contre les chocs électriques peut être obtenue ou complétée par d'autres particularités de l'équipement, telle que la **masse**. Des parties du **circuit secondaire** peuvent être connectées au **circuit primaire** ou à la terre de protection.

c) **Blocs d'alimentation et blocs d'alimentation à découpage associés ou indépendants, fixes ou mobiles**, à refroidissement par air (circulation naturelle ou forcée), monophasés ou polyphasés, incorporant un ou plusieurs transformateur(s) de type a) ou b), présentant les caractéristiques suivantes:

- **tension primaire assignée** ne dépassant pas 1 000 V en courant alternatif;
- **fréquence d'alimentation assignée** ne dépassant pas 500 Hz;
- fréquence de fonctionnement interne pour les blocs d'alimentation ne dépassant pas 500 Hz et pour les blocs d'alimentation à découpage ne dépassant pas 100 MHz;

et satisfaisant aux limites suivantes sauf spécification contraire dans les parties appropriées de l'IEC 61558-2:

- pour les blocs d'alimentation et pour les blocs d'alimentation à découpage incorporant des **transformateurs de séparation des circuits**:
 - une **puissance assignée** pour les **blocs d'alimentation** monophasés ou polyphasés ou pour les **blocs d'alimentation à découpage** n'excédant pas 1 kVA;
 - une **tension secondaire à vide** et une **tension secondaire assignée** excédant 50 V en courant alternatif ou 120 V en courant continu lissé, et n'excédant pas 500 V en courant alternatif ou 708 V en courant continu lissé, ou n'excédant pas 1 000 V en courant alternatif ou 1 415 V en courant continu lissé conformément aux règles nationales d'installation ou pour des applications spéciales;
- pour les **blocs d'alimentation** et pour les **blocs d'alimentation à découpage** incorporant des **transformateurs de sécurité**:
 - une **puissance assignée** pour les **blocs d'alimentation** monophasés ou polyphasés et pour les **blocs d'alimentation à découpage** n'excédant pas 1 kVA;
 - une **tension secondaire à vide** et une **tension secondaire assignée** n'excédant pas 50 V en courant alternatif ou 120 V en courant continu lissé entre conducteurs, ou entre n'importe quel conducteur et la terre de protection.

NOTE 5 Les **blocs d'alimentation** et les **blocs d'alimentation à découpage** incorporant des **transformateurs de séparation des circuits** et des **transformateurs de sécurité** sont utilisés lorsque la

double isolation ou l'**isolation renforcée** est requise entre les circuits par les règles d'installation ou par la spécification de l'appareil d'utilisation (par exemple: jouets, sonneries, **outils** portatifs, baladeuses).

- pour les **blocs d'alimentation** et pour les **blocs d'alimentation à découpage** incorporant des **transformateurs à enroulements séparés**, des **autotransformateurs**, et des **transformateurs variables**:
 - une **puissance assignée** pour les **blocs d'alimentation** monophasés ou polyphasés et pour les **blocs d'alimentation à découpage** n'excédant pas 1 kVA;
 - une **tension secondaire à vide** et une **tension secondaire assignée** pour les **transformateurs associés** ou **indépendants** n'excédant pas 15 kV en courant alternatif et pour les **transformateurs indépendants**, une **tension secondaire assignée** excédant 50 V en courant alternatif.

NOTE 6 Les **blocs d'alimentation** et les **blocs d'alimentation à découpage** incorporant un **transformateur à enroulements séparés** sont utilisés lorsque la **double isolation** ou l'**isolation renforcée** n'est pas requise entre les circuits par les règles d'installation ou par la spécification de l'appareil.

Ce document s'applique également aux **transformateurs**, **blocs d'alimentation**, **blocs d'alimentation à découpage**, et **bobines d'inductance** incorporant des circuits électroniques.

Ce document s'applique aux **transformateurs** sans limitation de la **puissance assignée**, sous réserve d'un accord entre l'utilisateur et le fabricant.

Ce document ne s'applique pas aux circuits externes et à leurs composants destinés à être connectés aux bornes d'entrée et de sortie ou aux socles de prise de courant des **transformateurs**, **blocs d'alimentation**, **blocs d'alimentation à découpage**, et **bobines d'inductance**.

L'attention est attirée sur le fait que:

- pour les **transformateurs** prévus pour être utilisés dans des véhicules ou à bord de navires ou d'avions, des exigences complémentaires (provenant d'autres normes en vigueur, règlements nationaux, etc.) peuvent être nécessaires;
- des mesures sont prises pour protéger les **enveloppes** et les composants qu'elles contiennent contre les influences du milieu extérieur comme la moisissure, la vermine, les termites, les radiations solaires, le givre;
- les différentes conditions de transport, de stockage et de fonctionnement du **transformateur** sont également prises en compte;
- des exigences supplémentaires, conformes à d'autres normes appropriées ou règles nationales, peuvent être applicables aux **transformateurs** destinés à des environnements particuliers, par exemple des environnements tropicaux.

Il est possible que des évolutions technologiques futures des **transformateurs** nécessitent d'augmenter la limite supérieure de la fréquence; en attendant, le présent document peut être utilisé pour fournir des lignes directrices.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60065:2014, *Appareils audio, vidéo et appareils électroniques analogues – Exigences de sécurité*

IEC 60068-2-6, *Essais d'environnement – Partie 2-6: Essais – Essai Fc: Vibrations (sinusoïdales)*

IEC 60068-2-14, *Essais d'environnement – Partie 2-14: Essais – Essai N: Variation de température*

IEC 60068-2-31, *Essais d'environnement – Partie 2-31: Essais – Essai Ec: Choc lié à des manutentions brutales, essai destiné en premier lieu aux matériels*

IEC 60068-2-75, *Essais d'environnement – Partie 2-75: Essais – Essai Eh: Essais au marteau*

IEC 60076-1, *Transformateurs de puissance – Partie 1: Généralités*

IEC 60076-11:2004, *Transformateurs de puissance – Partie 11: Transformateurs de type sec*

IEC TR 60083, *Prises de courant pour usages domestiques et analogues normalisées par les pays membres de l'IEC*

IEC 60085:2007, *Isolation électrique – Evaluation et désignation thermiques*

IEC 60112:2003, *Méthode de détermination des indices de résistance et de tenue au cheminement des matériaux isolants solides*

IEC 60127 (toutes les parties), *Coupe-circuit miniatures*

IEC 60127-3, *Coupe-circuit miniatures – Partie 3: Eléments de remplacement subminiatures*

IEC 60216 (toutes les parties), *Matériaux isolants électriques – Propriétés d'endurance thermique*

IEC 60227 (toutes les parties), *Conducteurs et câbles isolés au polychlorure de vinyle, de tension nominale au plus égale à 450/750 V*

IEC 60227-5:2011, *Conducteurs et câbles isolés au polychlorure de vinyle, de tension assignée au plus égale à 450/750 V – Partie 5: Câbles souples*

IEC 60245 (toutes les parties), *Conducteurs et câbles isolés au caoutchouc – Tension assignée au plus égale à 450/750 V*

IEC 60245-4:2011, *Conducteurs et câbles isolés au caoutchouc – Tension assignée au plus égale à 450/750 V – Partie 4: Câbles souples*

IEC 60269 (toutes les parties), *Fusibles basse tension*

IEC 60269-2:2013, *Fusibles basse tension – Partie 2: Exigences supplémentaires pour les fusibles destinés à être utilisés par des personnes habilitées (fusibles pour usages essentiellement industriels) – Exemples de systèmes de fusibles normalisés A à K*

IEC 60269-3:2010, *Fusibles basse tension – Partie 3: Exigences supplémentaires pour les fusibles destinés à être utilisés par des personnes non qualifiées (fusibles pour usages essentiellement domestiques et analogues) – Exemples de systèmes de fusibles normalisés A à F*

IEC 60309 (toutes les parties), *Prises de courant pour usages industriels*

IEC 60317 (toutes les parties), *Spécifications pour types particuliers de fils de bobinage*

IEC 60317-0-7:2012, *Spécifications pour types particuliers de fils de bobinage – Partie 0-7: Exigences générales – Fil de section circulaire en cuivre émaillé sans défaut d'isolation électrique avec diamètre nominal de conducteur compris entre 0,040 mm et 1,600 mm*

IEC 60317-56, *Spécifications pour types particuliers de fils de bobinage – Partie 56: Fil brasable de section circulaire, isolé en continu, en cuivre émaillé avec polyuréthane sans défaut d'isolation électrique, avec diamètre nominal de conducteur compris entre 0,040 mm et 1,600 mm, classe 180*

IEC 60320 (toutes les parties), *Connecteurs pour usages domestiques et usages généraux analogues*

IEC 60320-2-3, *Connecteurs pour usages domestiques et usages généraux analogues – Partie 2-3: Connecteurs avec degré de protection supérieur à IPX0*

IEC 60384-14:2013, *Condensateurs fixes utilisés dans les équipements électroniques – Partie 14: Spécification intermédiaire – Condensateurs fixes d'antiparasitage et raccordement à l'alimentation*

IEC 60417, *Symboles graphiques utilisables sur le matériel*
(disponible à l'adresse <http://www.graphical-symbols.info/equipment>)

IEC 60454 (toutes les parties), *Rubans adhésifs sensibles à la pression à usages électriques*

IEC 60529:1989, *Degrés de protection procurés par les enveloppes (Code IP)*
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 60664-1:2007, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, exigences et essais*

IEC 60664-3:2016, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 3: Utilisation de revêtement, d'empotage ou de moulage pour la protection contre la pollution*

IEC 60691:2015, *Protecteurs thermiques – Exigences et guide d'application*

IEC 60695-2-10:2013, *Essais relatifs aux risques du feu – Partie 2-10: Essais au fil incandescent/ chauffant – Appareillage et méthode commune d'essai*

IEC 60695-2-11:2014, *Essais relatifs aux risques du feu – Partie 2-11: Essais au fil incandescent/chauffant – Méthode d'essai d'inflammabilité pour produits finis (GWEPT)*

IEC 60721-3-2, *Classification des conditions d'environnement – Partie 3: Classification des groupements des agents d'environnement et de leurs sévérités – Section 2: Transport*

IEC 60730 (toutes les parties), *Dispositifs de commande électrique automatiques*

IEC 60730-1:2013, *Dispositifs de commande électrique automatiques – Partie 1: Exigences générales*

IEC 60851-3:2009, *Fils de bobinage – Méthodes d'essai: Partie 3: Propriétés mécaniques*

IEC 60851-5:2008, *Fils de bobinage – Méthodes d'essai: Partie 5: Propriétés électriques*

IEC 60851-6:2012, *Fils de bobinage – Méthodes d'essai: Partie 5: Propriétés thermiques*

IEC 60884-1:2002, *Prises de courant pour usages domestiques et analogues – Partie 1: Règles générales*

IEC 60884-1:2002/AMD1:2006

IEC 60884-1:2002/AMD2:2013

IEC 60884-2-4, *Prises de courant pour usages domestiques et analogues – Partie 2-4: Règles particulières pour prises de courant pour TBTS*

IEC 60898 (toutes les parties), *Petit appareillage électrique – Disjoncteurs pour la protection contre les surintensités pour installations domestiques et analogues*²

IEC 60906-1, *Système CEI de prises de courant pour usages domestiques et analogues – Partie 1: Prises de courant 16 A 250 V c.a.*

IEC 60906-3, *Système CEI de prises de courant pour usages domestiques et analogues – Partie 3: Prises de courant pour TBTS, 16 A 6 V, 12 V, 24 V, 48 V courant alternatif et courant continu*

IEC 60947-7-1, *Appareillage à basse tension – Partie 7-1: Matériels accessoires – Blocs de jonction pour conducteurs en cuivre*

IEC 60990:2016, *Méthodes de mesure du courant de contact et du courant dans le conducteur de protection*

IEC 60998-2-1, *Dispositifs de connexion pour circuits basse tension pour usage domestique et analogue – Partie 2-1: Règles particulières pour dispositifs de connexion en tant que parties séparées à organes de serrage à vis*

IEC 60998-2-2, *Dispositifs de connexion pour circuits basse tension pour usage domestique et analogue – Partie 2-2: Règles particulières pour dispositifs de connexion en tant que parties séparées avec organes de serrage sans vis*

IEC 60999-1, *Dispositifs de connexion – Conducteurs électriques en cuivre – Prescriptions de sécurité pour organes de serrage à vis et sans vis – Partie 1: Prescriptions générales et particulières pour les organes de serrage pour les conducteurs de 0,2 mm² à 35 mm² (inclus)*

IEC 61032, *Protection des personnes et des matériels par les enveloppes – Calibres d'essai pour la vérification*

IEC 61058-1:2016, *Interrupteurs pour appareils – Partie 1: Exigences générales*

IEC 61058-1-1:2016, *Interrupteurs pour appareils – Partie 1-1: Exigences relatives aux interrupteurs mécaniques*

IEC 61140:2016, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61373, *Applications ferroviaires – Matériel roulant – Essais de chocs et vibrations*

ISO 8820 (toutes les parties), *Véhicules routiers – Liaisons fusibles*

² L'IEC 60898-2 est publiée sous le titre général de *Disjoncteurs pour la protection contre les surintensités pour installations domestiques et analogues* (le premier élément du titre, « Petit appareillage électrique », n'est pas mentionné).

EN 50075:1990, *Specification for flat non-wirable two-pole plugs 2.5 A 250 V, with cord, for the connection of class II-equipment for household and similar purposes* (disponible en anglais seulement)

DIN 43671:1975, *Copper bus bars; design for continuous current* (disponible en anglais seulement)

DIN 43670:1975, *Aluminium bus bars; design for continuous current* (disponible en anglais seulement)

DIN 43670-2:1985, *Aluminium bus bars copper cladding; design for continuous current* (disponible en anglais seulement)

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

NOTE Les définitions de **transformateurs** destinés à un usage particulier sont fournies dans les parties de l'IEC 61558-2 correspondantes.

Lorsque le terme **transformateur** est utilisé, il couvre les **transformateurs**, les **bobines d'inductance** et les **blocs d'alimentation**, suivant le cas.

Sauf spécification contraire, les termes «tension» et «courant» indiquent les valeurs efficaces des tensions et courants alternatifs et, pour les tensions et courants continus, ils indiquent les valeurs moyennes arithmétiques correspondantes.

«Lissé» signifie, par convention, la valeur efficace d'une tension d'ondulation, inférieure ou égale à 10 % de la composante en courant continu.

Un index des termes et définitions souvent utilisés est fourni à la fin du document.

3.1 Transformateurs

3.1.1

transformateur

appareil statique à induction électromagnétique, à deux enroulements ou plus, destiné à transformer un système de tension(s) et courant(s) alternatifs en un autre système de tension(s) et courant(s) alternatifs, de valeurs généralement différentes et de même fréquence, en vue de transférer une puissance électrique

Note 1 à l'article: Le terme fréquence implique également que la forme de l'onde reste la même.

[SOURCE: IEC 60050-421:1990, 421-01-01, modifiée – «de puissance» supprimé et «NOTE» ajoutée]

3.1.2

transformateur de séparation des circuits

transformateur avec une **séparation de protection** entre les **enroulements primaires** et **secondaires**

3.1.3

transformateur de sécurité

transformateur de séparation des circuits destiné à alimenter des circuits **TBTS** (très basse tension de sécurité) et **TBTP** (très basse tension de protection)

3.1.4

transformateur à enroulements séparés

transformateur avec le ou les **enroulements primaires** séparés du ou des **enroulements secondaires** par au moins une **isolation principale**

3.1.5

autotransformateur

transformateur dans lequel les **enroulements primaires** et **secondaires** ont une partie commune

Note 1 à l'article: Les **autotransformateurs** peuvent avoir des enroulements supplémentaires ou des prises à des fins de réglage.

Note 2 à l'article: Les transformateurs ayant des enroulements séparés au moins par une isolation fonctionnelle et reliés électriquement, seront considérés comme des **autotransformateurs**.

3.1.6

transformateur associé

transformateur conçu pour alimenter un appareil ou un équipement spécifique ou des parties de celui-ci, et qui est soit un **transformateur incorporé**, soit un **transformateur pour usage spécifique**

3.1.6.1

transformateur incorporé

transformateur associé conçu pour être intégré dans un appareil ou un équipement spécifique ou dans une partie de celui-ci, et dont l'**enveloppe** procure une protection contre les chocs électriques

3.1.6.2

transformateur pour usage spécifique

transformateur associé fixé sur ou fourni avec l'appareil ou l'équipement sans être incorporé à cet appareil ou à cet équipement et dont la propre **enveloppe** procure une protection contre les chocs électriques

3.1.7

transformateur indépendant

transformateur conçu pour alimenter un appareil indéterminé et destiné à être utilisé sans **enveloppe** additionnelle procurant une protection contre les chocs électriques

Note 1 à l'article: Un **transformateur** peut être soit un **transformateur** fixe soit un **transformateur** mobile.

3.1.8

vide

3.1.9

transformateur résistant aux courts-circuits

transformateur ne dépassant pas les limites de température spécifiées lorsqu'il est surchargé ou mis en court-circuit, et qui continue à satisfaire à toutes les exigences du présent document après disparition de la surcharge ou du court-circuit, et qui n'est pas prévu pour fonctionner continuellement en surcharge ou en court-circuit

Note 1 à l'article: «Continue à satisfaire à toutes les exigences du présent document» n'implique pas que tous les types de **transformateurs** résistants aux courts-circuits continuent à fonctionner.

3.1.9.1

transformateur résistant aux courts-circuits par dispositif incorporé

transformateur résistant aux courts-circuits qui comporte un dispositif de protection ou une **partie affaiblie intentionnellement**, qui ouvre le **circuit d'entrée** ou le **circuit de sortie** ou réduit le courant du **circuit d'entrée** ou du **circuit de sortie** lorsque le **transformateur** est en surcharge ou en court-circuit, et qui continue à satisfaire à toutes les exigences du présent document après suppression de la surcharge ou du court-circuit

3.1.9.1.1

transformateur résistant aux courts-circuits par dispositif incorporé avec dispositif de protection réarmable, à réarmement automatique ou remplaçable

transformateur résistant aux courts-circuits qui comporte un dispositif de protection qui continue à fonctionner après réarmement ou remplacement

Note 1 à l'article: Comme exemples de dispositifs de protection réarmable, à réarmement automatique ou remplaçable, on peut citer les fusibles, **relais à maximum de courant**, fusibles thermiques ou rubans thermiques, **coupe-circuits thermiques**, résistances CTP ou dispositifs mécaniques à coupure automatique.

3.1.9.1.2

transformateur résistant aux courts-circuits par dispositif incorporé avec dispositif de protection non réarmable ou non remplaçable

transformateur résistant aux courts-circuits qui comporte un dispositif de protection non réarmable ou non remplaçable ou une **partie affaiblie intentionnellement** non remplaçable qui continue à satisfaire à toutes les exigences du présent document après suppression de la surcharge ou du court-circuit mais qui ne continue pas à fonctionner après suppression de la surcharge ou du court-circuit

3.1.9.2

transformateur résistant aux courts-circuits par construction

transformateur résistant aux courts-circuits, sans dispositif de protection en cas de surcharge ou de court-circuit

Note 1 à l'article: Le **transformateur**, par construction, ne dépasse pas les limites de température spécifiées en cas de surcharge ou de court-circuit, et il continue à fonctionner et à satisfaire à toutes les exigences du présent document, après suppression de la surcharge ou du court-circuit.

3.1.10

transformateur non résistant aux courts-circuits

transformateur prévu pour être protégé contre une température excessive au moyen d'un dispositif de protection non fourni avec le **transformateur** et qui continue à satisfaire à toutes les exigences de ce document après suppression de la surcharge ou du court-circuit et, si applicable, après réarmement ou remplacement du dispositif de protection

3.1.11

transformateur non dangereux en cas de défaillance

transformateur doté d'un dispositif de protection ou d'une **partie affaiblie intentionnellement** qui ne remplit plus sa fonction de façon permanente à la suite à l'interruption du **circuit primaire** lorsque le **transformateur** est surchargé ou en court-circuit, mais qui ne présente aucun danger pour l'utilisateur ou l'environnement

Note 1 à l'article: Il continue à satisfaire à toutes les exigences du présent document après suppression de la surcharge ou du court-circuit.

Note 2 à l'article: «Continue à satisfaire à toutes les exigences du présent document» n'implique pas que le **transformateur** non dangereux en cas de défaillance continue à fonctionner. Après l'interruption, il satisfait à l'essai de rigidité diélectrique réalisé à 35 % des valeurs d'origine (voir 15.5).

