IEC 61558-2-10

Edition 2.0 2024-06
EXTENDED VERSION

INTERNATIONAL STANDARD

colour inside

This extended version of IEC 61558-2-10:2024 includes the content of the references made to IEC 61558-1:2017

GROUP ENERGY EFFICIENCY PUBLICATION

Safety of transformers, reactors, power supply units and combinations thereof – Part 2-10: Particular requirements and tests for separating transformers with high insulation level and separating transformers with output voltages exceeding 1 000 V

IEC 61558-2-10:2024-06 EXV(en)

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INTERNATIONAL
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COMMISSION

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SAFETY OF TRANSFORMERS, REACTORS, POWER SUPPLY UNITS AND COMBINATIONS THEREOF –

Part 2-10: Particular requirements and tests for separating transformers with high insulation level and separating transformers with output voltages exceeding 1 000 V

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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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

This extended version (EXV) of the official IEC Standard provides the user with the comprehensive content of the Standard.

IEC 61558-2-10:2024 EXV includes the content of IEC 61558-2-10:2024, and the references made to IEC 61558-1:2017.

The specific content of IEC 61558-2-10:2024 is displayed on a blue background.

IEC 61558-2-10 has been prepared by IEC technical committee 96: Transformers, reactors, power supply units and combinations thereof. It is an International Standard.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

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

a) adjustment of structure and references in accordance with IEC 61558-1:2017;
b) overvoltage categories I, II, III and IV for clearances and dielectric strength tests are included;
c) clearances for homogenous field conditions deleted.

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

Draft	Report on voting
96/589/FDIS	96/595/RVD

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

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

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

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

This International Standard is to be used in conjunction with IEC 61558-1:2017.

This document supplements or modifies the corresponding clauses in IEC 61558-1:2017, so as to convert that publication into the IEC standard: *Particular requirements and tests for separating transformers with high insulation level and separating transformers with output voltages exceeding 1 000 V.*

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

Where this document states "*addition*", "*modification"* or "*replacement*", the relevant text of IEC 61558-1:2017 is to be adapted accordingly.

In this document, the following print types are used:

– requirements proper: in roman type;
– *test specifications: in italic type*;
– explanatory matter: in smaller roman type.

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

Subclauses, notes, figures and tables additional to those in IEC 61558-1:2017 are numbered starting from 101; supplementary annexes are entitled AA, BB, etc.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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

INTRODUCTION to IEC 61558-1:2017

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 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 **transformer**s, 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.

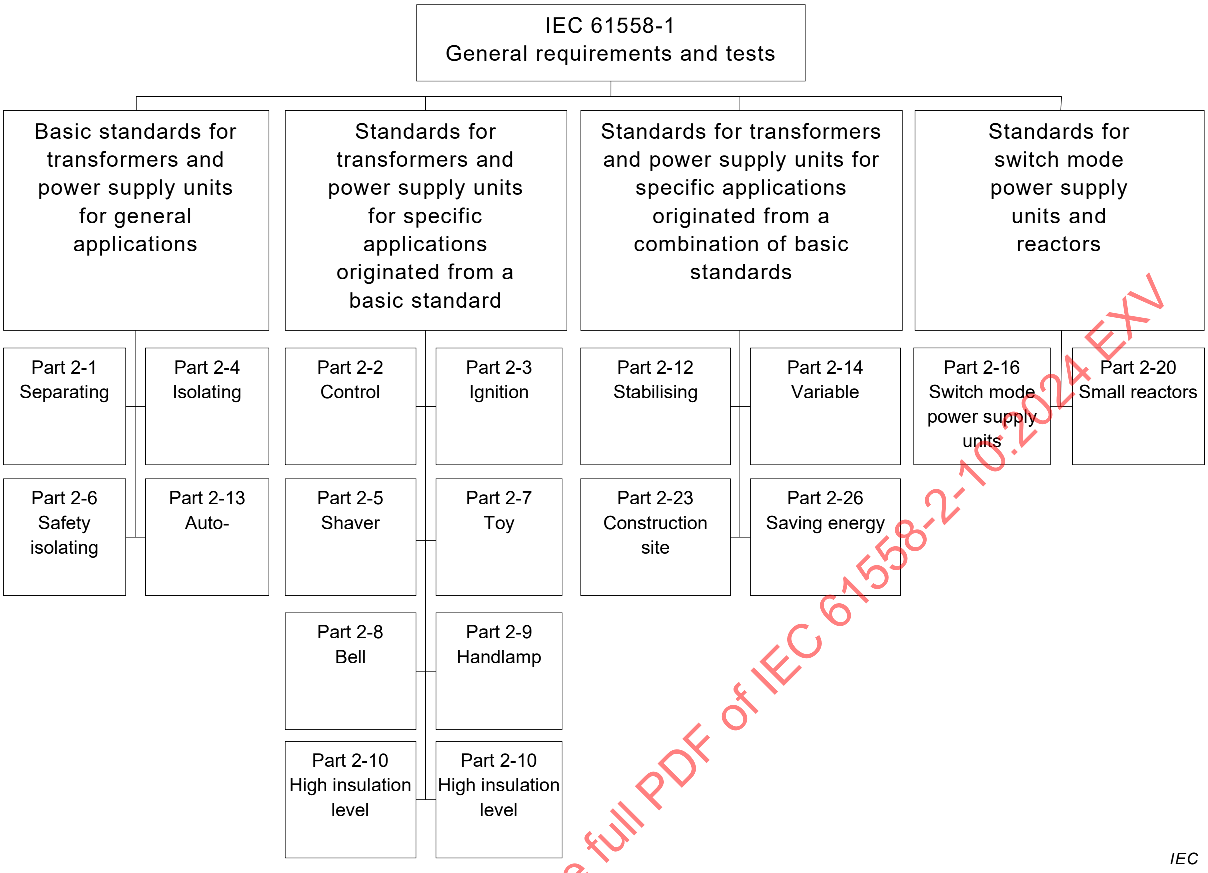


Figure 1 – IEC 61558 principle

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.

INTRODUCTION to 61558-2-10:2024

IEC TC 96 has a group safety function in accordance with IEC Guide 104 for transformers other than those intended to supply distribution networks, in particular transformers and **power supply units** intended to allow the application of protective measures against electric shock as defined by TC 64, which is about electrical installations and protection against electric shock, but in certain cases including the limitation of voltage and horizontal safety function for SELV, in accordance with IEC 60364-4-41.

The group safety function (GSF) is used because of responsibility for **safety extra-low voltage** (**SELV**) in accordance with IEC 61140:2016, 5.2.6 and IEC 60364-4-41:2005, 414.3.1 or control circuits in accordance with IEC 60204-1:2016, 7.2.4.

The group safety function is used for each part of IEC 61558-2 because different standards of the IEC 61558 series can be combined in one construction but in certain cases with no limitation of **rated output** power.

For example an auto-transformer in accordance with IEC 61558-2-13 can be designed with a separate **SELV-circuit** in accordance with the particular requirements for IEC 61558-2-6 relating to the general requirements of IEC 61558-1.

SAFETY OF TRANSFORMERS, REACTORS, POWER SUPPLY UNITS AND COMBINATIONS THEREOF –

Part 2-10: Particular requirements and tests for separating transformers with high insulation level and separating transformers with output voltages exceeding 1 000 V

1 Scope

This part of IEC 61558 deals with the safety of **separating transformers with high insulation level** and **separating transformers with output voltages exceeding 1 000 V**. **Transformers** incorporating **electronic circuits** are also covered by this document.

NOTE 1 Safety includes electrical, thermal and mechanical aspects.

Unless otherwise specified, from here onward, the term **transformer** covers **separating transformers** with **high insulation level** and **separating transformers** with **output voltages** exceeding 1 000 V AC or 1 500 V DC.