3.1.12

transformateur mobile

transformateur qui est déplacé pendant son fonctionnement, ou **transformateur** qui peut être facilement déplacé lorsqu'il est relié au circuit d'alimentation, ou **transformateur** avec fiche incorporée

3.1.13

transformateur pour pose encastrée

transformateur destiné à être monté dans une boîte d'encastrement

3.1.14

transformateur installé à poste fixe

transformateur destiné à être utilisé attaché à un support dans une position qui peut être spécifiée par le constructeur

3.1.15

transformateur fixe

transformateur installé à poste fixe, ou transformateur ayant une masse supérieure à 18 kg et fourni sans poignée(s)

3.1.16

transformateur portatif

transformateur mobile prévu pour être tenu à la main en usage normal

3.1.17

vide

3.1.18

transformateur sec

transformateur dont le diélectrique est non liquide et dont les enroulements peuvent être imprégnés ou enrobés

3.1.19

bloc d'alimentation

dispositif incorporant un ou plusieurs **transformateurs** et un ou plusieurs circuits électroniques qui convertit le signal de l'alimentation en une ou plusieurs sorties

Note 1 à l'article: Il peut aussi servir à isoler le **circuit primaire** du **circuit secondaire**, réguler et/ou convertir la tension ou le courant secondaire. Le dispositif peut être constitué d'une ou plusieurs unités séparées, ayant des formes d'onde, des fréquences, y compris la sortie en courant continu, identiques ou différentes, la **fréquence de fonctionnement interne** et la forme d'onde étant différentes de la fréquence d'alimentation, et la **fréquence de fonctionnement interne** n'excédant pas 500 Hz.

3.1.20

bloc d'alimentation à découpage

dispositif incorporant un ou plusieurs **transformateurs** et un ou plusieurs circuits électroniques qui convertit le signal de l'alimentation en une ou plusieurs sorties

Note 1 à l'article: Il peut aussi servir à isoler le **circuit primaire** du **circuit secondaire**, réguler et/ou convertir la tension ou le courant secondaire. Le dispositif peut être constitué d'une ou plusieurs unités ayant des formes d'onde et des fréquences, y compris la sortie en courant continu, identiques ou différentes, la fréquence de **fonctionnement interne** et la forme d'onde étant différentes des fréquences et forme d'onde de l'alimentation, et la **fréquence de fonctionnement interne** excédant 500 Hz mais n'excédant pas 100 MHz.

3.1.21

bobine d'inductance

dispositif comprenant un ou plusieurs enroulements ayant une impédance variant en fonction de la fréquence, fonctionnant suivant le principe d'auto-induction selon lequel un courant magnétisant génère un champ magnétique à travers un noyau de bonne perméabilité magnétique ou dans l'air

Note 1 à l'article: Les **bobines d'inductance** avec noyau toroïdal sont aussi incluses dans cette définition.

3.2 Termes généraux

3.2.1

câble souple externe

câble souple, destiné à la connexion externe au **circuit primaire** ou **secondaire**, fixé ou monté sur le **transformateur** selon la méthode de fixation du type X, du type Y ou du type Z

3.2.1.1

fixation du type X

méthode de fixation permettant un remplacement facile du câble ou du cordon, qu'il s'agisse d'un câble ou cordon ordinaire ou d'un câble ou cordon spécialement préparé

3.2.1.2

fixation du type Y

méthode de fixation destinée à être remplacée seulement par le constructeur, son représentant ou une personne qualifiée similaire

Note 1 à l'article: Une **fixation du type Y** peut être utilisée soit avec des câbles ou cordons souples ordinaires, soit avec des câbles ou cordons spéciaux.

3.2.1.3

fixation du type Z

méthode de fixation qui ne permet pas de remplacer le câble souple ou le cordon sans briser ou détruire une partie du transformateur

3.2.2

câble d'alimentation

câble souple externe, utilisé pour le raccordement à l'alimentation du circuit primaire

Note 1 à l'article: Les **câbles d'alimentation** sont:

- soit fixés au ou assemblés sur le **transformateur** par des **fixations** de type **X**, **Y** ou **Z**;
- soit raccordés au **transformateur** par un connecteur.

3.2.3

fil de connexion

fil connectant la fin d'un enroulement à la borne du **transformateur**

Note 1 à l'article: Les **fils de connexion** sont considérés comme des câblages internes.

3.2.4

masse

parties conductrices accessibles, axes, poignées, boutons, manettes et organes analogues, vis de fixation métalliques accessibles et feuille métallique appliquée sur les surfaces accessibles en matière isolante

3.2.5

partie accessible

partie qui peut être touchée avec le doigt d'essai normalisé après installation correcte du **transformateur**

3.2.6

partie amovible

partie qui peut être enlevée sans l'aide d'un **outil**

3.2.7

partie non détachable

partie qui ne peut être enlevée qu'avec l'aide d'un **outil**

3.2.8

outil

tournevis, pièce de monnaie ou tout autre objet pouvant être employé pour manœuvrer une vis ou un dispositif de fixation similaire

3.2.9

enveloppe

enceinte assurant le type et le degré de protection approprié pour l'application prévue

Note 1 à l'article: La protection contre, par exemple, les chocs mécaniques, la corrosion, les moisissures, les vermines, les radiations solaires, le gel et l'humidité.

[SOURCE: IEC 60050-195:1998, 195-02-35, modifiée – «NOTE» ajoutée]

3.2.10

partie conductrice intermédiaire

partie conductrice non accessible située entre des **parties actives dangereuses** ou entre la **masse** et une autre **partie active dangereuse**

3.2.11

partie conductrice

partie capable de conduire un courant électrique

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

3.2.12

composant électronique

partie dans laquelle la conduction est réalisée principalement par des électrons se déplaçant dans le vide, un gaz ou un semi-conducteur

Note 1 à l'article: Les indicateurs à néon ne sont pas considérés comme des composants électroniques.

3.2.13

circuit électronique

circuit comprenant au moins un composant électronique

3.2.14

vide

3.2.15

séparation électrique

séparation entre des parties conductrices réalisée au moyen d'air et/ou d'une isolation solide

3.3 Manœuvres et protections

3.3.1

coupure omnipolaire des pôles

déconnexion de tous les conducteurs actifs par une seule manœuvre

Note 1 à l'article: Un **conducteur de mise à la terre de protection** n'est pas considéré comme un conducteur d'alimentation.

Note 2 à l'article: Le conducteur neutre est considéré comme un conducteur d'alimentation.

Note 3 à l'article: Les règles d'installation nationales peuvent ou non exiger la déconnexion du conducteur neutre.

3.3.2

coupe-circuit thermique

dispositif sensible à la température qui limite, en fonctionnement anormal, la température d'un **transformateur** ou de parties de celui-ci, par l'ouverture automatique du circuit ou par la réduction du courant, et qui est construit de façon que son réglage ne puisse pas être modifié par l'utilisateur

3.3.3

coupe-circuit thermique à réenclenchement automatique

coupe-circuit thermique qui rétablit automatiquement le courant lorsque la partie correspondante du **transformateur** s'est suffisamment refroidie ou que la charge a disparu

3.3.4

coupe-circuit thermique sans réenclenchement automatique

coupe-circuit thermique qui nécessite une manœuvre à la main ou le remplacement d'un élément pour rétablir le courant

3.3.5

protecteur thermique

coupe-circuit thermique qui fonctionne une fois seulement

3.3.6

relais à maximum de courant

interrupteur fonctionnant selon le courant et protégeant un circuit contre les surcharges par déclenchement, lorsque le courant dans ce circuit atteint une valeur prédéterminée et qui reste en position ouverte

3.3.7

partie affaiblie intentionnellement

partie autre qu'un dispositif de protection contre les surcharges (fusibles, disjoncteur, coupe-circuits thermiques, etc.) destinée à se rompre dans des conditions anormales de fonctionnement afin d'éviter l'apparition d'une dégradation du fonctionnement non conforme au présent document

Note 1 à l'article: Il peut s'agir soit d'un composant remplaçable comme une résistance ou un condensateur ou d'une partie non remplaçable d'un composant tel qu'un point faible non accessible présent dans un enroulement.

3.3.8

tension locale

valeur efficace la plus élevée d'une tension alternative ou continue qui peut se produire (localement) à travers n'importe quel système d'isolation à la **tension assignée d'alimentation**, l'angle de phase et les surtensions transitoires n'étant pas pris en compte, sans charge ou dans les conditions normales de fonctionnement

Note 1 à l'article: Lorsque l'on considère un système d'isolation entre enroulements non destinés à être connectés ensemble, la **tension locale** est considérée comme étant la tension la plus élevée apparaissant sur n'importe lequel de ces enroulements.

Note 2 à l'article: Sur les systèmes triphasés la **tension locale** peut être différente de la tension nominale.

3.3.9

tension de court-circuit

tension qu'il faut appliquer à l'**enroulement primaire**, lorsque les enroulements sont à la température ambiante, pour que l'**enroulement secondaire**, mis en court-circuit, soit parcouru par un courant égal au **courant secondaire assigné**.

Note 1 à l'article: La **tension de court-circuit** est généralement exprimée en pourcentage de la **tension primaire assignée**.

3.3.10

type de service

service continu ou périodique consistant en une ou plusieurs séries de charges qui restent constantes pendant les durées spécifiées

3.3.10.1

service permanent

fonctionnement pendant une durée illimitée

3.3.10.2

service temporaire

fonctionnement pendant une période définie, à partir d'un état froid, les intervalles entre chaque période de fonctionnement étant suffisants pour permettre au **transformateur** de refroidir jusqu'à une température voisine de la température ambiante

3.3.10.3

service intermittent

fonctionnement suivant une série de cycles identiques spécifiés

3.3.11

conducteur de mise à la terre de protection

PE

conducteur de protection prévu pour réaliser la mise à la terre de protection

[SOURCE: IEC 60050-195:1998, 195-02-11]

3.4 Circuits et enroulements

3.4.1

circuit primaire

circuit destiné à être raccordé à l'alimentation et constitué de l'**enroulement primaire** et des **circuits internes** s'y rattachant

3.4.2

circuit secondaire

circuit auquel le circuit d'utilisation, un appareil, ou un autre équipement, sont destinés à être raccordés, et qui est constitué de l'**enroulement secondaire** et des **circuits internes** s'y rattachant

3.4.3

enroulement primaire

enroulement du **circuit primaire**

3.4.4

enroulement secondaire

enroulement du **circuit secondaire**

3.4.5

circuit interne

circuit constitué de composants, d'interconnexions et de connexions aux bornes des enroulements, à l'exception du circuit de mise à la terre de protection

3.4.6

fil de bobinage totalement isolé

FIW

fil conforme à l'IEC 60317-0-7 et à l'IEC 60317-56 et soumis à essai conformément à l'IEC 60851-5:2008 et de construction sans défaut

3.4.7

grade de FIW

gamme de diamètre extérieur d'un fil (FIW3 à FIW9)

3.4.8

fil de bobinage isolé

fil de bobinage pour isolation principale, isolation supplémentaire ou isolation renforcée

Note 1 à l'article: Les exigences sont fournies à l'Annexe K.

3.4.9

fil de bobinage extrudé

TIW

fil de bobinage dont l'isolation principale, supplémentaire ou renforcée est obtenue par extrusion

Note 1 à l'article: Le terme TIW est couramment utilisé pour couvrir tous les types de fils de bobinage extrudés.

3.5 Valeurs assignées

3.5.1

tension primaire assignée

tension d'alimentation (dans le cas de courant polyphasé, la tension entre phases) attribuée au **transformateur** par le constructeur pour les conditions spécifiées de fonctionnement du **transformateur**

3.5.2

plage de tensions primaires assignées

plage de tensions primaires attribuée au **transformateur** par le constructeur et exprimée par ses limites inférieure et supérieure

3.5.3

fréquence assignée

fréquence attribuée au **transformateur** par le constructeur pour les conditions spécifiées de fonctionnement du **transformateur**

3.5.3.1

fréquence d'alimentation assignée

fréquence au primaire du transformateur assignée par le fabricant

Note 1 à l'article: La fréquence d'alimentation est la fréquence du réseau.

3.5.3.2

fréquence de fonctionnement interne

fréquence interne la plus élevée assignée par le fabricant comme la fréquence de fonctionnement du **transformateur** ou d'autres composants d'un **bloc d'alimentation**

3.5.4

courant secondaire assigné

courant secondaire sous la **tension primaire assignée**, à la **fréquence d'alimentation assignée** et à la **tension secondaire assignée**, sous un **facteur de puissance assigné**, attribué au **transformateur** par le constructeur pour les conditions de fonctionnement spécifiées du **transformateur**

3.5.5

tension secondaire assignée

tension secondaire (dans le cas de courants polyphasés, la tension entre phases) sous la **tension primaire assignée**, à la **fréquence d'alimentation assignée**, au **courant secondaire assigné**, sous un **facteur de puissance assigné**, attribuée au **transformateur** par le constructeur pour les conditions de fonctionnement spécifiées du **transformateur**

3.5.6

facteur de puissance assigné

facteur de puissance attribué par le constructeur au **transformateur** pour les conditions de fonctionnement spécifiées du **transformateur**

3.5.7

puissance assignée

produit de la **tension secondaire assignée** par le **courant secondaire assigné** ou, pour les **transformateurs triphasés**, $\sqrt{3}$ fois le produit de la **tension secondaire assignée** par le **courant secondaire assigné**

Note 1 à l'article: Si le **transformateur** a plus d'un **enroulement secondaire** ou est à prises multiples, la **puissance assignée** est la somme des produits de la **tension secondaire assignée** par le **courant secondaire assigné** pour les **circuits secondaires** prévus pour être chargés simultanément.

3.5.8

température ambiante assignée

t_a

température maximale à laquelle le **transformateur** peut fonctionner de façon continue dans les conditions normales d'utilisation

Note 1 à l'article: La valeur de la **température ambiante assignée** (t_a) n'exclut pas le fonctionnement temporaire du **transformateur** à une température n'excédant pas ($t_a + 10$) °C.

3.5.9

température ambiante minimale assignée

t_{amin}

température minimale à laquelle le transformateur peut fonctionner en permanence dans les conditions normales d'utilisation

3.5.10

température minimale assignée

t_{min}

température minimale pour le transport et le stockage seulement

3.5.11

catégorie de surtension

chiffre définissant une condition de surtension transitoire

Note 1 à l'article: Les catégories de surtensions I, II, III et IV sont utilisées, voir l'IEC 60664-1:2007, 4.3.3.2.

[SOURCE: IEC 60050-581:2008, 581-21-02, modifiée – «NOTE» ajoutée]

3.5.11.1

catégorie de surtension I

OVC I

matériel pour le raccordement à des circuits dans lesquels des mesures sont prises pour limiter les surtensions transitoires à un niveau convenablement bas

Note 1 à l'article: Les exemples de matériels de ce type sont ceux contenant des circuits électroniques protégés à ce niveau. Cependant, à moins que les circuits ne soient conçus pour prendre en compte les surtensions provisoires, le matériel de catégorie de surtension I ne peut pas être raccordé directement au réseau d'alimentation.

3.5.11.2

catégorie de surtension II

OVC II

matériel consommateur d'énergie qui doit être alimenté à partir de l'installation fixe

Note 1 à l'article: Les exemples de matériels de ce type comprennent des transformateurs pour appareils domestiques, télécommunications, jouets et autres charges similaires.

3.5.11.3

catégorie de surtension III

OVC III

matériel utilisé dans des installations fixes et dans des cas où la fiabilité et la disponibilité du matériau fait l'objet d'exigences particulières

Note 1 à l'article: Les exemples de matériels de ce type comprennent des transformateurs dans des installations fixes et des **transformateurs** destinés à un usage industriel avec raccordement permanent à l'installation fixe.

3.5.11.4

catégorie de surtension IV

OVC IV

matériel utilisé en tête d'installation.

Note 1 à l'article: Les exemples de matériels de ce type comprennent des **transformateurs** dans des installations fixes de centrales électriques ou à proximité immédiate de telles installations.

3.6 Valeurs à vide

3.6.1

puissance à vide

puissance absorbée par le **transformateur** lorsqu'il est alimenté à la **tension d'alimentation assignée** à la **fréquence d'alimentation assignée**, le transformateur fonctionnant à vide

3.6.2

tension secondaire à vide

tension secondaire obtenue lorsque le **transformateur** est alimenté à la **tension d'alimentation assignée**, à la **fréquence d'alimentation assignée**, le transformateur fonctionnant à vide

3.7 Isolation

3.7.1

isolation principale

isolation des **parties actives** qui assure la protection principale

Note 1 à l'article: **Cette notion n'est pas applicable à l'isolation exclusivement utilisée à des fins fonctionnelles**, par exemple vernis isolant pour fils.

[SOURCE: IEC 60050-195:1998, 195-06-06, modifiée – «dangereuses» supprimé et «par exemple vernis isolant pour fils» ajoutée]

3.7.1.1

isolation fonctionnelle

isolation entre parties conductrices, nécessaire pour le bon fonctionnement du transformateur

Note 1 à l'article: Pour les **transformateurs**, une isolation fonctionnelle correcte peut avoir une influence sur la sécurité. L'**isolation fonctionnelle** est vérifiée par les exigences du présent document mais des exigences supplémentaires peuvent exister dans l'IEC 61558-2 (toutes les parties).

[SOURCE: IEC 60050-195:1998, 195-02-41, modifiée – «transformateur» remplace «matériel» et «NOTE» ajoutée]

3.7.2

isolation supplémentaire

isolation indépendante des **parties actives dangereuses** prévue, en plus de l'**isolation principale**, en tant que protection en cas de défaut

Note 1 à l'article: Protection en cas de défaut signifie: afin d'assurer la protection contre les chocs électriques en cas de défaillance de l'**isolation principale**.

[SOURCE: IEC 60050-195:1998, 195-06-07, modifiée – «parties actives dangereuses» et «NOTE» ajoutée]

3.7.3

double isolation

isolation comprenant à la fois une **isolation principale** et une **isolation supplémentaire**

[SOURCE: IEC 60050-195:1998, 195-06-08]

3.7.4

isolation renforcée

isolation des **parties actives dangereuses** assurant un degré de protection contre les chocs électriques équivalent à celui d'une **double isolation**

Note 1 à l'article: L'isolation renforcée peut comporter plusieurs couches qui ne peuvent pas être soumises à essai séparément en tant qu'isolation principale ou isolation supplémentaire.

[SOURCE: IEC 60050-195:1998, 195-06-09]

3.7.5

transformateur de classe I

transformateur dans lequel la protection contre les chocs électriques ne repose pas uniquement sur l'**isolation principale**, mais qui comporte une mesure de sécurité supplémentaire sous la forme d'une borne de mise à la terre de protection pour le raccordement des **parties conductrices** accessibles au câblage fixe de l'installation

Note 1 à l'article: Le raccordement de mise à la terre de protection empêche que les **parties conductrices** ne puissent devenir actives en cas de défaut de l'**isolation principale**.

Note 2 à l'article: Les **transformateurs de classe I** peuvent avoir des parties à **double isolation** ou à **isolation renforcée**.

3.7.6

transformateur de classe II

transformateur dans lequel la protection contre les chocs électriques ne repose pas uniquement sur l'**isolation principale**, mais qui comporte des mesures supplémentaires de sécurité telles qu'une **double isolation** ou une **isolation renforcée**, ces mesures ne comportant pas de moyens de mise à la terre de protection et ne dépendant pas des conditions d'installation

Note 1 à l'article: Un **transformateur de classe II** peut être muni de moyens pour assurer la continuité des circuits de mise à la terre de protection à condition que ces moyens fassent partie intégrante du **transformateur** et soient isolés des surfaces accessibles conformément aux exigences de la **classe II**.

Note 2 à l'article: Dans certains cas, il peut être nécessaire de faire la distinction entre les **transformateurs de classe II** «totalement isolés» et «sous enveloppe métallique».

Note 3 à l'article: Un **transformateur** ayant une **enveloppe** durable et pratiquement continue en matière isolante enfermant toutes les **parties conductrices**, à l'exception de petites **pièces conductrices**, telles que des plaques signalétiques, vis et rivets, qui sont séparées de **parties actives dangereuses** par une isolation au moins équivalente à l'**isolation renforcée**, est appelé **transformateur de classe II** totalement isolé.

Note 4 à l'article: Un **transformateur** ayant une **enveloppe** métallique pratiquement continue dans laquelle la **double isolation** est partout utilisée, à l'exception des parties où l'on utilise une **isolation renforcée**, parce qu'une **double isolation** est manifestement irréalisable, est appelé **transformateur de classe II** sous enveloppe métallique.

Note 5 à l'article: Si un **transformateur** ayant en toutes ses parties une **double isolation** et/ou une **isolation renforcée** comporte une borne de mise à la terre de protection, il est considéré comme étant de la **classe I**.

Note 6 à l'article: Un **transformateur de classe II** peut être muni d'un circuit de mise à la terre fonctionnelle.

3.7.7

transformateur de classe III

transformateur dans lequel la protection contre les chocs électriques repose sur une alimentation sous très basse tension de sécurité (**TBTS**) et dans lequel ne sont pas engendrées des tensions supérieures à la **TBTS**

Note 1 à l'article: La classification en classes I, II, III ne se rapporte pas au système d'isolation entre les enroulements primaires et les enroulements secondaires.

3.7.8

distance d'isolement

CL

distance la plus courte dans l'air entre deux **parties conductrices**

Note 1 à l'article: Dans le but de déterminer une **distance d'isolement** entre **parties accessibles**, la surface accessible d'une **enveloppe** isolante est considérée comme conductrice, comme si elle était recouverte par une feuille métallique, partout où elle peut être accessible au doigt d'épreuve normalisé (voir Figure 4).