This document is applicable to **stationary** or **portable**, single-phase or polyphase, air-cooled (natural or forced) **independent** or **associated dry-type transformers.** The windings can be encapsulated or non-encapsulated.

For **power supply units** (linear) this document is applicable. For **switch mode power supply units**, IEC 61558-2-16 is applicable together with this document. Where two requirements are in conflict, the most severe takes precedence.

The **rated supply voltage** does not exceed 1 000 V AC, and the **rated supply frequency** and the **internal operating frequencies** do not exceed 500 Hz.

The **rated output** does not exceed:

- 25 kVA for single-phase **transformers**;
- 40 kVA for polyphase **transformers**.

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

Where applicable the **no-load output voltage** or the **rated output voltage**:

- does not exceed 1 000 V AC or 1 500 V DC for **separating transformers with high insulation level**;
- does exceed 1 000 V AC or 1 500 V DC and does not exceed 15 000 V AC or 15 000 V DC for **separating transformers with output voltage exceeding 1 000 V**.

This document does not apply to:

- **transformers** covered by IEC 60076-11;
- neon **transformers** covered by IEC 61050; and
- **power supplies** and converters for use with or in products according to IEC 61347-2-10.

This document is not applicable to external circuits and their components intended to be connected to the input terminals and output terminals of the **transformers**.

NOTE 2 **Transformers** covered by this document are used only in applications where **double or reinforced insulation** between circuits is not required by the installation rules or by the end product standard.

NOTE 3 Normally, the **transformers** are intended to be used with 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 circuits** or to **protective earthing**.

This document is applicable to **transformers** associated with specific equipment, to the extent decided upon by the relevant IEC technical committees.

Attention is drawn to the following if necessary:

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

It is possible that future technological development of **transformers** will require an increase in the upper limit of the frequencies. Until then this document can be used as a guidance document.

This group safety publication focusing on safety guidance is primarily intended to be used as a product safety standard for the products mentioned in the scope, but is also intended to be used by technical committees in the preparation of publications for products similar to those mentioned in the scope of this group safety publication, in accordance with the principles laid down in IEC Guide 104 and ISO/IEC Guide 51.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications and/or group safety publications in the preparation of its publications.

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, *Grapahical 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 mm^2 up to 35 mm^2 (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*

IEC 61558-1:2017, *Safety of transformers, reactors, power supply units and combinations thereof – Part 1: General requirements and 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 terms and definitions given in IEC 61558-1 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 tappings 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.

3.1.101
separating transformer with high insulation level
separating transformer where the **output voltage** does not exceed 1 000 V AC or 1 500 V DC and does exceed 50 V AC or DC for **independent transformers, the output winding(s)** is (are) isolated from both, **input winding(s)** and **body** for **a working voltage** exceeding 1 000 V AC or 1 500 V DC but not exceeding 15 000 V AC or 15 000 V DC

3.1.102
separating transformer with output voltages exceeding 1 000 V
separating transformer where the **output circuits** of which are designed to give voltages exceeding 1 000 V AC or 1 500 V DC and not exceeding 15 000 V AC or 15 000 V DC

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 an 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 ± 5) °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 ± 2) °C or (t_a ± 2) °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.*