[SOURCE: IEC 60664-1:2007, 3.2, modifiée – «NOTE» ajoutée]

3.7.9**ligne de fuite****CR**

distance la plus courte (dans l'air), le long de la surface d'un isolant, entre deux **parties conductrices**

Note 1 à l'article: Dans le but de déterminer une **ligne de fuite** entre les **parties conductrices** et les **parties accessibles**, la surface accessible d'une **enveloppe** isolante est considérée comme conductrice, comme si elle était recouverte par une feuille métallique partout où elle peut être accessible au doigt d'épreuve normalisé (voir Figure 4).

[SOURCE: IEC 60050-151:2001, 151-15-50, modifiée – «dans l'air» et «NOTE» ajoutée]

3.7.10**pollution**

tout apport de matériau étranger solide, liquide ou gazeux (gaz ionisés) qui peut entraîner une réduction de la rigidité diélectrique ou de la résistivité de surface de l'isolation

[SOURCE: IEC 60664-1:2007, 3.11]

3.7.11**micro-environnement**

environnement immédiat de l'isolation qui influence en particulier le dimensionnement des **lignes de fuite** ou des **distances d'isolement**

Note 1 à l'article: Le **micro-environnement** des **lignes de fuite** et des **distances d'isolement**, et non l'environnement du matériel, détermine l'effet sur l'isolement. Le **micro-environnement** peut être meilleur ou pire que l'environnement du matériel. Il comprend tous les facteurs influençant l'isolement, tels que les conditions climatiques, les influences électromagnétiques, la génération de **pollution**, etc.

[SOURCE: IEC 60664-1:2007, 3.12.2, modifiée – «ou des distances d'isolement» et «NOTE» ajoutée]

3.7.12**degré de pollution**

degré de pollution au niveau des **micro-environnements**, établi dans le but d'évaluer les **lignes de fuite** et les **distances d'isolement**

3.7.12.1**degré de pollution 1****P1**

degré de pollution caractérisé par l'absence de **pollution** ou la seule présence d'une **pollution** sèche non conductrice

Note 1 à l'article: La **pollution** n'a pas d'influence.

3.7.12.2**degré de pollution 2****P2**

degré de pollution caractérisé par la seule présence d'une **pollution** non conductrice. On doit cependant s'attendre de temps en temps à une conductivité temporaire provoquée par la condensation

Note 1 à l'article: Les **transformateurs** ayant une **enveloppe** raisonnablement étanche sont considérés comme ayant le **degré de pollution 2** (P2), un scellement hermétique n'étant pas requis.

3.7.12.3**degré de pollution 3****P3**

degré de pollution caractérisé par la présence d'une **pollution** conductrice ou d'une **pollution** sèche non conductrice, qui devient conductrice par suite de la condensation attendue

3.7.13

séparation de protection

séparation entre circuits réalisée au moyen d'une protection principale et d'une protection supplémentaire (**isolation principale** plus **isolation supplémentaire** ou **écran de protection**) ou par un dispositif de protection équivalent (par exemple **isolation renforcée**)

[SOURCE: IEC 60050-195:1998, 195-06-19, modifiée – «(électrique)» supprimé et définition reformulée]

3.7.14

protection par écran

séparation des **parties actives dangereuses** au moyen d'un écran conducteur interposé, relié aux dispositifs de connexion des conducteurs de mise à la terre de protection extérieurs

[SOURCE: IEC 60050-195:1998, 195-06-18, modifiée – «(électrique)» supprimé et définition reformulée]

3.7.15

TBT

très basse tension

tension n'excédant pas 50 V en courant alternatif ou 120 V en courant continu lissé entre conducteurs ou entre un conducteur quel qu'il soit et la terre de protection

3.7.16

TBTS

très basse tension de sécurité

TBT dans un circuit dont la séparation du réseau d'alimentation est assurée par des moyens tels qu'un **transformateur de sécurité**

Note 1 à l'article: Une tension maximale inférieure à 50 V en courant alternatif ou 120 V en courant continu lissé peut être spécifiée dans des règles particulières, plus spécialement lorsque le contact direct avec des **parties actives** est autorisé.

Note 2 à l'article: La valeur crête maximale ne dépasse pas 140 V pour une tension nominale de 120 V d'un système en courant continu lissé et 70 V pour une tension nominale de 60 V d'un système en courant continu lissé.

3.7.17

circuit TBTS

circuit **TBT** comportant une **séparation de protection** par rapport aux autres circuits et qui ne comporte pas de dispositions prévoyant le raccordement à la terre du circuit ou des **parties conductrices**

3.7.18

circuit TBTP

très basse tension de protection

circuit **TBT** comportant une séparation de protection par rapport aux autres circuits, qui peut être raccordé à la terre et/ou dont les **parties conductrices** exposées peuvent être raccordées à la terre, pour des raisons fonctionnelles

Note 1 à l'article: Les **circuits TBTP** sont utilisés lorsque les circuits sont connectés à la terre et que la **TBTS** n'est pas exigée.

3.7.19

circuit TBTF

très basse tension de fonctionnement

circuit **TBT** ayant une très basse tension pour des raisons fonctionnelles mais qui ne répond pas aux exigences qui s'appliquent à la **TBTS** ou à la **TBTP**

3.7.20

partie active

conducteur ou partie conductrice destiné à être sous tension en service normal, y compris le conducteur de neutre, mais par convention, excepté le conducteur PEN, le conducteur PEM ou le conducteur PEL

Note 1 à l'article: Cette notion n'implique pas nécessairement un risque de choc électrique.

Note 2 à l'article: Pour les définitions de PEM et PEL, voir les définitions de l'IEC 60050-195:1998, 195-02-13 et 195-02-14.

[SOURCE: IEC 60050-195:1998, 195-02-19, modifiée – «NOTE 2» ajoutée]

3.7.21

partie active dangereuse

partie active qui peut provoquer, dans certaines conditions, un choc électrique nuisible

Note 1 à l'article: En cas de haute tension, il peut y avoir une tension dangereuse sur la surface de l'isolation solide. Dans ce cas, la surface est considérée comme une **partie active dangereuse**.

[SOURCE: IEC 60050-195:1998, 195-06-05, modifiée – «NOTE» ajoutée]

3.8 Courant de contact et courant dans le conducteur de mise à la terre de protection

3.8.1

courant de contact

courant électrique passant dans le corps humain ou dans le corps d'un animal lorsque ce corps est en contact avec une ou plusieurs parties accessibles d'une installation ou de matériels

[SOURCE: IEC 60050-195:1998, 195-05-21]

3.8.2

courant dans le conducteur de mise à la terre de protection

courant électrique qui circule dans un conducteur de mise à la terre de protection

Note 1 à l'article: Ce courant peut avoir une influence sur le fonctionnement des dispositifs de protection contre les courants résiduels (RCD) connectés dans le même circuit.

4 Exigences générales

4.1 Les transformateurs doivent être conçus et construits de façon que, lorsqu'ils sont utilisés, installés et entretenus conformément aux instructions du fabricant, et même dans l'éventualité d'une utilisation sans précautions susceptible d'advenir en service normal, ils ne peuvent présenter pour l'utilisateur ou pour l'environnement un danger qui n'a pas pu être raisonnablement prévu.

La vérification consiste en général à effectuer la totalité des essais applicables.

4.2 Lorsque des transformateurs associés sont utilisés dans un appareil ou équipement couvert par une norme spécifique à ce produit, ils peuvent être soumis à essai dans les mêmes conditions que celles de l'appareil ou l'équipement pour lequel ils ont été conçus.

*Si un **transformateur** est soumis à essai dans les conditions présentes dans l'appareil ou l'équipement pour lequel il est conçu, il doit satisfaire seulement aux articles et paragraphes suivants du présent document:*

1 – 2 – 3 – 4 – 5.1 – 5.2 – 5.3 – 5.4 – 5.5 – 5.6 – 5.7 – 7.1 – 7.2 – 7.5 – 7.6 – 7.8 – 8.2 – 8.11 – 14.1 – *excepté en ce qui concerne les exigences du Tableau 2 commençant à partir du premier: «enveloppes externes»...*, 14.2 – 14.3 – 15.1, *limité à la première case du Tableau 5* – 18.1 – 18.2 – 18.3 *uniquement entre les circuits primaires et secondaires* – 18.4 – 19.1 – 19.12 – 20.10 – 26.1 – 26.2 – 26.3 – Annexes A, G, L, M, N, P

Les autres articles doivent être couverts par la norme de produits correspondante. Si la norme de produits ne couvre pas complètement les articles restants, l'article de ce document applicable aux **transformateurs** qui correspond à l'article manquant doit être utilisé.

4.3 Pour les autres dangers non couverts par le présent document (par exemple EMF, sécurité fonctionnelle liée aux perturbations électriques, magnétiques et électromagnétiques, etc.), le constructeur doit procéder à une évaluation des risques.

5 Généralités sur les essais

5.1 Les essais mentionnés dans le présent document sont:

- des essais de type (définis au 8.1 à l'Article 28);
- des essais individuels de série (définis en Annexe L).

Chaque échantillon de **transformateur** doit satisfaire à tous les essais correspondants. Dans le but de réduire le temps d'essai et de permettre des essais qui peuvent être destructifs, le constructeur peut soumettre des **transformateurs** ou des parties de **transformateurs** supplémentaires, à la condition qu'ils soient réalisés dans les mêmes matériaux et selon la même conception que le **transformateur** d'origine, et que les résultats des essais soient les mêmes que s'ils avaient été effectués sur un **transformateur** identique à ce dernier. Lorsque l'essai de conformité est indiqué comme étant «par examen», cela doit comprendre toutes les opérations de manutention nécessaires.

Sauf spécification contraire, les essais doivent être effectués dans des conditions d'équilibre.

Les **transformateurs** destinés à être utilisés avec des câbles souples **non détachables** sont soumis à essai avec le câble souple raccordé au **transformateur**.

5.2 Les essais sont effectués sur des spécimens en l'état de livraison et installés comme en usage normal selon les instructions du fabricant. S'il n'est pas nécessaire d'effectuer les essais de 14.3, 15.5, 16.4 et 26.2, le nombre de spécimens est de un pour toutes les **puissances assignées**.

Si les essais de 14.3 sont nécessaires, ils doivent être effectués sur trois spécimens supplémentaires. S'il est nécessaire de répéter ces essais, ils doivent être réalisés sur trois autres spécimens.

Si les essais de 15.5 sont nécessaires, ils doivent être effectués sur trois spécimens supplémentaires. Ces spécimens ne sont utilisés que pour les essais de 15.5.

Si les essais de 16.4 sont nécessaires, ils sont effectués sur quatre spécimens supplémentaires.

Si les essais de 26.2 sont nécessaires, ils sont effectués sur trois spécimens supplémentaires.

Pour les composants soumis à essai dans les conditions existantes dans le **transformateur**, le nombre de spécimens est celui prescrit par la norme correspondante.

Pour l'essai d'une série de **transformateurs**, voir l'Annexe B.

Tous les spécimens doivent satisfaire à tous les essais correspondants, sauf pour le cas mentionné en 14.3.

NOTE 1 Pour les **transformateurs associés**, la norme de l'équipement peut prescrire un nombre différent de spécimens à soumettre à essai.

NOTE 2 Dans le cas où le dispositif de protection n'est ni interchangeable ni réarmable, la conformité est vérifiée sur un spécimen spécialement préparé.

5.3 Les essais sont effectués dans l'ordre des articles et paragraphes, à moins qu'il en soit spécifié autrement.

5.4 Si les résultats des essais ne sont pas influencés par la température ambiante, la température de la salle d'essais est, en général, maintenue à $(20 \pm 5) ^\circ\text{C}$. Autrement et si, toutefois, la température atteinte par une partie quelconque est limitée par un dispositif sensible à la température ou est influencée par la température à laquelle un changement d'état intervient, la température de la salle d'essais est, en cas de doute, maintenue à $(23 \pm 2) ^\circ\text{C}$ ou à $(t_a \pm 2) ^\circ\text{C}$ pour les **transformateurs** marqués t_a .

Les essais sont effectués avec le **transformateur**, ou toute partie mobile de celui-ci, placé dans la position la plus défavorable susceptible d'apparaître en usage normal.

5.5 Pour le courant alternatif, les tensions d'essai sont pratiquement sinusoïdales et ont une fréquence de 50 Hz ou 60 Hz sauf spécification contraire.

5.6 Les **transformateurs** prévus pour plusieurs **tensions primaires assignées**, pour une **plage de tensions primaires assignées** ou pour plusieurs **fréquences d'alimentation assignées** sont soumis à essai sous la tension ou à la fréquence qui conduit aux conditions les plus sévères pour le **transformateur** lors de l'essai considéré, à moins qu'il en soit spécifié autrement dans le présent document.

5.7 Dans la mesure du possible, les mesures sont effectuées à l'aide d'instruments qui n'ont pas d'effet appréciable sur les valeurs à mesurer; si nécessaire, des corrections doivent être faites.

5.8 Sauf spécification contraire, les **transformateurs** destinés à être utilisés avec un **câble souple externe** (voir 3.2.1) sont soumis à essai avec un ou plusieurs câbles reliés au transformateur.

5.9 Si des **transformateurs de classe I** ont des parties conductrices accessibles non connectées à une borne de mise à la terre ou à un contact de mise à la terre de protection, et non séparées des **parties actives dangereuses** par une **partie intermédiaire conductrice** connectée à une borne de mise à la terre de protection ou à un contact de mise à la terre de protection, on contrôle ces parties pour s'assurer de la conformité aux règles appropriées spécifiées pour les **transformateurs de classe II** dans le présent document.

5.10 Les **transformateurs pour pose encastrée** sont soumis à essai avec une boîte d'encastrement appropriée en matière isolante. Cette boîte est placée dans une **enveloppe** en contreplaqué d'une épaisseur de 20 mm, comme indiqué à la Figure 2, dont les parois internes sont peintes en noir mat. La distance du fond de la boîte de montage à la paroi de l'**enveloppe** est de 5 mm.

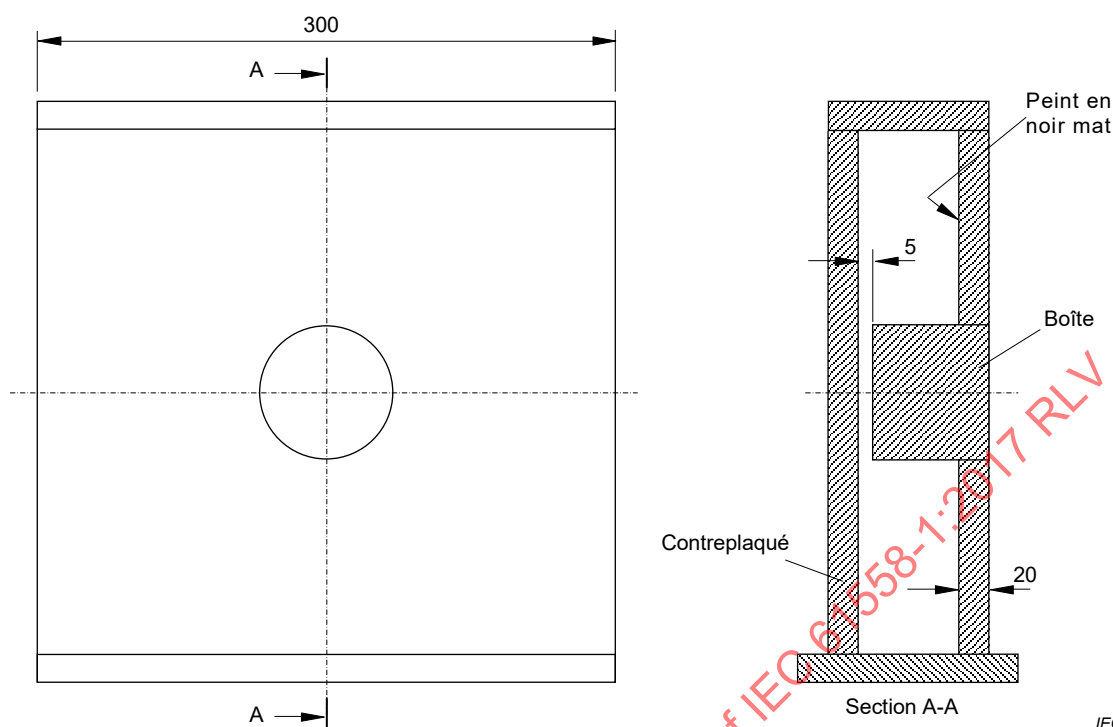


Figure 2 – Boîte de montage pour transformateur pour pose encastrée

5.11 Les **transformateurs pour usage spécifique**, s'il n'existe pas de norme spécifique à l'appareil ou à l'équipement auxquels ils sont destinés, sont soumis à essai de la même façon que les **transformateurs** d'usage courant, leurs caractéristiques assignées étant considérées comme la puissance et le facteur de puissance du ou des appareils ou équipements pour lesquels ils ont été conçus.

5.12 Vide

5.13 Les **transformateurs** ayant un indice IP00 dont l'utilisation n'est pas connue sont soumis à essai sans **enveloppe**.

Pour ces **transformateurs**, les exigences de l'Article 9 ne sont pas applicables. De plus, l'essai décrit en 272 n'est pas réalisé parce que le résultat peut être influencé par l'**enveloppe** dans l'application finale, par exemple sur le point de fixation du **transformateur** au support en plastique. Le cas échéant, la norme produit du produit final s'applique pour l'essai en condition de défaut.

5.14 Les **transformateurs** ayant un indice IP00 dont l'utilisation est connue sont soumis à essai montés selon les instructions du constructeur.

5.15 Les essais dans les Articles 18 et 26 sont basés sur un niveau de 2 000 m au-dessus de la mer. Si les essais sont effectués au-dessus de 2 000 m, l'Annexe A de l'IEC 60664-1:2007 s'applique.

6 Caractéristiques assignées

Les caractéristiques assignées sont indiquées dans la partie de l'IEC 61558-2 correspondante pour les différents types de **transformateurs**.

7 Classification

7.1 Les transformateurs sont classés selon leur protection contre les chocs électriques en:

- **transformateurs de classe I;**
- **transformateurs de classe II;**
- **transformateurs de classe III.**

NOTE Les **transformateurs à incorporer** ne sont pas rattachés à une classe; leur protection contre les chocs électriques est déterminée par la façon dont ils sont incorporés.

7.2 Les transformateurs sont classés selon la caractéristique de court-circuit ou la protection contre une utilisation anormale en:

- **transformateurs résistants aux courts-circuits par construction;**
- **transformateurs résistants aux courts-circuits par dispositif incorporé;**
- **transformateurs non résistants aux courts-circuits;**
- **transformateurs non dangereux en cas de défaillance.**

7.3 Les transformateurs sont classés selon le degré de protection procuré par l'**enveloppe** et défini selon l'IEC 60529 (système IP) sauf IP1X.

NOTE Pour plus d'information voir l'Annexe Q.

7.4 Les transformateurs sont classés selon leur mobilité en:

- **transformateurs fixes;**
- **transformateurs installés à poste fixe;**
- **transformateurs mobiles;**
- **transformateurs portatifs.**

7.5 Les transformateurs sont classés selon le type de service:

- **service permanent;**
- **service temporaire;**
- **service intermittent.**

7.6 Les transformateurs sont classés selon l'usage auquel ils sont destinés:

7.6.1 Associés

- **à incorporer;**
- **pour usage spécifique.**

7.6.2 Indépendants

7.7 Les transformateurs sont classés selon les conditions environnementales dans lesquelles ils sont destinés à être utilisés:

- environnement normal;
- environnements particuliers (par exemple, l'arctique).

7.8 Les transformateurs sont classés selon leur **condition de surtension transitoire**:

- **catégorie de surtension I;**
- **catégorie de surtension II;**
- **catégorie de surtension III;**

– **catégorie de surtension IV.**

Les **transformateurs** pour usage général sont de **catégorie de surtension III** ou plus élevée.

Les transformateurs, par exemple pour usage domestique ou dans des appareils audio/vidéo, du matériel de technologie de l'information et de communication sont de **catégorie de surtension II** ou plus élevée.

8 Marquage et indications

8.1 Les **transformateurs** doivent porter les indications suivantes (pour les symboles, se référer au Tableau 1):

- a) la ou les tensions primaires assignées, ou la ou les plages de tensions primaires assignées en volts;

Les **transformateurs** ayant une plage de valeurs assignées et qui peuvent fonctionner dans toute la plage sans réglage doivent être marqués des limites inférieure et supérieure de la plage, séparées par un tiret.

NOTE 1 Exemple 115 V – 230 V: le **transformateur** convient pour toute valeur comprise entre 115 V et 230 V.

Les **transformateurs** ayant différentes valeurs assignées et qui doivent être réglés par l'utilisateur ou l'installateur pour pouvoir être utilisés à une valeur particulière, doivent être marqués des différentes valeurs séparées par un trait oblique.

NOTE 2 Exemple 1: 115 V / 230 V: le **transformateur** est utilisable seulement pour 115 V ou 230 V (par exemple un **transformateur** ayant un sélecteur ou des bornes avec différentes valeurs).

NOTE 3 Exemple 2: 230 V/400 V: le **transformateur** est utilisable seulement pour 230 V ou 400 V, 230 V étant valable en fonctionnement monophasé et 400 V en fonctionnement triphasé (**transformateur** avec des bornes pour les deux modes d'alimentation).

- b) la ou les **tensions secondaires assignées** en volts ou kilovolts;

Pour les **transformateurs** combinés avec un redresseur, la **tension secondaire assignée** en aval du redresseur doit être indiquée en valeur moyenne arithmétique, ou la tension secondaire en amont du redresseur doit être exprimée en valeur efficace.

NOTE 4 La valeur efficace est distinguée de la valeur moyenne arithmétique en utilisant V_{eff} dans le marquage.

- c) la **puissance assignée** en voltampères ou en kilovoltampères, et en voltampères réactifs (VAR) ou en kilovoltampères réactifs (kVAR) pour les bobines d'inductance;

NOTE 5 Pour les **transformateurs** combinés avec un redresseur, la **puissance assignée** peut être exprimée en watts au lieu d'être exprimée en voltampères ou en kilovoltampères.

- d) le ou les **courants secondaires assignés** en ampères ou milliampères, en remplacement du marquage de la **puissance assignée**;

- e) la ou les fréquences assignées en hertz;

- f) le **facteur de puissance assigné**, s'il est différent de l'unité, pour les **transformateurs** au-dessus de 25 VA;

- g) le symbole ou l'abréviation AC pour sortie en courant alternatif ou DC pour sortie en courant continu;

- h) le symbole indiquant le type de **transformateur** tel que précisé dans la partie de l'IEC 61558-2 correspondante; si un **transformateur** ayant un indice IP00 ou un **transformateur associé** a plusieurs circuits conformes à différentes parties 2 de la même construction (par exemple un **circuit secondaire TBTS** conforme à l'IEC 61558-2-6 et le **circuit secondaire** 230 V conforme à l'IEC 61558-2-4) les symboles appropriés doivent être utilisés;

- i) le nom du constructeur ou du vendeur responsable ou la marque de fabrique;

- j) le numéro du modèle ou la référence du type;

- k) le groupe de couplage correspondant à l'IEC 60076-1 (pour les **transformateurs** triphasés si exigé);
- l) le symbole de la **classe II**, pour les **transformateurs de classe II** seulement;
le symbole de la **classe III**, pour les **transformateurs de classe III** seulement;
- m) l'indication de l'indice de protection IP, s'il est différent de IP00;
- n) la température ambiante assignée maximale t_a , si elle diffère de 25 °C;
Il est recommandé que les valeurs de t_a soient données par échelons de 5 °C pour $t_a \leq 50$ °C et par échelons de 10 °C pour $t_a > 50$ °C;
- o) **température ambiante minimale assignée** t_{amin} , si elle est inférieure à + 10 °C et si un dispositif sensible à la température est utilisé;
Il est recommandé que les valeurs de t_{amin} soient données par échelons de 5 °C;
- p) type de cycle en service, s'il y a lieu, à moins que le temps de service ne soit limité par la construction du **transformateur** ou corresponde à des conditions de service spécifiées dans la partie concernée de l'IEC 61558-2. Le marquage de **service temporaire** ou de **service intermittent** doit correspondre aux conditions d'usage normal. Le temps de fonctionnement pour des **transformateurs** pour **service temporaire** doit être exprimé en secondes (s) ou en minutes (min); le temps de fonctionnement et le temps de mise au repos pour les transformateurs pour service intermittent doivent être exprimés en secondes (s) ou en minutes (min), les deux indications étant séparées par une barre oblique;
- q) le symbole pour la catégorie de surtension, si elle diffère de OVC II;
- r) les **transformateurs** destinés à être utilisés avec une ventilation forcée lorsque le ventilateur n'est pas une partie du transformateur doivent être marqués avec «AF» suivi par la vitesse de l'air exprimée en m/s;
- s) de plus, le fabricant doit être en mesure de fournir à l'utilisateur les informations suivantes (soit dans la documentation, soit d'une autre façon):
 - pour les **transformateurs fixes** ayant une **puissance assignée** supérieure à 1 000 VA, la **tension de court-circuit** exprimée en pourcentage de la **tension primaire assignée**;
 - la fonction électrique du **transformateur**.

NOTE 6 Si le **transformateur** a plus d'un enroulement secondaire, la tension de court-circuit à marquer est la plus faible valeur des différents enroulements.

Des marquages supplémentaires sont autorisés sous réserve qu'ils ne prêtent pas à confusion.

Tous les marquages, à l'exception de ceux indiqués en i) et j), peuvent être illustrés en Code QR conformément à l'ISO/IEC 18004.

- t) symbole indiquant l'altitude maximale d'installation, si elle est supérieure à 2 000 m.

8.2 Pour les **transformateurs** à indice de protection IP00 ou pour les **transformateurs associés**, il est admis de marquer seulement le nom du constructeur ou du vendeur responsable (ou la marque de fabrique) et la référence du type (ou du catalogue). Les autres caractéristiques doivent alors figurer sur les feuilles de caractéristiques du **transformateur** ou dans les feuilles d'instructions du constructeur.

Le nom du constructeur ou du vendeur responsable et la référence du type peuvent être remplacés par un numéro de code permettant la traçabilité.

Ces informations doivent permettre de remplacer le **transformateur** d'origine par un **transformateur** équivalent.

NOTE Equivalent signifie électriquement, mécaniquement, dimensionnellement et fonctionnellement interchangeable.

8.3 Si le **transformateur** peut être adapté à différentes **tensions primaires assignées**, la tension de réglage doit pouvoir être facilement et clairement distinguée.

8.4 Les **transformateurs** à prises multiples ou à **enroulements secondaires** multiples doivent porter les indications suivantes:

- la **tension secondaire assignée** pour chaque prise ou enroulement, à moins que le **transformateur** ne soit destiné à des usages spéciaux impliquant de fréquents changements de la tension secondaire;
- la **puissance assignée** pour chaque prise ou enroulement; si la **puissance assignée** pour chaque prise ou enroulement est la même, au moins une prise ou un enroulement doit être marqué.

La disposition des connexions nécessaires pour obtenir les différentes tensions secondaires doit être clairement indiquée sur le **transformateur**.

8.5 Les **transformateurs résistants aux courts-circuits par dispositif incorporé**, comportant des fusibles incorporés et les **transformateurs non résistants aux courts-circuits** conçus pour être protégés par des fusibles doivent en outre porter l'indication du courant assigné (en ampères ou milliampères) de l'élément de remplacement servant à la protection, suivi ou précédé du symbole de la caractéristique temps-courant des fusibles en conformité avec la norme correspondante, s'il y a lieu.

Les **transformateurs résistants aux courts-circuits par dispositif incorporé** ayant des dispositifs de protection interchangeables autres que des fusibles et les **transformateurs non résistants aux courts-circuits** conçus pour être protégés par des dispositifs de protection autres que des fusibles doivent porter en outre l'indication du numéro du modèle ou la référence du type du dispositif et/ou les caractéristiques assignées du dispositif.

NOTE 1 Un symbole conforme à l'Annexe V peut être utilisé en complément.

NOTE 2 Les **transformateurs résistants aux courts-circuits par dispositif incorporé** non interchangeables n'ont pas besoin de marquage supplémentaire concernant le dispositif de protection.

Le marquage doit être tel que le remplacement du dispositif de protection puisse être assuré correctement.

Dans les cas où des dispositifs de protection interchangeables autres que des fusibles sont utilisés, une feuille d'instructions ou analogue, accompagnant le **transformateur**, doit donner les informations qui conviennent sur leur remplacement.

8.6 Les bornes prévues exclusivement pour le conducteur neutre doivent être identifiées par le symbole pour le neutre.

Les bornes de mise à la terre de protection doivent être identifiées par le symbole pour la mise à la terre de protection.

Les bornes des **enroulements primaires** et **secondaires** doivent être clairement identifiées.

Si un point quelconque d'un enroulement ou d'une borne est connecté au châssis ou au noyau, cela doit être indiqué au moyen du symbole correspondant.

8.7 Les **transformateurs** doivent être munis de marquages montrant clairement la façon dont le **transformateur** doit être raccordé, à moins que cela ne soit évident compte tenu de la conception du **transformateur**.

8.8 Pour les **transformateurs** pourvus d'une **fixation** du type **X**, **Y** et **Z**, la notice d'utilisation doit porter les informations suivantes ou leur équivalent:

- pour les **fixations du type X** comportant un cordon spécialement préparé:
«En cas d'endommagement du **câble souple externe**, celui-ci doit être remplacé par un cordon spécial disponible auprès du constructeur ou de son agent»;
- pour les **fixations du type Y**:
«En cas d'endommagement du **câble souple externe**, celui-ci doit être remplacé par le constructeur ou son agent ou par une personne qualifiée dans le but d'éviter tout danger»;
- pour les **fixations du type Z**:
«Le **câble souple externe** de ce **transformateur** ne peut pas être remplacé; en cas d'endommagement du cordon, le **transformateur** doit être mis au rebut».

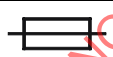
8.9 Les **transformateurs** utilisables seulement à l'intérieur doivent être marqués du symbole correspondant.

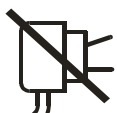
8.10 Les **transformateurs de classe II** doivent être marqués du symbole graphique IEC 60417-5172:2003-02 placé à côté des informations pour l'alimentation (par exemple sur la plaque signalétique), de sorte qu'il soit évident que le symbole fait partie de l'information technique et qu'il ne puisse en aucun cas être confondu avec le nom du constructeur ou une autre identification (voir 7.4.4 de l'IEC 61140:2016).

Les **transformateurs de classe II** ayant des parties à monter doivent être fournis avec tous les éléments qui en font un transformateur de classe II après montage conformément aux instructions de montage du fabricant, et ils doivent être marqués du symbole de la classe II. De plus, si le **transformateur** peut être monté sans couvercle (par exemple, sur un coffret de distribution), le marquage de la classe II doit être placé sur la partie qui donne effectivement la classe II (par exemple sur un couvercle de bornier pour connexion à l'alimentation).

8.11 Lorsqu'il est fait usage de symboles sur l'équipement ou dans les instructions, on doit utiliser les symboles suivants:

Tableau 1 – Symboles utilisés sur l'équipement ou dans les instructions

Symbole ou symbole graphique	Explication ou titre	Identification
V ^a	Volts	
A ^a	Ampères	
VA ou (VAR) ^a	Voltampères (ou voltampères réactifs pour les bobines d'inductance)	
W ^a	Watts	
Hz ^a	Hertz	
PRI	Primaire	
SEC	Secondaire	
— — —	Courant continu	IEC 60417-5031:2002-10
N	Neutre	
~	Courant alternatif monophasé	IEC 60417-5032:2002-10
3~	Courant alternatif triphasé	IEC 60417-5032-1:2002-10
3N~	Courant alternatif triphasé avec neutre	IEC 60417-5032-2:2002-10
cos φ	Facteur de puissance	
	Construction de classe II	IEC 60417-5172:2003-02
	Construction de classe III	IEC 60417-5180:2003-02
	Construction de catégorie de surtension I	IEC 60417-6348:2015-10
	Construction de catégorie de surtension II	IEC 60417-6349:2015-10
	Construction de catégorie de surtension III	IEC 60417-6350:2015-10
	Construction de catégorie de surtension IV	IEC 60417-6351:2015-10
	Coupe-circuit à fusibles (en ajoutant le symbole de la caractéristique temps-courant)	IEC 60417-5016:2002-10
t_a	Température ambiante maximale assignée Température maximale à laquelle le transformateur peut fonctionner de façon continue dans les conditions normales d'utilisation	
t_{amin}	Température ambiante minimale assignée Température minimale à laquelle le transformateur peut fonctionner en permanence dans les conditions normales d'utilisation	
t_{min}	Température minimale assignée Température minimale pour le transport et le stockage	
	Borne reliée au châssis ou au noyau	IEC 60417-5020:2002-10

Symbole ou symbole graphique	Explication ou titre	Identification
	Terre de protection	IEC 60417-5019:2006-08
IPXX	Code IP ^b	
	Terre fonctionnelle	IEC 60417-5017:2006-08
	Pour usage intérieur uniquement	IEC 60417-5957:2004-12
	Pour indiquer que l'appareil est destiné à être utilisé jusqu'à une altitude maximale de 3 000 m. Les symboles littéraux «3 000» peuvent être remplacés par ceux utilisés pour une valeur numérique différente (en mètres) en accord avec les applications réelles. Il est recommandé d'utiliser la valeur 2 000, 3 000, 4 000, ou 5 000 (mètres).	IEC 60417-6343:2015-06
	Pour indiquer que le bloc d'alimentation ne doit pas être utilisé si les broches de la partie fiche sont endommagées. NOTE Voir 8.8, fixations de type C	IEC 60417-6352:2015-10
^a Les multiples ou sous-multiples sont autorisés (exemple: kV, mA, ...). ^b Les «X» utilisés dans le code IP tel qu'il est représenté dans ce tableau indiquent un nombre manquant dans l'exemple, mais les deux nombres appropriés doivent être marqués sur le transformateur , si applicable. Des lettres additionnelles et supplémentaires mentionnées dans l'IEC 60529 peuvent être utilisées si nécessaire.		

8.12 Les différentes positions des dispositifs de réglage et les différentes positions des interrupteurs doivent être désignées par des chiffres, des lettres ou d'autres indications visuelles.

S'il est fait usage de chiffres pour la désignation des différentes positions, la position «ouverte» doit être désignée par le chiffre 0 et la position correspondant à une charge, une puissance, etc. plus élevées doit être désignée par un chiffre plus élevé.

Le chiffre 0 ne doit être employé pour aucune autre indication. Les indications utilisées doivent être compréhensibles sans la connaissance des langues, des normes nationales, etc.

8.13 Le marquage ne doit pas être placé sur des vis ou d'autres parties facilement amovibles.

A l'exception des cas mentionnés ci-dessous, les marquages et indications doivent pouvoir être distingués facilement lorsque le **transformateur** est prêt à l'usage.

Le marquage relatif aux bornes doit être placé de façon qu'on puisse le distinguer facilement après enlèvement du capot, si nécessaire; il doit être tel qu'il ne puisse pas y avoir confusion entre les bornes primaires et les bornes secondaires.

Le marquage relatif aux dispositifs de protection interchangeables doit être placé à proximité de la base de ces dispositifs, et de façon qu'on puisse le distinguer facilement après enlèvement de tout capot et du dispositif de protection.

8.14 Une information visuelle (symbole) doit être fournie lorsqu'il est nécessaire de prendre des précautions particulières pour l'installation, le transport ou l'utilisation (sur le catalogue, la fiche signalétique, les instructions d'utilisation ou l'emballage):

- un **transformateur résistant aux courts-circuits par dispositif incorporé avec dispositif de protection non réarmable ou non remplaçable** ou une **partie affaiblie intentionnellement** non remplaçable doit avoir une information expliquant que le dispositif de protection ne peut pas être réarmé ou remplacé après un court-circuit ou une surcharge;
- pour les **transformateurs** générant un **courant dans le conducteur de mise à la terre de protection** supérieur à 10 mA et conçus pour une connexion permanente, le **courant dans le conducteur de mise à la terre de protection** doit être clairement établi dans les instructions et il doit être indiqué que l'installation doit être faite conformément aux règles de câblage;
- pour les **transformateurs fixes** ayant une **puissance assignée** supérieure à 1 000 VA, la tension de court-circuit exprimée en pourcentage de la tension primaire assignée;
- la fonction électrique du **transformateur**;
- en tant qu'information relative à la conception d'un appareil, la limite en température de l'enroulement dans des conditions anormales à ne pas dépasser si le **transformateur** est intégré dans un appareil;
- pour les **transformateurs** non conçus pour une connexion en série et/ou parallèle de plusieurs enroulements secondaires, que le **transformateur** n'est pas destiné à être connecté en série ou en parallèle.

La conformité aux exigences de 8.1 à 8.14 est vérifiée par examen.

Pour les **transformateurs** IP00, le cas échéant, l'essai décrit en 27.2 n'est pas réalisé, le résultat pouvant être affecté par l'**enveloppe** dans l'application finale.

8.15 Le marquage doit être durable et facilement lisible.

La conformité est vérifiée par examen et en frottant le marquage à la main pendant 15 s avec un chiffon de coton imbibé d'eau et de nouveau pendant 15 s avec un chiffon de coton imbibé d'essence.

L'essence à utiliser pour cet essai se compose d'hexane aliphatique comme solvant avec une teneur aromatique ayant un maximum de 0,1 % en volume, un indice de kauributanol de 29, un point d'ébullition initial d'environ 65 °C, un point de siccité d'environ 69 °C et une masse volumique d'environ 0,68 g/cm³.

Le marquage fait par moulage, pression ou gravure n'est pas soumis à cet essai.

Après tous les essais du présent document, le marquage doit être facilement lisible; il ne doit pas être possible d'enlever facilement les étiquettes et celles-ci ne doivent pas se recroqueviller.

8.16 Les transformateurs mobiles équipés de fiches intégrées conformes à l'EN 50075 (fiche IEC de type C), doivent utiliser le symbole IEC 60417-6352:2015-10.

La feuille d'instructions de la fiche du transformateur doit contenir les informations suivantes ou un équivalent:

si les broches de la partie fiche sont endommagées, la prise dans le bloc d'alimentation doit être mise au rebut.

NOTE Les pays utilisant ce type de prise sont mentionnés par le terme «prise de type C» (disponibles à l'adresse <http://www.iec.ch/worldplugs/typeC.htm>).

La conformité aux exigences est vérifiée par examen.

9 Protection contre les chocs électriques

9.1 Généralités

Les **transformateurs** doivent être construits et enfermés de façon qu'il y ait une protection appropriée contre les contacts accidentels avec les **parties actives dangereuses** et ne doivent présenter aucun risque de choc électrique à partir de charges emmagasinées dans les condensateurs.

La conformité est vérifiée par examen et par les essais de 9.2.1, 9.2.2 et 9.3.

9.2 Protection contre le contact avec les parties actives dangereuses

9.2.1 Détermination des parties actives dangereuses

9.2.1.1 Une **partie active** n'est pas **dangereuse** lorsqu'elle est séparée de l'alimentation par une **isolation double** ou **renforcée** et qu'elle est conforme aux exigences de 9.2.1.2 ou 9.2.1.3 quand le **transformateur** est alimenté à sa **tension primaire assignée**.

9.2.1.2 La tension ne doit pas dépasser 35 V (crête) en courant alternatif ou 60 V en courant continu lissé

La conformité est vérifiée par les mesures effectuées entre deux parties conductrices.

9.2.1.3 Si la tension dépasse 35 V (crête) en courant alternatif ou 60 V en courant continu lissé, le courant de contact ne doit pas dépasser:

- pour l'alternatif: 0,7 mA (crête);
- pour le continu: 2,0 mA.

La conformité est vérifiée en mesurant le courant de contact comme spécifié dans l'Annexe J.

*En complément, quand un condensateur est connecté aux **parties actives**:*

9.2.1.3.1 La décharge ne doit pas dépasser 45 μC pour les tensions emmagasinées entre 60 V et 15 kV; ou

9.2.1.3.2 L'énergie de décharge ne doit pas dépasser 350 mJ pour les tensions emmagasinées dépassant 15 kV.

La conformité de 9.2.1.3.1 et 9.2.1.3.2 est vérifiée en effectuant les mesures avec une charge de 2 000 Ω .

9.2.2 Accessibilité aux parties actives dangereuses

Les **transformateurs** doivent être construits de façon à fournir une protection appropriée contre l'accessibilité aux **parties actives dangereuses**.

Les **transformateurs de classe I** et **II** doivent être construits et enfermés de façon à fournir une protection appropriée contre les contacts accidentels **avec les parties actives dangereuses**.

Pour les **transformateurs de classe I**, les parties accessibles doivent être séparées des **parties actives dangereuses** au moins par une **isolation principale**.

Les **transformateurs de classe II** doivent être construits et enfermés de façon que soit assurée une protection contre l'accessibilité à l'**isolation principale** et aux **parties**

conductrices séparées des **parties actives dangereuses** uniquement par l'**isolation principale**. Seules les parties séparées des **parties actives dangereuses** par une **isolation double** ou **renforcée** peuvent être accessibles.

Les **parties actives dangereuses** ne doivent pas être accessibles après enlèvement des parties amovibles à l'exception:

- des lampes munies de culots de taille supérieure aux culots B9 et E10;
- des porte-fusibles de type D.

Après leur incorporation dans le produit fini, les **transformateurs** IP00 doivent être conformes à la norme du produit dans lequel ils sont incorporés.

Les propriétés isolantes des vernis, de l'émail, du papier, du coton, d'une pellicule d'oxyde sur des parties conductrices et de la matière de remplissage ne doivent pas être considérées comme assurant la protection requise contre les contacts accidentels avec des **parties actives dangereuses**, à l'exception du **fil de bobinage totalement isolé (FIW)**.

NOTE 1 Les résines durcissant à l'air peuvent être considérées comme fournissant une protection adéquate contre les contacts accidentels avec les **parties actives dangereuses**.

Les axes, poignées, leviers de manœuvre, boutons et organes analogues ne doivent pas être des **parties actives dangereuses**.

La conformité est vérifiée par examen et par les essais de l'IEC 60529.

De plus, les ouvertures dans les **transformateurs de classe II** et les ouvertures dans les **transformateurs de classe I** autres que celles dans des **parties conductrices** reliées à une borne de mise à la terre de protection sont soumises à essai au moyen de la broche d'essai représentée à la Figure 3.