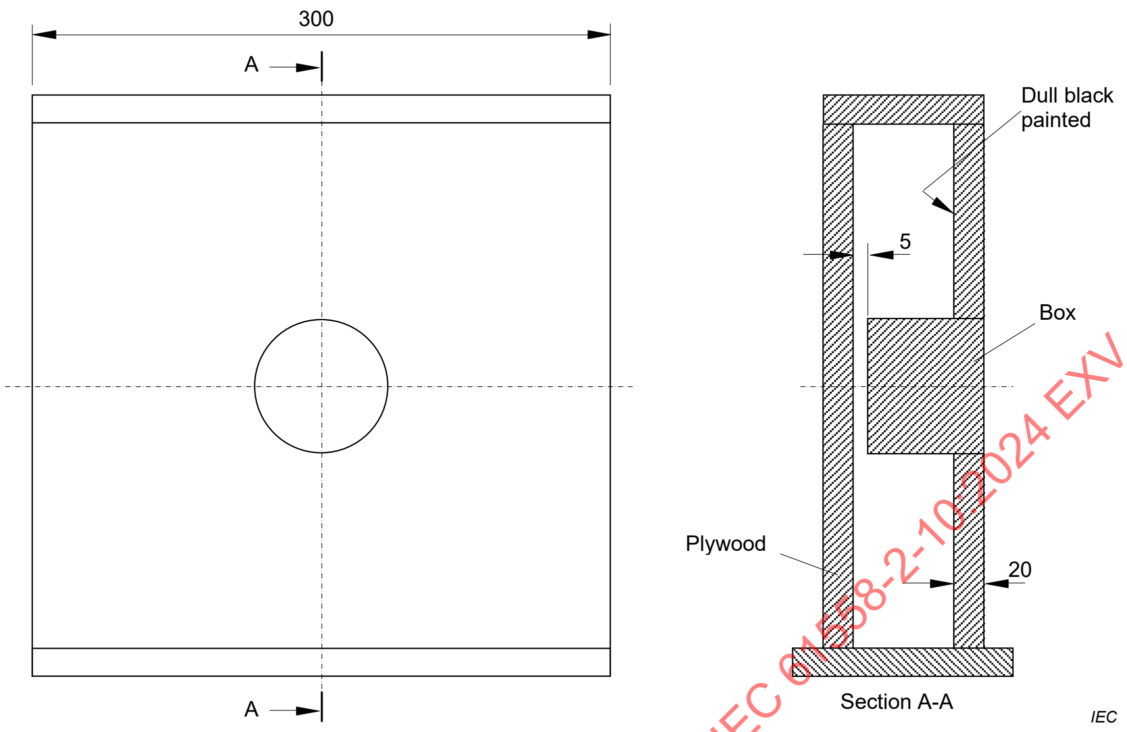


Figure 2 – Mounting box for flush-type transformer

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.**

6.101 The **rated output voltage** is limited as follows.

For **separating transformers with high insulation level**:

– the **no-load output voltage** or the **rated output voltage** shall not exceed 1 000 V AC or 1 500 V DC;
– for **independent transformers** the **rated output voltage** shall exceed 50 V AC or 50 V DC and this **output voltage** applies even when **output windings**, not intended for interconnection, are connected in series.

For **separating transformers with no load output voltages exceeding 1 000 V**:

– the **rated output voltage** shall exceed 1 000 V AC or 1 500 V DC and shall not exceed 15 000 V AC or 15 000 V DC;
– for **independent transformers** these **output voltage** limitations apply even when **output windings**, not intended for interconnection, are connected in series.

6.102 The **rated output** shall not exceed:

– 25 kVA for single-phase **transformers**;
– 40 kVA for polyphase **transformers**.

Transformers without limitation of the **rated output** shall be subject to agreement between the purchaser and the manufacturer.

6.103 The **rated supply frequency** and the **internal operating frequencies** shall not exceed 500 Hz.

6.104 The **rated supply voltage** shall not exceed 1 000 V AC.

Compliance with the requirements of 6.101 to 6.104 is checked by inspection of the marking.

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) relevant graphical symbols shown in Table 101 that indicate the kind of **transformer**; 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.

The voltage of the **insulation level**, expressed in kV is not a part of the symbol.

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".

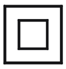
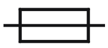
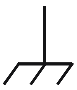
8.9 **Transformers** for indoor use only shall be marked with the relevant symbol.