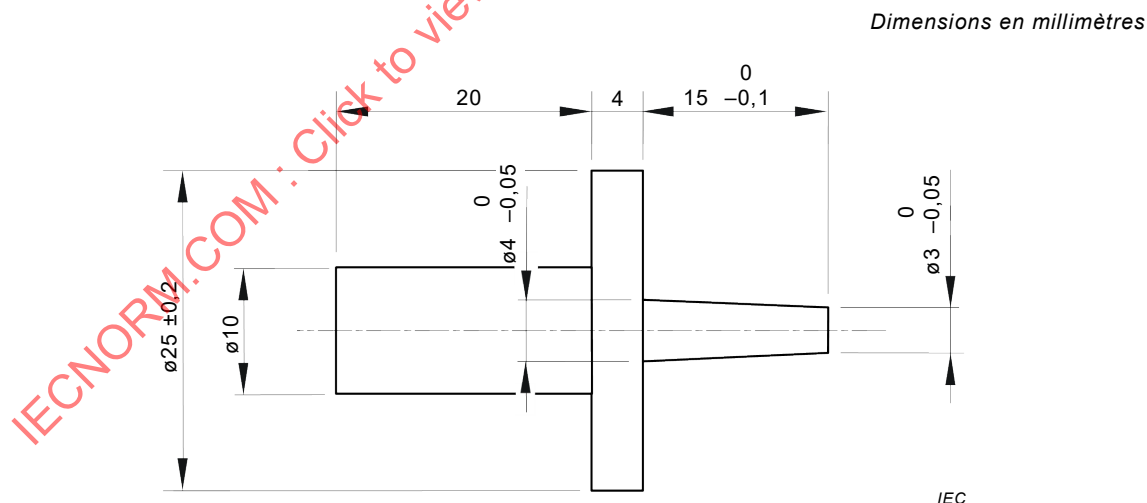
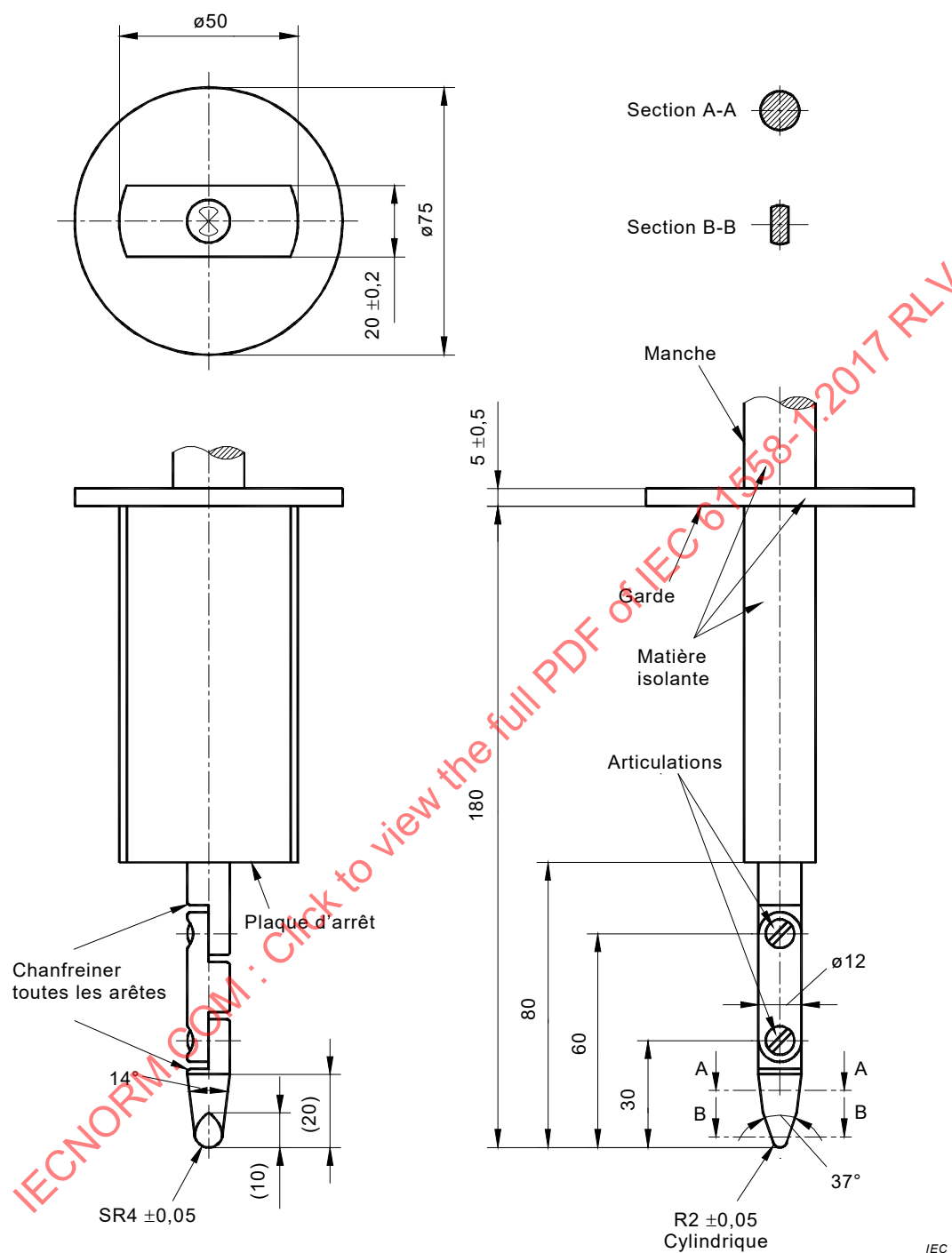


Figure 3 – Broche d'essai (voir l'IEC 61032, calibre d'essai 13)

Le doigt d'épreuve et la broche d'essai sont appliqués, sans force appréciable, dans toutes les positions possibles.

Le doigt d'épreuve de la Figure 4 est appliqué sans force appréciable, le **transformateur** étant incliné dans toutes les directions possibles, à l'exception des **transformateurs** utilisés normalement posés sur le sol et ayant une masse supérieure à 40 kg qui eux ne sont pas inclinés. Le doigt d'épreuve est appliqué aux ouvertures sur toute la profondeur possible, il est tourné ou plié en angle avant, pendant et après insertion dans toute position. Si l'ouverture ne permet pas l'entrée du doigt d'épreuve, la force est augmentée jusqu'à 20 N, le

doigt étant en position rectiligne. Si alors le doigt d'épreuve pénètre dans l'ouverture, l'essai est répété avec le doigt d'épreuve plié en angle.



Matériau: métal sauf spécification contraire

Dimensions linéaires en millimètres

Tolérances applicables aux dimensions sans indication de tolérance

sur les angles: $0/-10^\circ$

sur les dimensions:

- jusqu'à 25 mm: $\begin{matrix} 0 \\ -0,05 \end{matrix}$
- au-dessus de 25 mm: $\pm 0,2$

Les deux articulations doivent permettre un mouvement dans le même plan et le même sens de 90° avec une tolérance de 0° à $+10^\circ$.

Figure 4 – Doigt d'épreuve normalisé (voir l'IEC 61032, calibre d'essai B)

*Il ne doit pas être possible de toucher avec le doigt d'épreuve des **parties actives dangereuses** nues ou des **parties actives dangereuses** protégées seulement par un vernis, de l'émail, du papier, du coton, une pellicule d'oxyde ou de la matière de remplissage, à l'exception du **fil de bobinage totalement isolé (FIW)**.*

*Il ne doit pas être possible de toucher avec le doigt d'épreuve les parties conductrices des **transformateurs de classe II** séparées des **parties actives dangereuses** uniquement par l'**isolation principale**.*

*De plus, il ne doit pas être possible de toucher des **parties actives dangereuses** nues avec la broche d'essai.*

NOTE 2 Cette exigence ne s'applique pas aux douilles et aux prises de courant.

En cas de doute, un indicateur électrique dont la tension est de 40 V au moins est utilisé avec la broche d'essai.

9.2.3 Accessibilité aux parties actives non dangereuses

Les **parties actives non dangereuses** du **circuit secondaire** isolées du **circuit primaire** par une **isolation double** ou **renforcée** peuvent être accessibles sous les conditions suivantes:

- pour les **tensions secondaires à vide** ne dépassant pas 35 V (crête) en courant alternatif ou 60 V en courant continu lissé, les deux pôles peuvent être accessibles;
- pour les **tensions secondaires à vide** dépassant 35 V (crête) en courant alternatif ou 60 V en courant continu lissé et ne dépassant pas 250 V en courant alternatif, seul un pôle peut être accessible.

9.3 Protection contre les décharges électriques dangereuses

Pour les **transformateurs** munis d'une prise d'alimentation primaire, les broches de la prise ne doivent pas être une partie active dangereuse lors d'une mesure effectuée 1 s après débrogage de la prise.

Pour les **transformateurs** sans prise d'alimentation primaire, les bornes du **transformateur** pour la connexion à la source d'alimentation ne doivent pas être des parties actives dangereuses lors d'une mesure effectuée 5 s après coupure de la source d'alimentation.

NOTE Pour les besoins du présent paragraphe, les connecteurs de prise et socles de connecteurs sont considérés comme des fiches pour l'alimentation.

La conformité est vérifiée par l'essai suivant:

Si la capacité nominale dans les broches n'excède pas 0,1 μ F, aucun essai n'est conduit.

*S'il existe un interrupteur de l'alimentation primaire du **transformateur**, il est en position arrêt, à moins que la position marche ne soit plus défavorable.*

L'essai doit être effectué 10 fois ou à l'aide d'un dispositif de coupure avec l'angle électrique de tension d'alimentation le plus défavorable.

La tension est étre mesurée entre les bornes d'entrée ou entre les câbles d'alimentation ou entre les broches de la fiche d'alimentation utilisée pour la connexion à la source d'alimentation 1 s à 5 s après la coupure de la source d'alimentation.

Si la tension excède 60 V en courant continu lissé, la décharge est mesurée dans les mêmes conditions et ne doit pas excéder 45 μ C.

10 Changement de la tension primaire d'alimentation

Les **transformateurs** à plusieurs **tensions primaires assignées** doivent être construits de façon telle que le changement de tension ne soit pas possible sans l'aide d'un **outil**.

NOTE À titre d'exemple, l'exigence concernant le changement de tension est satisfaite s'il faut employer un **outil** pour enlever un capot avant de pouvoir changer la tension d'alimentation.

Lorsque les **transformateurs** peuvent être réglés sur plusieurs **tensions primaires assignées**, ils doivent être construits de façon telle que l'indication de la tension pour laquelle le **transformateur** est réglé soit visible sur le **transformateur** lorsqu'il est prêt à l'usage.

Les **transformateurs** avec fiche munis d'un dispositif de réglage des connexions primaires (par exemple un sélecteur) conçu pour ajuster les tensions d'alimentation à l'intérieur d'une gamme donnée dont les valeurs n'excèdent pas de plus de 10 % la valeur de tension correspondant au point milieu de cette gamme, ne sont pas considérés comme des **transformateurs** à plusieurs tensions primaires.

Les **transformateurs de sécurité** à prise ne doivent avoir qu'une seule **tension primaire assignée** à moins que le **transformateur** ne soit pas capable de produire une tension secondaire dépassant la limite autorisée pour la tension secondaire des **transformateurs de sécurité** si la tension marquée la plus élevée est appliquée à l'enroulement de tension au marquage le plus faible.

La conformité est vérifiée par mesure et examen.

11 Tension secondaire et courant secondaire en charge

11.1 Lorsque le **transformateur** est alimenté à la **tension primaire assignée**, à la **fréquence d'alimentation assignée**, et chargé avec une impédance donnant la **puissance assignée** sous la **tension secondaire assignée** et, pour le courant alternatif, sous le **facteur de puissance assigné**, la tension secondaire ne doit pas différer de la valeur assignée de plus de:

- a) 10 % pour la tension secondaire des **transformateurs résistants aux courts-circuits par construction**, à une seule **tension secondaire assignée**;
- b) 10 % pour la tension secondaire la plus élevée des **transformateurs résistants aux courts-circuits par construction**, à plusieurs **tensions secondaires assignées**;
- c) 15 % pour les autres tensions secondaires des **transformateurs résistants aux courts-circuits par construction** à plusieurs **tensions secondaires assignées**;
- d) 5 % pour les tensions secondaires des autres **transformateurs**.

Pour les **transformateurs** avec redresseurs, les valeurs ci-dessus sont à augmenter de 5.

*La vérification de la conformité consiste à mesurer la tension secondaire lorsque l'état d'équilibre est atteint, le **transformateur** étant alimenté à la **tension primaire assignée**, à la **fréquence d'alimentation assignée** et chargé avec une impédance donnant la **puissance assignée**, sous la **tension secondaire assignée** et sous le **facteur de puissance assigné**.*

*Pour les **transformateurs** combinés avec un redresseur, la tension secondaire est mesurée aux bornes du circuit à courant continu à l'aide d'un voltmètre indiquant la valeur arithmétique moyenne, à moins que cette tension ne soit indiquée spécifiquement en valeur efficace (voir 8.1).*

*Pour les transformateurs à plusieurs **tensions primaires assignées**, l'exigence s'applique pour chacune des **tensions primaires assignées**.*

Pour les **transformateurs** à plusieurs **enroulements secondaires**, les charges sont appliquées à chaque section d'enroulement simultanément, à moins qu'il en soit déclaré autrement.

11.2 Si la **puissance assignée**, la **tension secondaire assignée**, le **courant secondaire assigné** et le **facteur de puissance assigné** sont indiqués sur le **transformateur**, ces valeurs doivent être sensiblement en concordance les unes avec les autres.

Si le **courant secondaire assigné** n'est pas spécifié, il peut être calculé à partir de la **puissance assignée** et de la **tension secondaire assignée**.

La conformité est vérifiée par calcul.

12 Tension secondaire à vide

Les exigences relatives à la limitation de la **tension secondaire à vide** en fonction des différents types de **transformateurs** sont indiquées dans la partie 2 de l'IEC 61558.

*Pour les **transformateurs** combinés avec un redresseur, les mesures des tensions secondaires sont effectuées à l'entrée et à la sortie du redresseur si elles sont raccordées à des bornes. La mesure aux bornes d'entrée du redresseur n'est faite que si elles sont accessibles à l'utilisateur. La **tension secondaire** est mesurée aux bornes du circuit secondaire à l'aide d'un voltmètre indiquant la valeur moyenne arithmétique, à moins que cette tension ne soit indiquée en valeur efficace (voir 8.1).*

13 Tension de court-circuit

Si la **tension de court-circuit** fait l'objet d'un marquage, la **tension de court-circuit** mesurée ne doit pas différer de plus de 20 % de la valeur indiquée.

*La vérification de la conformité consiste à mesurer la **tension de court-circuit**, le **transformateur** étant à la température ambiante.*

14 Echauffements

14.1 Exigences générales

14.1.1 Essai d'échauffement

Les **transformateurs** et leurs supports ne doivent pas atteindre en usage normal des températures excessives.

Le constructeur peut choisir les méthodes de charges simulées selon 14.1.2.1 ou 14.1.2.2 au lieu de la méthode de charge directe qui peut être appliquée.

NOTE 1 Les méthodes de charges simulées sont conformes à l'IEC 60076-11:2004, 23.2.1 et 23.2.2.

Les températures sont déterminées dans les conditions suivantes, lorsque l'état d'équilibre est atteint.

*L'essai et les mesures sont effectués dans un emplacement sans courant d'air et ayant des dimensions telles que les résultats d'essais n'en soient pas influencés. Si le **transformateur** a une t_a assignée, l'essai est effectué à $(t_a \pm 5) ^\circ\text{C}$.*

NOTE 2 L'essai d'échauffement est effectué en ne tenant compte que de t_a (et non de t_{amin}).

Les **transformateurs mobiles** sont placés sur un support en contreplaqué, peint en noir mat. Les **transformateurs fixes** sont installés comme en usage normal, sur un support en contreplaqué peint en noir mat. Le support a approximativement 20 mm d'épaisseur et des dimensions qui dépassent d'au moins 200 mm la projection orthogonale du spécimen sur le support.

Les **transformateurs** qui sont fournis avec des broches intégrées, destinées à être introduites dans des socles fixes de prise de courant, sont soumis à essai dans un socle encastré monté dans une boîte placée sur un support en contreplaqué peint en noir mat comme indiqué à la Figure 2.

Les **transformateurs** pour pose encastrée sont soumis à essai comme décrit en 5.10.

Les **transformateurs** ayant un indice de protection autre que IP00 sont soumis à essai avec leur **enveloppe**.

Les **transformateurs** ayant un indice de protection IP00, dont l'utilisation n'est pas connue, sont soumis à essai comme indiqué en 5.13.

NOTE 3 Dans le cas de **transformateurs** avec un indice de protection IP00, la température du support est mesurée, mais les valeurs données au Tableau 2 et au Tableau 5 ne sont pas prises en considération.

Les connexions des **transformateurs** ayant des bornes pour **fixations de type X** avec des cordons préparés spécialement et avec des bornes pour **fixations des types Y et Z** doivent être soumises à une traction de 5 N immédiatement avant l'essai d'échauffement.

Les **transformateurs** sont alimentés sous la **tension primaire assignée** et chargés avec une impédance donnant la **puissance assignée** sous la **tension secondaire assignée** et, pour le courant alternatif, sous le **facteur de puissance assigné**. La valeur du courant secondaire est mesurée lorsque l'état d'équilibre est atteint. La tension d'alimentation est ensuite augmentée de 10 % et le courant secondaire est ajusté à la valeur mesurée précédemment. Le courant secondaire n'est pas ajusté pour les **transformateurs indépendants**. Après cette augmentation de la tension, aucune modification n'est apportée au circuit. L'essai est répété sans charge si cela correspond à la situation la plus défavorable.

Les **transformateurs associés** sont mis en fonctionnement dans les conditions qui se présentent lorsque l'appareil ou l'équipement fonctionne dans les conditions d'utilisation normales indiquées dans les spécifications. Les **transformateurs** en régime intermittent doivent être soumis à essai aux régimes intermittents jusqu'à ce que les conditions d'équilibre soient atteintes.

Les températures des enroulements sont déterminées par la méthode de variation de résistance.

NOTE 4 Une des méthodes consiste à effectuer les mesures séparément sur chaque enroulement et à déterminer la résistance des enroulements à la fin de l'essai, en effectuant des mesures de résistance aussitôt que possible après ouverture du circuit, puis à des intervalles rapprochés de façon à pouvoir tracer une courbe de variation de la résistance en fonction du temps permettant de déterminer la résistance au moment de l'ouverture du circuit.

La valeur de l'échauffement d'un enroulement est calculée à partir de la Formule (1):

$$\Delta t = \frac{(R_2 - R_1)}{R_1} (x + t_1) - (t_2 - t_1) \quad (1)$$

Variante de calcul de la température maximale par rapport à la température ambiante donnée par les Formules (2) et (3):

$$T = t_a + \frac{(R_2 - R_1)}{R_1} (x + t_1) - (t_2 - t_1) \quad (2)$$

ou
$$T = t_a + \Delta t \quad (3)$$

où

$x = 234,5$ pour le cuivre;

$x = 225$ pour l'aluminium;

Δt est l'échauffement au-dessus de t_2 tel que la température maximale égale $\Delta t + t_2$;

R_1 est la résistance au début de l'essai, à la température t_1 ;

R_2 est la résistance à la fin de l'essai, quand les conditions d'équilibre ont été atteintes;

t_1 est la température ambiante au début de l'essai;

t_2 est la température ambiante à la fin de l'essai;

t_a est la température ambiante;

T est la température maximale.

Au début de l'essai, les enroulements doivent être à la température ambiante.

Pour déterminer les températures des enroulements, la température ambiante est mesurée à une distance du spécimen telle que la lecture de cette température ne puisse être influencée par l'appareil en essai. A ce point, la température de l'air ne doit pas varier de plus de 10 °C pendant l'essai. Pour les **transformateurs** t_a , la température d'essai est égale à $\Delta t + t_a$.

Pour les **transformateurs** à plusieurs **enroulements primaires** ou **secondaires** ou à **enroulement primaire** ou **secondaire** à prises multiples, les résultats à considérer sont ceux qui conduisent à la température la plus élevée.

Les transformateurs ayant une résistance inférieure à 50 mΩ peuvent être également mesurés à l'aide de couples thermoélectriques. Les couples thermoélectriques doivent être uniquement montés sur des surfaces accessibles des enroulements des transformateurs. Les valeurs maximales du Tableau 2, pour les températures des enroulements, doivent être réduites de 10 °C pour les mesures effectuées à l'aide de couples thermoélectriques.

Les autres températures sont déterminées au moyen de couples thermoélectriques choisis et disposés de façon à réduire le plus possible leur influence sur la température de la partie à soumettre à essai.

Les couples thermoélectriques employés pour déterminer la température de la surface des supports sont fixés sur la face intérieure de plaquettes en cuivre ou laiton noircies de 1 mm d'épaisseur et 15 mm de diamètre, encastrées, de niveau avec la surface.