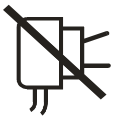
8.10 **Class II transformers** shall be marked with the graphical symbol IEC 60417-5172:2003-02 placed adjacent to the supply information (e.g. on the rating plate), such that it is obvious the symbol is part of the technical information and can in no way be confused with the manufacturer's name or any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

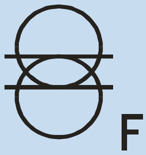
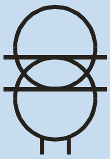
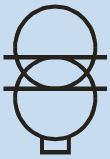
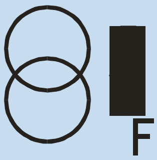
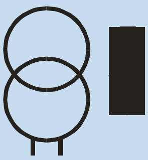
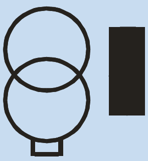
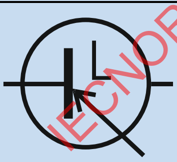
Symbol or graphical symbol	Explanation or title	Identification
IPXX	IP number [b]	
	Earth (ground or functional earth)	IEC 60417-5017:2006-08
	indoor use only	IEC 60417-5957:2004-12
	To indicate that the appliance is intended to be usable up to the maximum altitude 3 000 m. The letter symbols "3 000" 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.

The symbol for linear **power supply units** shall be used in conjunction with the symbol indicating the kind of **transformer**.

Table 101 – Symbols indicating the kind of transformer

Symbol or graphical symbol	Explanation or title	Identification
	**Fail-safe separating transformers with high insulation level** The voltage of the insulation level, expressed in kV, shall be marked adjacent to the symbol.	IEC 60417-6063:2011-05
	**Non-short-circuit proof separating transformer with high insulation level** The voltage of the insulation level, expressed in kV, shall be marked adjacent to the symbol.	IEC 60417-6064:2011-05
	**Short-circuit-proof separating transformer with high insulation level** (inherently or non-inherently) The voltage of the insulation level, expressed in kV, shall be marked adjacent to the symbol.	IEC 60417-6065:2011-05
	**Fail-safe separating transformers with output voltages exceeding 1 000 V**	IEC 60417-6066:2011-06
	**Non-short-circuit-proof separating transformer with output voltages exceeding 1 000 V**	IEC 60417-6067:2011-06
	**Short-circuit-proof separating transformer with output voltages exceeding 1 000 V** (inherently or non-inherently)	IEC 60417-6068:2011-06
	**Power supply unit,** linear	IEC 60417-6210:2013-10

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/cm^3.

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.

8.101 Separating transformers with high insulation level shall be marked with the voltage of the **insulation level**, expressed in kV on the right side of the symbol.

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.