La température de l'isolation électrique (autre que celle des enroulements) est déterminée à la surface de l'isolation, aux endroits où un défaut pourrait établir un contact entre les **parties actives dangereuses** et les **parties conductrices** accessibles ou réduire les **lignes de fuite** ou les **distances d'isolement** au-dessous des valeurs spécifiées à l'Article 26. De plus, des couples thermoélectriques doivent être placés sur les points les plus chauds du matériau isolant pour éviter un risque de feu.

Pendant l'essai, la température ne doit pas dépasser les valeurs indiquées au Tableau 2 lorsque le **transformateur** fonctionne à sa **température ambiante assignée** (25 °C ou t_a). Dans les cas où la température dans la zone d'essai est différente de la **température**

ambiante assignée, cette différence doit être prise en compte lorsque les limites du Tableau 2 sont appliquées et lorsque l'on fait les essais en température de 27.2 et 27.5.

14.1.2 Variante d'essai d'échauffement

14.1.2.1 Méthode de charge simulée

Cette méthode est applicable à un transformateur de type sec enfermé, non enfermé ou totalement enfermé avec ventilation naturelle ou forcée.

L'échauffement est établi en combinant l'essai en court-circuit (pertes dues à la charge) et l'essai en circuit ouvert (pertes à vide).

La température du **transformateur** doit être stabilisée par rapport à la température ambiante du laboratoire. La résistance des enroulements primaire et secondaire doit être mesurée; ces valeurs seront utilisées comme des valeurs de référence pour le calcul de l'échauffement des deux enroulements. La température ambiante du laboratoire d'essai doit être également mesurée et consignée.

Pour les **transformateurs** triphasés, les mesures de résistance doivent être effectuées entre la borne centrale et une borne d'extrémité de phase.

L'emplacement des points de mesure (à savoir, les thermomètres de température ambiante et capteurs sur le **transformateur**, le cas échéant) doit être le même pour les mesures de référence et les mesures finales.

L'essai en court-circuit doit être effectué avec le courant assigné circulant dans un enroulement et l'autre enroulement en court-circuit; l'essai doit se poursuivre jusqu'à ce que la condition d'équilibre des enroulements et du noyau magnétique soient atteintes. L'échauffement des enroulements, $\Delta\theta_c$, doit être déterminé à partir de l'échauffement obtenu par la méthode de variation de résistance ou par superposition.

L'essai en circuit ouvert, à la tension assignée et à la **fréquence assignée**, doit se poursuivre jusqu'à ce que la condition d'équilibre de l'enroulement et du noyau magnétique soit atteinte; ensuite, les échauffements des enroulements individuels, $\Delta\theta_e$, doivent être mesurés.

La procédure d'essai doit être comme suit:

- poursuite de l'essai d'enroulement en court-circuit jusqu'à stabilisation de la température du noyau et de l'enroulement. Ensuite, un essai en circuit ouvert doit être effectué jusqu'à ce que la température du noyau et de l'enroulement soit stabilisée;

ou

- l'essai d'enroulement en circuit ouvert doit être effectué jusqu'à ce que la température du noyau et de l'enroulement soit stabilisée. Ensuite, un essai d'enroulement en court-circuit doit être effectué jusqu'à ce que la température du noyau et de l'enroulement soit stabilisée.

L'échauffement total, $\Delta\theta'_c$, de chaque enroulement, avec circulation du courant assigné dans l'enroulement et excitation normale du noyau, est calculé par la Formule (4):

$$\Delta\theta'_c = \Delta\theta_c \left[1 + \left(\frac{\Delta\theta_e}{\Delta\theta_c} \right)^{1/K1} \right]^{K1} \quad (4)$$

où

$\Delta\theta'_c$ est l'échauffement total de l'enroulement;

$\Delta\theta_c$ est la température de l'enroulement lors de l'essai en court-circuit;

$\Delta\theta_e$ est la température de l'enroulement individuel lors de l'essai en circuit ouvert;

$Kl = 0,8$ pour une ventilation naturelle et $0,9$ pour une ventilation forcée.

14.1.2.2 Méthode d'essai en opposition

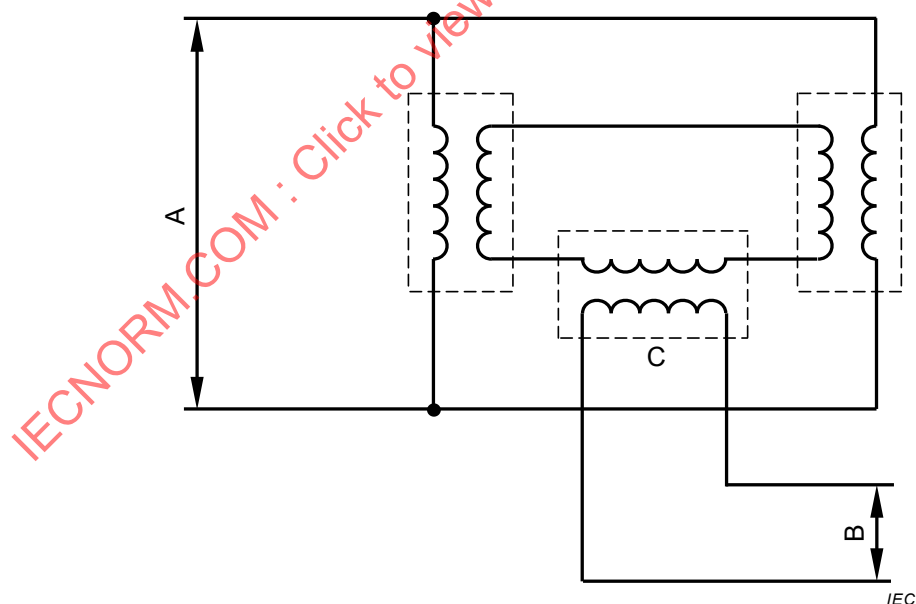
*Cette méthode est appropriée lorsqu'il y a deux **transformateurs** similaires et que le matériel d'essai nécessaire est disponible. Elle est applicable aux transformateurs enfermés ou non enfermés avec ventilation naturelle ou forcée.*

*La température du **transformateur** doit être stabilisée par rapport à la température ambiante du laboratoire. La résistance des enroulements haute tension et basse tension doit être mesurée; ces valeurs seront utilisées comme des valeurs de référence pour le calcul de l'échauffement des deux enroulements. La température ambiante du laboratoire d'essai doit être également mesurée et consignée.*

L'emplacement des points de mesure doit être le même pour les mesures de référence et les mesures finales.

*Deux **transformateurs**, dont l'un est le **transformateur** soumis à essai, sont connectés en parallèle et les enroulements, de préférence les enroulements intérieurs, sont alimentés sous la tension assignée du **transformateur** en essai. Au moyen de différents rapports de tensions ou d'une tension injectée, on fait circuler le courant assigné dans le **transformateur** en essai jusqu'à stabilisation des températures du noyau et des enroulements. Voir Figure 5 et Figure 6.*

La durée de l'essai peut être réduite en alimentant au préalable le noyau magnétique pendant une période (de préférence non inférieure à 12 h) avant d'appliquer le courant d'essai aux enroulements.



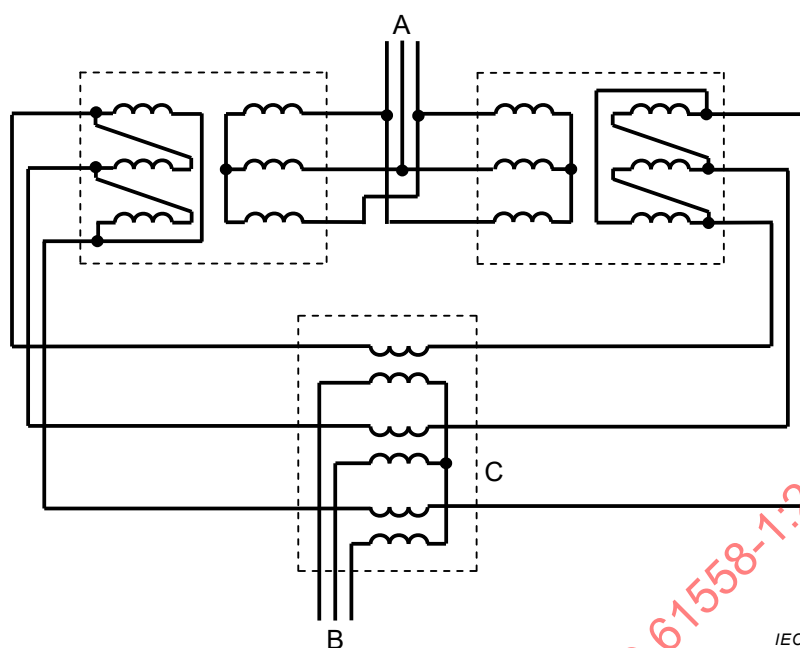
Légende

A = Source de tension à la fréquence assignée pour les pertes à vide

B = Source de courant assignée à la fréquence assignée pour les pertes dues à la charge

C = Transformateur survolteur-dévolteur

Figure 5 – Exemple de méthode d'essai en opposition – Transformateurs monophasés



Légende

- A = Source de tension à la fréquence assignée pour les pertes à vide
- B = Source de courant assigné à la fréquence assignée pour les pertes dues à la charge
- C = Transformateur survolteur-dévolteur

Figure 6 – Exemple de méthode d'essai en opposition – Transformateurs triphasés

14.1.3 Détermination des conditions d'équilibre

L'échauffement limite est atteint lorsque la température devient constante; on considère que cet état est atteint lorsque l'échauffement ne varie pas de plus de 1 K par heure.

Pour déterminer le moment auquel les conditions d'équilibre sont atteintes, des couples thermoélectriques doivent être appliqués aux surfaces suivantes:

- *Pour tous les types de transformateurs définis à l'Article 3: centre de la culasse supérieure et aussi près que possible de l'enroulement le plus intérieur au niveau de sa partie supérieure, la mesure étant effectuée au niveau de la jambe centrale pour un transformateur triphasé.*

Tableau 2 – Valeurs des températures maximales en usage normal

Parties ^a	Température °C
Enroulements, si le système d'isolation (c'est-à-dire bobines et tout autre matériau isolant en contact avec celles-ci), est:	
– en matériau de la classe A ^b	100
– en matériau de la classe E ^b	115
– en matériau de la classe B ^b	120
– en matériau de la classe F ^b	140
– en matériau de la classe H ^b	165
– en autre matériau ^c	–
Enveloppes externes ^{d,f} (qui peuvent être touchées avec le doigt d'épreuve normalisé) de transformateurs fixes , si elles sont en:	
– métal nu	65
– métal revêtu de vernis	70
– autre matériau	80
Enveloppes externes ^{d,f} (qui ne peuvent pas être touchées avec le doigt d'épreuve normalisé) de transformateurs fixes	85
Enveloppes externes ^{d,f} , poignées et organes analogues de transformateurs mobiles :	
– si, en usage normal, ces parties sont tenues de façon continue (par exemple pour les transformateurs portatifs):	
• en métal	48
• en autre matériau	48
– si, en usage normal, ces parties ne sont pas tenues de façon continue:	
• en métal	60
• en autre matériau	80
Bornes pour conducteurs externes et bornes d'interrupteurs	70
Enveloppe isolante des conducteurs internes et externes ^e :	
– en caoutchouc	65
• en polychlorure de vinyle	70
Parties dont la détérioration pourrait affecter la sécurité ^e :	
– en caoutchouc (autre que l'enveloppe isolante des conducteurs)	75
• en phénol-formaldéhyde	105
• en urée-formaldéhyde	85
• en papier et tissu imprégnés	85
• en bois imprégné	85
• en polychlorure de vinyle (autre que l'enveloppe isolante des conducteurs), polystyrène et matériaux thermoplastiques analogues	65
• en toile vernie	75
Supports	85
Circuits imprimés ^e :	
– imprégnés de phénol-formaldéhyde, mélamine-formaldéhyde, phénol-furfural ou polyester	105
• imprégnés de résines époxy	140
^a S'il est fait usage d'autres matériaux, ils ne doivent pas être exposés à des températures supérieures à celles qui sont admissibles pour ces matériaux. ^b La classification des matériaux est conforme à l'IEC 60085 et à l'IEC 60216 (toutes les parties); toutefois les valeurs ont été ajustées pour tenir compte du fait que, dans ces essais, les températures sont des températures moyennes et non des températures de point chaud. ^c Si des matériaux autres que ceux spécifiés dans l'IEC 60085 et l'IEC 60216 (toutes les parties) sont utilisés, ils doivent satisfaire à l'essai de 14.3. ^d Si un élément quelconque constitue une partie de la surface externe du transformateur, la température de cet élément ne doit pas dépasser la valeur spécifiée pour l'enveloppe considérée. ^e Les qualités des isolants en caoutchouc et en polychlorure de vinyle sont celles définies respectivement par l'IEC 60245 (toutes les parties) et l'IEC 60227 (toutes les parties). ^f Si la limite de température de surface des pièces accessibles dépasse les valeurs requises, le symbole d'avertissement IEC 60417-5041 (2002-10) doit être utilisé.	

On trouvera dans le Tableau 3 une explication de la réduction appropriée du point chaud pour la température maximale d'enroulement pour chaque classification d'isolation conforme à l'IEC 60085.

**Tableau 3 – Explication des températures maximales
des enroulements requises dans le Tableau 2**

Classification de l'isolation selon l'IEC 60085	Températures maximales du Tableau 2 °C	Réduction des points chauds K	Température finale maximale selon l'IEC 60085 °C
Classe A	100	5	105
Classe E	115	5	120
Classe B	120	10	130
Classe F	140	15	155
Classe H	165	15	180
Le mesurage de la température des enroulements est basé sur la méthode de résistance. Ainsi, les valeurs mesurées sont des valeurs moyennes de la température des enroulements. Pour couvrir également les valeurs de crête à l'intérieur de l'enroulement, la réduction des points chauds est nécessaire.			

L'élévation de température d'éléments chauffants du dispositif de protection en contact avec les matériaux isolants doit être mesurée également.

*Immédiatement après l'essai, le spécimen doit satisfaire à l'essai de rigidité diélectrique spécifié en 18.3, les valeurs sont spécifiées dans le Tableau 14, la tension d'essai étant appliquée uniquement entre les enroulements **primaires** et **secondaires**.*

*Pendant et après l'essai, les connexions électriques ne doivent pas s'être desserrées, les **lignes de fuite** et **distances d'isolement** ne doivent pas être réduites au-dessous des valeurs prescrites à l'Article 26, la matière de remplissage ne doit pas s'écouler et les dispositifs de protection contre les surcharges ne doivent pas fonctionner.*

NOTE Selon l'IEC 60038, la tolérance de $\pm 10\%$ pour la tension nominale s'applique également pour une valeur de tension alternative jusqu'à 1 000 V et une valeur de tension continue jusqu'à 1 415 V.

14.2 Application de 14.1 ou 14.3 selon le système d'isolation

Ce qui suit s'applique aux enroulements.

14.2.1 *Si le constructeur a spécifié quelle classe de système d'isolation a été utilisée, la température mesurée de l'enroulement ne doit pas dépasser la valeur correspondante donnée au Tableau 2 (compte tenu de la valeur de t_a si spécifiée).*

14.2.2 *Si le constructeur n'a pas spécifié quelle classe de système d'isolation a été utilisée, la température mesurée de l'enroulement ne doit pas dépasser la valeur donnée au Tableau 2 pour les systèmes d'isolation de classe A (compte tenu de la valeur de t_a si spécifiée).*

14.2.3 *Si le constructeur n'a pas spécifié quelle classe de système d'isolation a été utilisée et si la température mesurée de l'enroulement dépasse la valeur donnée au Tableau 2 pour les systèmes d'isolation de classe A (compte tenu de la valeur de t_a si spécifiée), les **parties actives** (noyau et enroulements) du **transformateur** sont soumises aux essais de 14.3. La température dans l'enceinte thermique est choisie selon le Tableau 4, en prenant en compte la valeur de t_a . La valeur de la température à choisir dans le Tableau 4 est la valeur immédiatement supérieure à la valeur de la température mesurée.*

14.3 Essai de vieillissement accéléré pour système d'isolation non classifié

14.3.1 Généralités

*Dans les cas où cela s'applique (voir 14.2, 19.12.3 et 26.3), les **parties actives** du transformateur (noyau et enroulements) sont soumises à l'essai de vieillissement ci-après,*

chaque cycle étant constitué par un essai à la chaleur, un essai à l'humidité et un essai de vibrations. Les mesures sont effectuées conformément à 14.3.5.

Le nombre de spécimens est celui indiqué en 5.2. Les spécimens sont soumis à 10 cycles d'essai.

14.3.2 Essai à la chaleur

En fonction du type d'isolation, les spécimens sont maintenus dans une enceinte thermique selon la combinaison température-durée spécifiée au Tableau 4. Les 10 cycles sont réalisés avec la même combinaison.

La température dans l'enceinte est maintenue avec une tolérance de ± 3 °C.

Tableau 4 – Température et durée d'essai (en jours) par cycle

Température d'essai °C	Durée d'essai en fonction de la température des systèmes d'isolation (jours)				
	100 °C	115 °C	120 °C	140 °C	165 °C
220					4
210					7
200					14
190				4	
180				7	
170				14	
160			4		
150		4	7		
140		7			
130	4				
120	7				
Classification correspondante selon l'IEC 60085 et l'IEC 60216 (toutes les parties)	A	E	B	F	H

Après les essais à la chaleur, les spécimens sont ramenés à la température ambiante avant l'exécution de l'essai de vibrations.

14.3.3 Essai de vibrations

Les spécimens sont fixés, dans leur position normale d'utilisation, au générateur de vibrations, comme spécifié dans l'IEC 60068-2-6 au moyen de courroies passées autour de l'enveloppe. La direction des vibrations est verticale, et la sévérité est définie comme suit:

- durée: 30 min;
- amplitude: 0,35 mm;
- plage de fréquences: 10 Hz, 55 Hz, 10 Hz;
- balayage: approximativement une octave par minute.

14.3.4 Essai d'humidité

Les spécimens sont soumis pendant deux jours (48 h) à l'essai d'humidité prévu en 17.2.

14.3.5 Mesures

Tous les essais et mesures qui suivent sont effectués avant le premier cycle et après chaque fin des cycles suivants:

- le courant primaire à vide ou sa valeur ohmique.
La valeur du courant primaire à vide ou la valeur ohmique du courant primaire à vide ne doit pas être supérieure de plus 30 % à la valeur correspondante obtenue lors de la mesure initiale;
- la résistance d'isolement est mesurée selon 18.1 et 18.2;
- un essai de rigidité diélectrique selon 18.3 et 18.4. Cependant les valeurs des tensions d'essai sont réduites à 35 % des valeurs spécifiées et le temps d'essai est doublé;
- l'essai suivant seulement pour les **transformateurs** ayant une **fréquence d'alimentation assignée** de 50 Hz ou 60 Hz. Après l'essai de rigidité diélectrique, un **circuit primaire** est alimenté pendant 5 min sous une tension d'essai d'au moins 1,2 fois la **tension d'alimentation assignée**, la fréquence étant égale à deux fois la **fréquence d'alimentation assignée**. Aucune charge n'est connectée au **transformateur**. Pendant l'essai, les enroulements multifilaires, s'il y a lieu, sont connectés en série. Une fréquence d'essai plus élevée que le double de la fréquence d'alimentation peut être utilisée; la durée de la période de connexion, en minutes, étant égale à 10 fois la **fréquence d'alimentation assignée** divisée par la fréquence d'essai, mais pas inférieure à 2 min.

Au cours des essais ci-dessus, il ne doit se produire aucune perforation de l'isolation entre les spires d'un enroulement, entre les **circuits primaire et secondaire**, entre les **circuits primaire et secondaire** adjacents, ou entre les enroulements et un noyau conducteur quel qu'il soit.

Si après l'achèvement de l'ensemble des 10 cycles, un ou plusieurs spécimens sont défaillants, le **transformateur** est considéré comme ne satisfaisant pas à l'essai de vieillissement accéléré.

15 Protection contre les courts-circuits et les surcharges

15.1 Exigences générales

15.1.1 Méthode d'essai de court-circuits et de surcharges

Les **transformateurs** ne doivent pas devenir dangereux en cas de courts-circuits et de surcharges susceptibles de se produire en usage normal.

La conformité est vérifiée par examen et par les essais suivants, qui sont effectués immédiatement après l'essai selon 14.1, à la même température ambiante, sans changer la position du **transformateur**, à 1,1 fois la **tension primaire assignée** ou, pour les **transformateurs résistants aux courts-circuits par dispositif incorporé**, à toute valeur de la tension d'alimentation comprise entre 0,9 fois et 1,1 fois la **tension primaire assignée**:

- pour les **transformateurs résistants aux courts-circuits par construction**, par les essais de 15.2;
- pour les **transformateurs résistants aux courts-circuits par dispositif incorporé**, par les essais de 15.3;
- pour les **transformateurs non résistants aux courts-circuits**, par les essais de 15.4;
- pour les **transformateurs non dangereux en cas de défaillance**, par les essais de 15.5;
- pour les **transformateurs** combinés avec un redresseur, les essais de 15.2 ou 15.3 sont effectués deux fois, une fois avec le court-circuit appliqué sur la borne d'entrée du redresseur et ensuite avec le court-circuit appliqué sur les bornes de sortie du redresseur;
- pour les **transformateurs à plusieurs enroulements secondaires** ou à **enroulement secondaire** à prises multiples, les résultats à prendre en considération sont ceux qui

conduisent à la température la plus élevée. Dans le premier cas, tous les enroulements destinés à être chargés en même temps sont chargés à leur **puissance assignée** et le court-circuit est établi sur l'**enroulement secondaire** sélectionné.

Pour les essais de 15.2, 15.3 et 15.4, les températures ne doivent pas dépasser les valeurs données au Tableau 5 lorsque le **transformateur** fonctionne à sa **température ambiante assignée** (25 °C ou t_a). Dans les cas où la température dans la zone d'essai est différente de la **température ambiante assignée**, cette différence doit être prise en compte lorsque les limites du Tableau 5 sont appliquées.

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**Tableau 5 – Valeurs maximales des températures
en cas de court-circuit ou de surcharge**

Classification de l'isolation	A	E	B	F	H
	Température maximale °C				
Enroulement protégé par construction Paragraphe 15.2	150	165	175	190	210
Enroulement protégé par un dispositif de protection:					
a) Paragraphes 15.3.2 – 15.3.3 – 15.3.4 — pendant le temps requis <i>T</i> donné au Tableau 6 ^a	200	215	225	240	260
b) Paragraphe 15.3.1 — pendant la première heure, valeur de crête — après la première heure, valeur de crête — après la première heure, valeur arithmétique moyenne ^b	200 175 150	215 190 165	225 200 175	240 215 190	260 235 210
c) Paragraphe 15.3.5	175	190	200	215	235
Enveloppes extérieures (qui peuvent être touchées avec le doigt d'épreuve normalisé)	105				
Isolation caoutchouc du câblage	85				
Isolation PVC du câblage	85				
Support (c'est-à-dire tout point situé sur la surface de contreplaqué en pin couverte par le transformateur)	105				

^a La température maximale à considérer est la température maximale atteinte durant et après l'essai en raison de l'inertie thermique du **transformateur**.

^b La moyenne arithmétique est déterminée de la façon suivante:

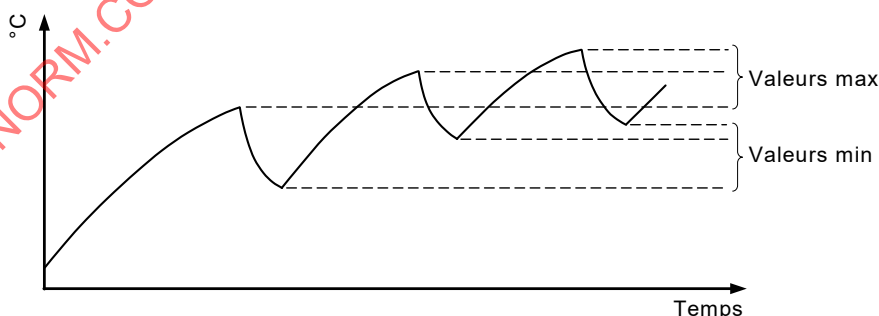
Le graphe de la température en fonction du temps pendant que le **transformateur** est alimenté de façon cyclique est tracé pendant toute la durée de l'essai en considération. La température moyenne arithmétique (*t_A*) est déterminée par la Formule (5):

$$t_A = (t_{\max} + t_{\min})/2 \tag{5}$$

où

t_{max} est la moyenne des valeurs maximales;

t_{min} est la moyenne des valeurs minimales.



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Pendant l'essai, le **transformateur** ne doit pas émettre de flammes, de métal en fusion, de gaz toxique ou inflammable en quantité dangereuse, et les températures ne doivent pas dépasser les valeurs indiquées au Tableau 5.

Pendant et après tous les essais, le **transformateur** doit répondre aux exigences de l'Article 9.

Après les essais, l'isolation, refroidie approximativement à la température ambiante, doit satisfaire à l'essai de rigidité diélectrique de 18.3.

NOTE L'épreuve d'humidité de 17.2 n'est pas réalisée avant cet essai de rigidité diélectrique.

15.1.2 Variante de méthode d'essai de court-circuits et de surcharges

Le constructeur peut choisir d'appliquer l'une des méthodes suivantes, décrites aux 14.1.2.1 et 14.1.2.2. Ces procédures d'essai sont conformes à l'IEC 60076-11:2004, 23.2.1 et 23.2.2.

15.2 Transformateurs résistants aux courts-circuits par construction

Les **transformateurs résistants aux courts-circuits par construction** sont soumis à essai en mettant en court-circuit les **enroulements secondaires** jusqu'à ce que les conditions d'équilibre soient atteintes.

15.3 Transformateurs résistants aux courts-circuits par dispositif incorporé

Les **transformateurs résistants aux courts-circuits par dispositif incorporé** sont soumis à essai comme indiqué ci-dessous:

15.3.1 Les bornes secondaires sont mises en court-circuit. Le dispositif de protection contre les surcharges incorporé doit fonctionner avant que la température ne dépasse les valeurs indiquées dans le Tableau 5 pour toute valeur de la tension d'alimentation comprise entre 0,9 fois et 1,1 fois la **tension primaire assignée**.

15.3.2 Si la protection est assurée par un fusible conforme soit à l'IEC 60269-2, soit à l'IEC 60269-3, ou par un fusible techniquement équivalent, le **transformateur** est chargé pendant un temps T avec un courant égal à k fois le courant marqué sur le **transformateur** comme courant assigné de l'élément de remplacement du fusible de protection, où k et T ont la valeur indiquée au Tableau 6. Le courant dans le fusible doit être maintenu constant pendant l'essai. L'élément fusible est remplacé par une connexion d'impédance négligeable.

Tableau 6 – Valeurs de T et k pour les fusibles

Valeur indiquée comme courant assigné I_n de l'élément de remplacement du fusible de protection gG et gTr A	T h	k
$I_n \leq 4$	1	2,1
$4 < I_n \leq 16$	1	1,9
$16 < I_n \leq 63$	1	1,6
$63 < I_n \leq 160$	2	1,6
$160 < I_n \leq 200$	3	1,6
$200 < I_n \leq 1\,000$	2	1,5

NOTE 1 Pour les fusibles cylindriques gG de type B destinés à être utilisés par des personnes non qualifiées selon l'IEC 60269-3:2010 et pour les fusibles utilisables par des personnes autorisées avec des éléments de remplacement pour raccords boulonnés selon l'IEC 60269-2:2013, la valeur de k est de 1,6 pour $I_n < 16$ A.

NOTE 2 Pour les fusibles de type D destinés à être utilisés par des personnes non qualifiées selon l'IEC 60269-3:2010 pour un courant assigné de 16 A, la valeur de k est de 1,9.

15.3.3 Si la protection est assurée par des fusibles miniatures conformes à l'IEC 60127 (toutes les parties) ou par des éléments fusibles de type à lame pour véhicules routiers conformes à l'ISO 8820 (toutes les parties) ou par un fusible techniquement équivalent, le **transformateur** est chargé pendant une période correspondant au plus long temps de pré-arc avec le courant adéquat comme spécifié dans la feuille de norme appropriée. Le courant dans le fusible doit être maintenu constant pendant l'essai. L'élément fusible est remplacé par une connexion d'impédance négligeable.

NOTE Un fusible techniquement équivalent est un élément fusible ayant les mêmes caractéristiques temps/courant que l'un de ceux indiqués dans l'IEC 60127 (toutes les parties) ou l'ISO 8820 (toutes les parties).

*Si la protection du **transformateur** est assurée par des fusibles miniatures conformes à l'IEC 60127 (toutes les parties), un essai de surcharge supplémentaire doit être effectué à 1,5 fois le courant assigné du fusible jusqu'à ce que les conditions d'équilibre soient atteintes.*

15.3.4 *Si la protection est assurée par un disjoncteur conforme à l'IEC 60898 (toutes les parties), ou par un disjoncteur techniquement équivalent, le **transformateur** est chargé pendant le temps requis par l'IEC 60898 (toutes les parties) avec un courant égal à 1,45 fois la valeur du courant assigné du disjoncteur. Le courant dans le fusible doit être maintenu constant pendant l'essai. Le disjoncteur est remplacé par une connexion d'impédance négligeable.*

15.3.5 Si la protection est assurée par:

- *un dispositif de protection contre les surcharges autre qu'un fusible conforme à l'IEC 60127 (toutes les parties) ou à l'IEC 60269 (toutes les parties) ou qu'un disjoncteur, ou*
- *une **partie affaiblie intentionnellement***

*le **transformateur** est chargé avec un courant égal à 0,95 fois la valeur la moins élevée du courant qui provoque le fonctionnement du dispositif, jusqu'à ce que les conditions d'équilibre soient atteintes. Le courant de déclenchement le plus faible est déterminé en commençant par faire fonctionner le **transformateur** à 100 % de sa **puissance assignée** et en augmentant progressivement le courant par paliers de 2 % jusqu'à ce que le dispositif de protection fonctionne (chaque palier étant maintenu jusqu'à obtention des conditions d'équilibre).*

*Si le dispositif de protection est une **partie affaiblie intentionnellement**, l'essai ci-dessus est répété sur deux nouveaux échantillons. Pendant l'essai sur le premier de ces nouveaux échantillons, la partie affaiblie doit ouvrir le circuit de la même façon et au même endroit que dans l'essai ci-dessus. Pendant l'essai sur le second échantillon, la température ne doit pas dépasser les valeurs du Tableau 5 dans les conditions d'équilibre.*

15.4 Transformateurs non résistants aux courts-circuits

*Les **transformateurs non résistants aux courts-circuits** sont soumis à essai comme indiqué en 15.3, avec le dispositif de protection adéquat spécifié par le constructeur inséré dans le **circuit primaire** ou **secondaire** approprié.*

*Les **transformateurs** associés **non résistants aux courts-circuits** sont soumis à essai dans les conditions les plus défavorables en usage normal, le dispositif de protection spécifié par le constructeur étant inséré dans le **circuit primaire** ou dans le **circuit secondaire**, et dans les conditions de charge les plus défavorables pour le type d'appareil ou de circuit pour lequel le **transformateur** est conçu. Comme exemples de conditions de charges défavorables, on peut citer le fonctionnement en service permanent, intermittent ou temporaire.*

15.5 Transformateurs non dangereux en cas de défaillance

15.5.1 Trois spécimens supplémentaires sont utilisés seulement pour l'essai ci-après.

Pendant cet essai, si le **transformateur** est défaillant, la coupure doit se produire dans le **circuit primaire**.

*Chacun des trois spécimens est monté comme en usage normal sur une surface de contreplaqué de 20 mm d'épaisseur peinte en noir mat et mis en température conformément à 14.1 jusqu'à ce que la température se stabilise. Chaque **transformateur** est alimenté sous 1,1 fois la **tension primaire assignée**, l'**enroulement secondaire** qui présente l'échauffement le plus élevé pendant l'essai de 14.1 étant initialement chargé à 1,5 fois le*

courant secondaire assigné (ou, si cela n'est pas possible, à la valeur maximale du courant secondaire que l'on peut obtenir) jusqu'à ce que l'état d'équilibre soit atteint ou que le **transformateur** soit défaillant (selon ce qui advient en premier).

Si le **transformateur** est défaillant, il doit, pendant et après les essais, répondre aux critères de 15.5.2.

Si le **transformateur** n'est pas défaillant, le temps pour atteindre l'état d'équilibre est noté et l'**enroulement secondaire** choisi est alors en court-circuit. L'essai est poursuivi jusqu'à ce que le **transformateur** soit défaillant. Pour cette partie de l'essai, le temps jusqu'à la défaillance du spécimen ne doit pas être plus long que le temps nécessaire pour atteindre l'état d'équilibre, et ne doit pas être supérieur à 5 h.

Le **transformateur** doit devenir défaillant sans danger et répondre, pendant et après les essais, aux critères de 15.5.2.

15.5.2 A tout moment, pendant les essais de 15.5.1:

- aucune partie de l'**enveloppe des transformateurs** pouvant être touchée par le doigt d'épreuve normalisé (Figure 4) ne doit présenter une température supérieure à 175 °C;
- la température du support en contreplaqué ne doit en aucun endroit dépasser 125 °C;
- les **transformateurs** ne doivent pas émettre de flammes, de matière fondue, de particules incandescentes ou de gouttes brûlantes de matière isolante.

Après les essais de 15.5.1 et après refroidissement à la température ambiante:

- les **transformateurs** doivent résister à un essai de rigidité diélectrique, la tension d'essai étant égale à 35 % des valeurs indiquées à l'Article 18, Tableau 14. L'essai est effectué entre primaire et **masse** pour tous les types de **transformateurs** et, en plus, entre primaire et secondaire pour les **transformateurs de sécurité, de séparation de circuits et d'isolement à enroulements séparés**;
- les **enveloppes**, s'il y a lieu, ne doivent pas présenter d'orifices permettant la pénétration du doigt d'épreuve normalisé (Figure 4) jusqu'à des **parties actives dangereuses** nues. En cas de doute, le contact avec des **parties actives dangereuses** nues est décelé électriquement, la tension étant de 40 V au moins.

Si le **transformateur** ne satisfait pas à l'une ou l'autre des parties de ce paragraphe, le **transformateur** est considéré comme non conforme à l'essai d'endurance ci-dessus.

16 Résistance mécanique

16.1 Généralités

Les **transformateurs** doivent avoir une résistance mécanique suffisante et être construits de façon à pouvoir supporter les manutentions brutales susceptibles de se produire en usage normal.

La conformité est vérifiée par les essais de 16.2 pour les **transformateurs fixes**, et par les essais de 16.2, 16.3 et 16.4, selon ce qui s'applique, pour les **transformateurs mobiles**.

Après les essais, le **transformateur** ne doit présenter aucun dommage conformément aux exigences du présent document. En particulier, les **parties actives dangereuses** ne doivent pas devenir accessibles lorsqu'elles sont soumises à essai comme indiqué en 9.2.2. Les barrières isolantes ne doivent pas être endommagées et les poignées, les leviers, les boutons et similaires ne doivent pas s'être déplacés sur leurs axes.

NOTE 1 Les détériorations de la finition, les faibles enfoncements qui ne réduisent pas les **lignes de fuite** ou les **distances d'isolement** au-dessous des valeurs spécifiées à l'Article 26, de même que les petites ébréchures qui n'altèrent pas la protection contre les chocs électriques ou l'humidité ne sont pas pris en compte.

NOTE 2 Les fissures non visibles à la vision normale ou corrigée sans grossissement et les fissures superficielles dans des matières moulées renforcées de fibres et matières analogues ne sont pas prises en compte.

De plus, pour l'essai de 16.4, la courbure des broches pendant l'essai n'est pas prise en compte.

16.2 Transformateurs fixes

Le **transformateur**, muni de ses capots ou pièces analogues, est maintenu fermement contre un support rigide et est soumis à trois chocs au moyen du marteau à ressort conformément à l'essai Ehb de l'IEC 60068-2-75, avec une énergie de $(0,5 \pm 0,05)$ J, appliqués à tous les points, y compris les leviers, poignées, boutons et organes analogues, de la surface extérieure qui protège les **parties actives dangereuses** et qui sont susceptibles d'être faibles en appuyant le nez du marteau perpendiculairement à la surface. Avant que les coups ne soient appliqués, les vis ou écrous des bases et capots sont serrés avec un couple égal aux deux tiers de celui spécifié au Tableau 18.

En cas de doute quant à l'apparition d'un défaut produit par l'application des coups précédents, le défaut en question n'est pas pris en compte, et le groupe de trois coups est appliqué au même emplacement sur un nouvel échantillon, qui doit alors résister à l'essai.

Les parties des **transformateurs** ayant un indice IP00 qui ne sont pas accessibles quand le **transformateur** est monté sur un appareil ou un autre équipement ne sont pas soumises à cet essai.

16.3 Transformateurs mobiles (excepté les transformateurs mobiles avec fiches intégrées pour enfichage dans une prise de courant de l'installation fixe)

Les **transformateurs mobiles**, excepté les **transformateurs mobiles** avec fiches intégrées pour enfichage dans une prise de courant de l'installation fixe, sont maintenus dans leur position normale d'emploi et sont alors soumis à 100 chutes d'une hauteur de 25 mm, sur une plaque lisse d'acier d'au moins 5 mm d'épaisseur, placée sur un support plan de béton, à une cadence n'excédant pas une chute toutes les 5 s.

La hauteur de chute doit être mesurée à partir de la partie du spécimen la plus proche de la surface d'essai lorsque le spécimen est suspendu, avant qu'on ne le laisse tomber.

La méthode de libération du spécimen doit être telle que la chute se produise librement depuis la position de suspension, avec un minimum de perturbation au moment de la libération.

Si le **transformateur** est fourni avec un ou plusieurs **câbles souples externes** fixes, les câbles sont coupés à une longueur de 100 mm.

16.4 Transformateurs mobiles avec fiches intégrées pour enfichage dans une prise de courant de l'installation fixe

16.4.1 Exigences générales

Les **transformateurs mobiles** qui sont fournis avec des broches intégrées, prévues pour être introduites dans des prises de courant fixes, doivent avoir une résistance mécanique adéquate.

Les blocs d'alimentation enfichables avec prise principale intégrée conforme à l'IEC TR 60083, sans prises conformes à l'EN 50075 (prise IEC de type C), doivent être soumis à essai conformément à 16.4.1.

Les blocs d'alimentation enfichables avec prise principale intégrée conforme à l'EN 50075 (prise IEC de type C) doivent être soumis à essai conformément à 16.4.2, si aucune norme nationale ou réglementation supplémentaire supplémentaire n'est requise pour une prise conforme à l'IEC TR 60083.

NOTE 1 Les pays utilisant ce type de prise sont mentionnés par le terme «prise de type C» (disponibles à l'adresse <http://www.iec.ch/worldplugs/typeC.htm>).

La conformité est vérifiée en réalisant les essais a) b) et c). L'essai a) est réalisé sur 3 échantillons qui doivent tous satisfaire à cet essai. Les deux essais b) et c) sont effectués sur un nouvel échantillon.

- a) *L'essai est réalisé dans un tambour tournant comme décrit dans l'IEC 60068-2-31. Si le transformateur est fourni avec un ou plusieurs câbles souples externes fixes, ils sont coupés à une longueur de 100 mm. Chaque échantillon est soumis à essai individuellement.*

Le tambour est soumis à une rotation de cinq tours par minute conduisant à 10 chutes par minute, le nombre total de chutes étant de:

- 50 si la masse de l'échantillon ne dépasse pas 250 g;*
- 25 si la masse de l'échantillon dépasse 250 g.*

Après l'essai, l'échantillon ne doit pas présenter de dommage au sens du présent document, mais il n'est pas nécessaire qu'il soit en état de fonctionner.

De petites parties peuvent être cassées, sous réserve que la protection contre les chocs électriques ne soit pas affectée.

*La déformation des broches, les dommages à la finition et les petites ébréchures qui ne réduisent pas les **lignes de fuite** et les **distances d'isolement** au-dessous des valeurs spécifiées en 27.1 de l'IEC 60884-1:2002, de l'IEC 60884-1:2002/AMD1:2006 et de l'IEC 60884-1:2002/AMD2:2013 ne sont pas pris en compte.*

- b) *Les broches ne doivent pas tourner quand un couple de 0,4 Nm est appliqué, dans une première direction pendant 1 min et ensuite dans la direction opposée pendant 1 min.*

NOTE 2 Cet essai n'est pas réalisé quand la rotation des broches ne compromet pas la sécurité au sens de ce document.

- c) *Une force de traction comme indiqué au Tableau 7 est appliquée sans à-coups, pendant 1 min sur chaque broche à tour de rôle, dans la direction de l'axe longitudinal de la broche.*

La force de traction est appliquée à l'intérieur d'une enceinte thermique à une température de $(70 \pm 2) ^\circ\text{C}$, 1 h après que l'appareil a été placé dans l'enceinte thermique.

Tableau 7 – Force de traction sur les broches

Valeur assignée du type de fiches équivalentes	Nombre de pôles	Force de traction N
Jusqu'à 10 A inclus 130/250 V	2 3	40 50
Supérieur à 10 A jusqu'à 16 A inclus 130/250 V	2 3	50 54
Supérieur à 10 A jusqu'à 16 A inclus 440 V	3 Plus de 3	54 70

Pour les besoins de cet essai, les contacts de mise à la terre de protection, indépendamment de leur nombre, sont considérés comme un pôle.

Après l'essai et après que l'appareil est revenu à température ambiante, les broches ne doivent pas avoir été déplacées dans le corps du dispositif de plus de 1 mm.

16.4.2 Transformateurs mobiles avec fiches intégrées conformes à l'EN 50075 (prise IEC de type C) pour enfichage dans une prise de courant de l'installation fixe

Les **transformateurs mobiles** qui sont fournis avec des broches intégrées, prévues pour être introduites dans des prises de courant fixes, doivent avoir une résistance mécanique adéquate.

La conformité est vérifiée en réalisant les essais a) et b). Les essais sont réalisés sur 3 échantillons qui doivent tous satisfaire à cet essai.

- a) L'essai est réalisé dans un tambour tournant comme décrit dans l'IEC 60068-2-31. Si le **transformateur** est fourni avec un ou plusieurs câbles souples externes fixes, ils sont coupés à une longueur de 100 mm. Chaque échantillon est soumis à essai individuellement.