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.*

Dimensions in millimeters

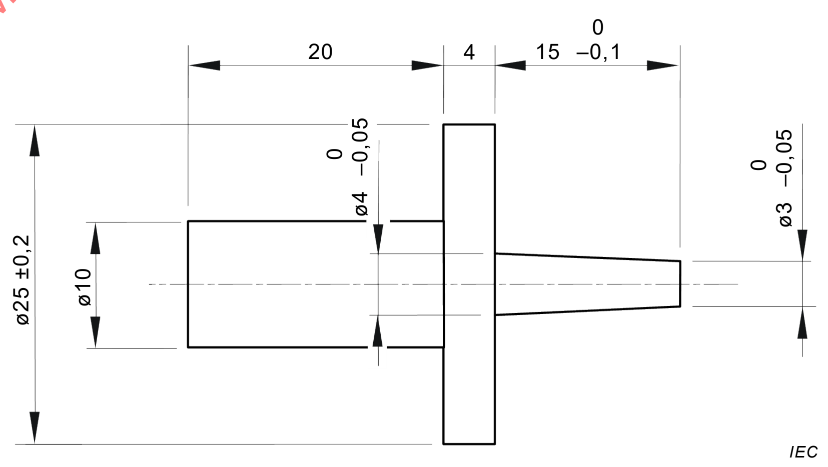
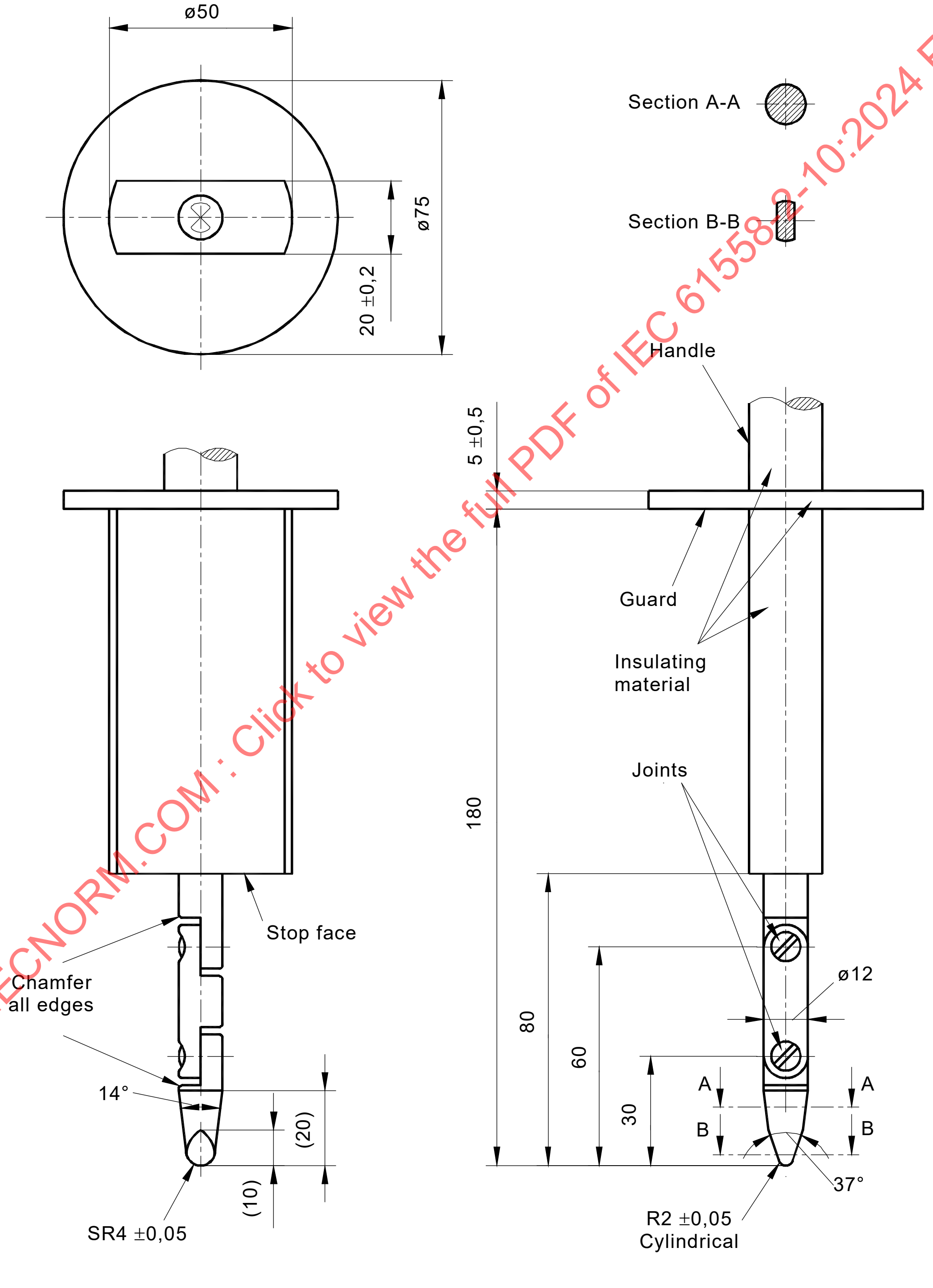


Figure 3 – Test pin (see IEC 61032, test probe 13)

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: $^{0}_{-0,05}$

– over 25 mm: ± 0,2

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

Figure 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 µF, 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 µC.