Le tambour est soumis à une rotation de cinq tours par minute conduisant à 10 chutes par minute, le nombre total de chutes étant de:

- 1 000 si la masse de l'échantillon ne dépasse pas 100 g;
- 500 si la masse de l'échantillon dépasse 100 g mais ne dépasse pas 200 g;
- 100 si la masse de l'échantillon dépasse 200 g.

À l'issue de l'essai, les exigences suivantes doivent être satisfaites:

- 1) L'échantillon ne doit pas présenter de dommage au sens du présent document, mais il n'est pas nécessaire qu'il soit en état de fonctionner.
- 2) De petites parties peuvent être cassées, sous réserve que la protection contre les chocs électriques ne soit pas affectée.
- 3) Aucune broche de la fiche ne doit se casser.
- 4) La déformation des broches, les dommages à la finition et les petites ébréchures ne sont pas pris en compte.
- 5) L'essai de traction conformément à l'IEC 60884-1:2002, 24.10 doit être effectué avec les mêmes échantillons que ceux utilisés lors de l'essai au tambour tournant. Pour l'essai de traction, les broches, si elles sont déformées, doivent avoir une position précise dans le sens vertical. La broche ne doit pas se casser.

La force de traction est appliquée à l'intérieur d'une enceinte thermique à une température de $(70 \pm 2) ^\circ\text{C}$, 1 h après que l'appareil a été placé dans l'enceinte thermique. Après l'essai et après que l'appareil est revenu à température ambiante, les broches ne doivent pas avoir été déplacées dans le corps du dispositif de plus de 1 mm.

- b) L'essai de couple de torsion doit être effectué avec de nouveaux échantillons. Les broches ne doivent pas tourner quand un couple de 0,4 Nm est appliqué, dans une première direction pendant 1 min et ensuite dans la direction opposée pendant 1 min.

NOTE Cet essai n'est pas réalisé quand la rotation des broches ne compromet pas la sécurité au sens de ce document.

16.5 Exigences supplémentaires pour les transformateurs destinés à être utilisés dans des véhicules et des applications ferroviaires

16.5.1 Transformateurs destinés à être utilisés dans des véhicules et des applications ferroviaires

Un essai supplémentaire conformément à l'IEC 61373 doit être effectué avec les conditions définies au Tableau 8 et au Tableau 9 et les valeurs de fréquence en fonction de la masse de l'échantillon sont définies au Tableau 10.

Tableau 8 – Conditions pour les essais de vibrations (aléatoires)

Directions	Durée des essais	Valeur efficace m/s ²	Plage de fréquences
X-Y-Z	5 h par axe	5,72	Figure 7

**Tableau 9 – Valeurs de densité spectrale d'amplitude (ASD)
pour les essais de vieillissement accéléré**

Directions	Valeur ASD (m/s ²) ² /Hz
X-Y-Z	0,964

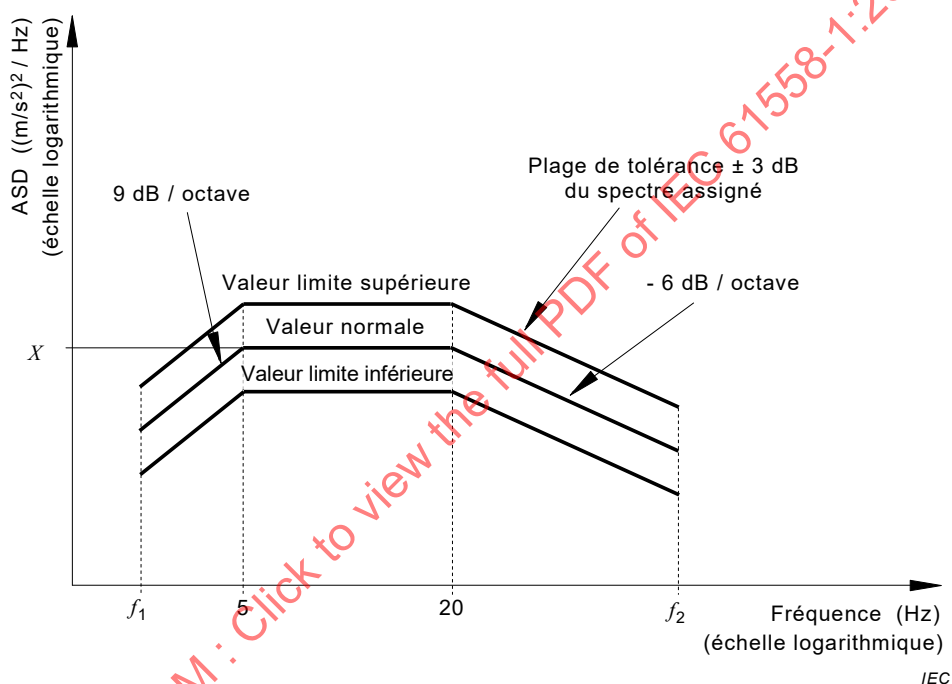


Figure 7 – Densité spectrale d'amplitude pour les essais aléatoires

Tableau 10 – Valeurs de fréquence en fonction de la masse de l'échantillon

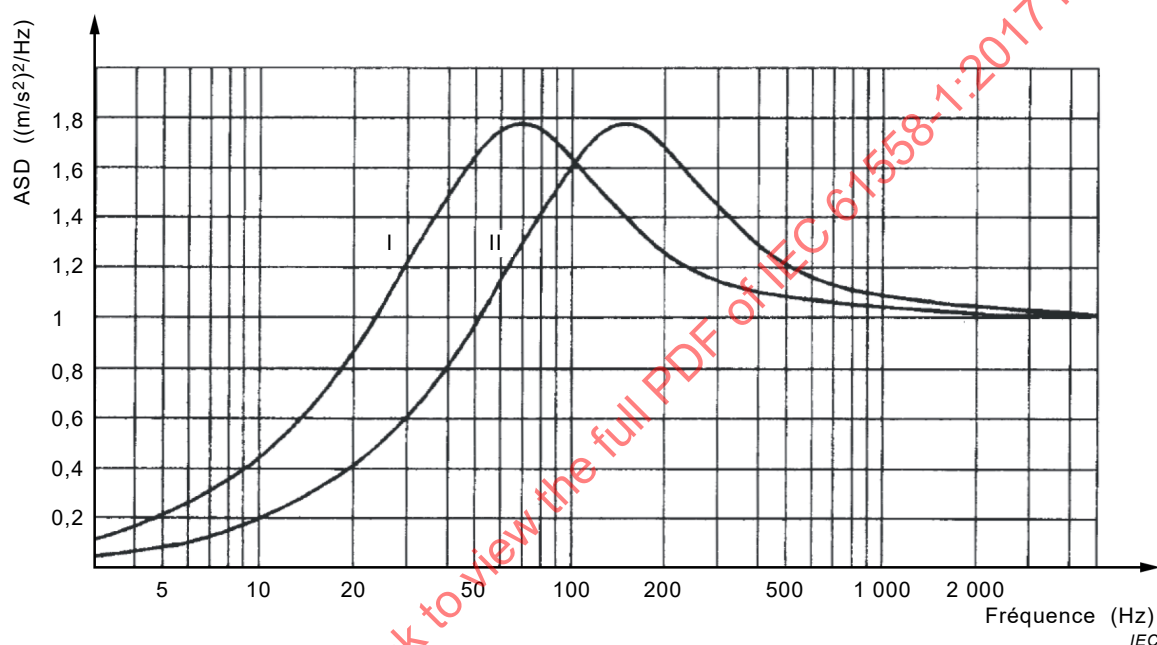
Valeurs de fréquence		
Pour une masse ≤ 500 kg	$f_1 = 5 \text{ Hz}$	$f_2 = 150 \text{ Hz}$
Pour une masse > 500 kg et ≤ 1 250 kg	$f_1 = \frac{1\,250}{\text{mass}} \times 2 \text{ Hz}$	$f_2 = \frac{1\,250}{\text{mass}} \times 60 \text{ Hz}$
Pour une masse > 1 250 kg	$f_1 = 2 \text{ Hz}$	$f_2 = 60 \text{ Hz}$

16.5.2 Exigences d'essai pour le transport des transformateurs

Exigences d'essais de chocs et de vibrations auxquels les transformateurs sont soumis au cours du transport, d'après l'IEC 60721-3-2 et avec les conditions selon le Tableau 11 et la Figure 8.

Tableau 11 – Valeurs d'excitation pour les essais de vibrations

Type de vibrations	Unité	Valeurs		
Sinusoïdales balayées	mm	3,5		
	m/s ²		10	15
	Hz	2 à 9	9 à 200	200 à 500
Aléatoires	(m/s ²) ² /Hz	1		0,3
	Hz	10 à 200		200 à 2 000
Chocs	Type I m/s ²	100		
	Type II m/s ²	300		



Exemple lié à la durée d'une impulsion semi-sinusoïdale

Spectre I Durée 11 ms

Spectre II Durée 6 ms

Figure 8 – Spectre normalisé de choc

17 Protection contre les effets nuisibles dus à la pénétration de poussière, d'objets solides et de l'humidité

17.1 Degré de protection procuré par les enveloppes (code IP)

17.1.1 Exigences générales

L'enveloppe d'un transformateur doit procurer le degré de protection contre la pénétration de poussière, d'objets solides et de l'humidité conformément à la classification du transformateur et au code IP marqué sur le transformateur, à l'exception de IP1X qui doit être marqué et soumis à essai comme un IP00.

NOTE 1 Une explication du système de chiffres IP est donnée à l'Annexe Q.

NOTE 2 Le degré de protection IP00 n'est pas couvert par l'Article 17.

La conformité est vérifiée par l'essai approprié spécifié en 17.1.2, et pour les autres valeurs d'IP par l'essai approprié spécifié dans l'IEC 60529. Si des lettres supplémentaires sont

utilisées, les transformateurs doivent satisfaire aux exigences applicables de l'IEC 60529 lorsque le calibre d'essai ne doit pas toucher des **parties actives dangereuses** et des parties mobiles dangereuses.

Avant l'essai du deuxième chiffre caractéristique, à l'exception de l'IPX8 et au-dessus, le **transformateur** doit être alimenté avec la **puissance assignée** et porté à une température de fonctionnement stable à la tension assignée.

L'eau pour l'essai doit être à une température de $(15 \pm 10) ^\circ\text{C}$.

Les **transformateurs** doivent être montés et câblés comme en usage normal avec, s'il y a lieu, une fiche appropriée insérée au **circuit secondaire**.

Les **transformateurs** non pourvus d'un **câble souple externe** sont équipés de conducteurs externes, comme spécifié à l'Article 22, le type et la section les plus défavorables étant utilisés.

Pour les essais du 17.1.2 A à J, un **transformateur installé à poste fixe** prévu pour montage avec sa **masse** en contact avec une surface doit être soumis à essai sur une planche égale à la taille hors tout de la projection du **transformateur**, s'il n'en est pas autrement spécifié.

Les **transformateurs** avec enveloppes ayant des dispositions pour l'écoulement de l'eau au moyen de trous de drainage doivent être montés avec le trou placé le plus bas ouvert à moins qu'il n'en soit spécifié autrement dans les instructions d'installation du constructeur. Les ouvertures de ventilation sont laissées ouvertes pendant l'essai.

Les **transformateurs mobiles**, câblés comme en usage normal, doivent être placés dans la position la plus défavorable de l'utilisation normale.

S'il y a des presse-étoupe, ils doivent être serrés avec un couple égal aux deux tiers de ceux appliqués aux presse-étoupe en 25.6.

Après achèvement des essais, le **transformateur** doit résister à l'essai de rigidité diélectrique spécifié en 18.3 et une inspection ne doit montrer:

- a) aucun accès aux **parties actives dangereuses** ou aux parties mobiles dangereuses au moyen du calibre d'essai correspondant conformément à l'essai décrit en 17.1.2, points A 1), B 1) et C 1). Le doigt d'épreuve peut pénétrer mais la face de butée (diamètre 50 mm x 20 mm) ne doit pas passer à travers les ouvertures, pour le degré 2 du premier chiffre IP.
- b) aucune entrée du calibre d'essai correspondant dans l'enveloppe du **transformateur** protégé contre la pénétration des corps solides, conformément à l'essai décrit en 17.1.2, points A 2) et B 2). La protection est satisfaisante si le diamètre total du calibre ne passe à travers aucune des ouvertures;
- c) aucun dépôt de poudre de talc à l'intérieur des enveloppes des **transformateurs** protégés contre les poussières, tel que, si la poudre était conductrice, l'isolation ne répondrait plus aux exigences de ce document (essai décrit en 17.1.2, point C 2);
- d) aucun dépôt de poudre de talc à l'intérieur des **enveloppes** des **transformateurs** étanches à la poussière (essai décrit en 17.1.2, point C 2);
- e) aucune trace d'eau sur les **parties actives** sauf les sorties TBTS de moins de 15 V en courant alternatif ou de 25 V en courant continu lissé, ou sur l'isolation, quand cela peut présenter un risque pour l'utilisateur ou le voisinage, par exemple quand les **lignes de fuite** risquent d'être réduites à une valeur inférieure à celles spécifiées à l'Article 26;
- f) aucune accumulation d'eau à l'intérieur des enveloppes des **transformateurs** protégés contre les chutes verticales de gouttes d'eau, contre l'eau tombant en pluie, contre les projections d'eau et les jets d'eau susceptibles de dégrader la sécurité;

- g) aucune eau ou trace d'eau ayant pénétré à l'intérieur de l'enveloppe d'un **transformateur** étanche à l'immersion.

17.1.2 Essais sur les transformateurs ayant une enveloppe

- A Les **transformateurs** protégés contre la pénétration des corps solides (degré 2 du premier chiffre IP) doivent être soumis à essai comme suit:

- 1) avec le doigt d'épreuve normalisé spécifié dans l'IEC 60529 appliqué avec une force de 10 N, avec une tolérance relative de $\pm 10\%$ et la broche d'essai spécifiée à la Figure 3 selon les exigences de l'Article 9 et 26.2;
- 2) avec une sphère rigide sans manche ni protecteur de $12,5^{+0,2}_0$ mm de diamètre, appliquée avec une force de 30 N avec une tolérance relative de $\pm 10\%$.

- B Les **transformateurs** protégés contre la pénétration des corps solides (degrés 3 et 4 du premier chiffre IP) doivent être soumis à essai comme suit:

- 1) au moyen d'un calibre d'essai correspondant au calibre C ou D de l'IEC 61032 appliqué en tout endroit possible avec une force spécifiée, comme indiqué dans le Tableau 12:

Tableau 12 – Essai des transformateurs protégés contre la pénétration des corps solides

	Calibre d'essai selon l'IEC 61032	Diamètre du fil du calibre mm	Force d'application
Degré 3 du premier chiffre IP	C	$2,5^{+0,05}_0$	$(3 \pm 0,3)$ N
Degré 4 du premier chiffre IP	D	$1^{+0,05}_0$	$(1 \pm 0,1)$ N

L'extrémité du calibre doit être exempte d'aspérités et être sectionnée, à ses deux extrémités, à angle droit.

- 2) Au moyen d'une tige rigide en acier de $2,5^{+0,05}_0$ mm de diamètre avec des bords exempts d'aspérités, appliquée avec une force de 3 N avec une tolérance relative de $\pm 10\%$ pour le degré 3 du premier chiffre IP et au moyen d'un fil rigide en acier de $1^{+0,05}_0$ de diamètre avec des bords exempts d'aspérités, applique avec une force de 1 N avec une tolérance relative de $\pm 10\%$ pour le degré 4 du premier chiffre IP. Les calibres sont destinés à simuler des corps solides étrangers pouvant avoir une forme sphérique. Si une enveloppe a un passage d'entrée indirect ou sinueux et qu'il existe un doute concernant la pénétration d'un objet sphérique capable de se déplacer, il peut être nécessaire d'examiner les dessins ou de prévoir un accès spécial pour le calibre à appliquer avec la force spécifiée pour la ou les ouvertures lorsque la pénétration doit être vérifiée.

- C Les **transformateurs** protégés contre les poussières (degré 5 du premier chiffre IP) doivent être soumis à essai comme suit:

- 1) En tout endroit possible au moyen d'un calibre correspondant au calibre d'essai D de B 1).
- 2) Dans une enceinte à poussière analogue à celle que représente la Figure 2 de l'IEC 60529:1989 et l'IEC 60529:1989/AMD1:1999, dans laquelle un courant d'air maintient en suspension de la poudre de talc; pendant l'essai, la pompe à vide indiquée n'est pas raccordée. L'enceinte doit contenir 2 kg de poudre de talc par mètre cube de son volume. La poudre de talc utilisée doit passer par un tamis à mailles carrées construit en fil de 50 μ m de diamètre nominal avec espacement nominal entre les fils de 75 μ m. Il convient que ce tamis ne soit pas utilisé pour plus de 20 essais.

L'essai doit être effectué de la façon suivante:

- a) le **transformateur** est suspendu à l'extérieur de l'enceinte à poussière et il est mis en fonctionnement à sa **puissance assignée** jusqu'à ce que la température de fonctionnement soit atteinte;
- b) le **transformateur**, toujours en fonctionnement, est placé dans l'enceinte à poussière en prenant soin d'apporter le moins de trouble possible;
- c) la porte de l'enceinte à poussière est fermée;
- d) le ventilateur mettant la poudre de talc en suspension est mis en marche;
- e) après 1 min, on coupe l'alimentation du **transformateur** et on le laisse refroidir pendant 3 h, la poudre de talc restant en suspension.

NOTE 1 L'intervalle de 1 min entre la mise en marche du ventilateur et le moment où l'on coupe l'alimentation du **transformateur** permet de s'assurer que le talc est bien en suspension autour du **transformateur** pendant la période initiale de refroidissement, laquelle est la plus importante dans le cas des petits **transformateurs**. Le **transformateur** est mis en fonctionnement au début de l'essai comme indiqué au point a) pour assurer que l'enceinte d'essai n'est pas surchauffée.

NOTE 2 Ce traitement de condition d'essai correspond à la catégorie 1 de l'IEC 60529.

- D Les **transformateurs étanches aux poussières** (degré 6 du premier chiffre IP) sont soumis à essai conformément à C.
- E Les **transformateurs** protégés contre les chutes d'eau verticales (degré 1 du second chiffre IP) sont soumis pendant 10 min à une pluie artificielle de $1^{+0,05}_0$ mm/min au moyen du dispositif représenté à la Figure 3 de l'IEC 60529:1989, tombant verticalement d'une hauteur de 200 mm sur le dessus du **transformateur**.
- F Les **transformateurs** protégés contre les chutes d'eau verticales (degré 2 du second chiffre IP) sont inclinés d'un angle quelconque pouvant aller jusqu'à 15° et sont soumis pendant 10 min (2,5 min dans chacune des quatre positions fixes d'inclinaison) à une pluie artificielle de $3^{+0,5}_0$ mm/min au moyen du dispositif représenté à la Figure 3 de l'IEC 60529:1989, tombant verticalement d'une hauteur de 200 mm sur le dessus du **transformateur**.
- G Les **transformateurs** protégés contre les projections d'eau (degré 3 du second chiffre IP) sont arrosés pendant 10 min au moyen de l'appareil représenté à la Figure 4 de l'IEC 60529:1989. Le rayon du tube semi-circulaire doit être aussi petit que possible et compatible avec la taille et la position du **transformateur**.
Le tube doit être perforé de sorte que les jets d'eau soient dirigés vers le centre du cercle et qu'il y ait un débit d'eau de 0,07 l/min, avec une tolérance relative de $\pm 5\%$ par orifice, multiplié par le nombre d'orifices (environ 80 kN/m²).
Le tube doit osciller sur un angle de 120°, soit 60° de chaque côté de la verticale, la durée d'une oscillation complète ($2 \times 120^\circ$) étant d'environ 4 s.
Le **transformateur** doit être monté au-dessus de l'axe de pivotement du tube de façon que les extrémités du **transformateur** soient convenablement arrosées par les jets. Le **transformateur** doit pivoter autour de son axe vertical comme spécifié dans l'IEC 60529.
Après cette période de 10 min, on doit couper l'alimentation du **transformateur** et le laisser refroidir naturellement tandis que l'aspersion d'eau est maintenue 10 min de plus.
- H Les **transformateurs** protégés contre les éclaboussures d'eau (degré 4 du second chiffre IP) sont arrosés de toutes les directions pendant 10 min au moyen de l'appareil représenté à la Figure 4 de l'IEC 60529:1989 et décrit en G. Le **transformateur** doit être monté au-dessus de l'axe de pivotement du tube de façon que les extrémités du **transformateur** soient convenablement arrosées par les jets.

Le tube doit osciller sur un angle de presque 360°, soit 180° de part et d'autre de la verticale, la durée d'une oscillation ($2 \times 360^\circ$) étant d'environ 12 s. Le **transformateur** doit pivoter autour de son axe vertical comme spécifié dans l'IEC 60529.

Le support du matériel en essai doit être en forme de grille pour éviter qu'il fasse écran. Après cette période de 10 min, on doit couper l'alimentation du **transformateur** et le laisser refroidir naturellement tandis que l'aspersion d'eau est maintenue 10 min de plus.