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 tappings) 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).*

The **no-load voltage** is measured when the **transformer** is connected to the **rated supply voltage** at the **rated supply frequency** at ambient temperature.

12.101 For **separating transformers with high insulation level**:

– the **no load output voltage** shall not exceed 1 000 V AC or 1 500 V DC. For **independent transformers** the **no-load output voltage** shall exceed 50 V AC or 50 V DC. This limitation applies even when independent **output windings**, not intended for interconnection, are connected in series.

12.102 For **separating transformers with output voltages exceeding 1 000 V**:

– the **no-load output voltage** shall exceed 1 000 V AC or 1 500 V DC and shall not exceed 15 000 V AC or DC. For **independent transformers** this limitation applies even when independent **output windings**, not intended for interconnection, are connected in series.

12.103 The difference between the **no-load output voltage** and the **output voltage** under load shall not be excessive.

The ratio between the **no-load output voltage** measured in Clause 12 and the **output voltage** under load measured during the test of Clause 11, expressed as a percentage of the latter voltage, shall not exceed the values shown in Table 102.

The ratio is determined by Formula (1):

$$\frac{U_{\text{no-load}} - U_{\text{load}}}{U_{\text{load}}} \times 100(\%) \qquad (1)$$

where

$U_{\text{no-load}}$ is the **no-load output voltage**, expressed in V;

U_{load} is the output voltage under load, expressed in V.

Table 102 – Output voltage difference

Type of transformer Rated output VA	Difference between no-load output voltage and output voltage under load %
Inherently short-circuit-proof transformers:	
– up to and including 63	100
– over 63 up to and including 630	50
– over 630	20
Other **transformers**:	
– up to and including 630	20
– over 630	15

Compliance with the requirements of 12.101, 12.102 and 12.103 shall be checked by measuring ***the no-load output voltage*** *at* ***ambient temperature*** *when the* ***transformer*** *is connected to the* ***rated supply voltage*** *at the* ***rated supply frequency****.*

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 *± 5) °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):

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

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

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

or

$$T = t_a + \Delta t \qquad (3)$$

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

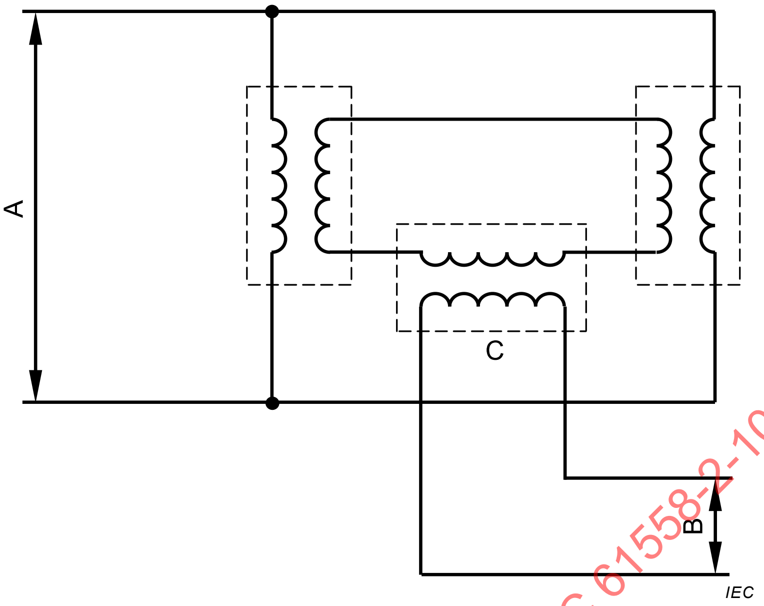
*This method is appropriate when there are two similar **transformers** and the necessary test equipment is available. It is applicable for enclosed or non-enclosed dry-type units with natural air or forced air cooling.*

*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.



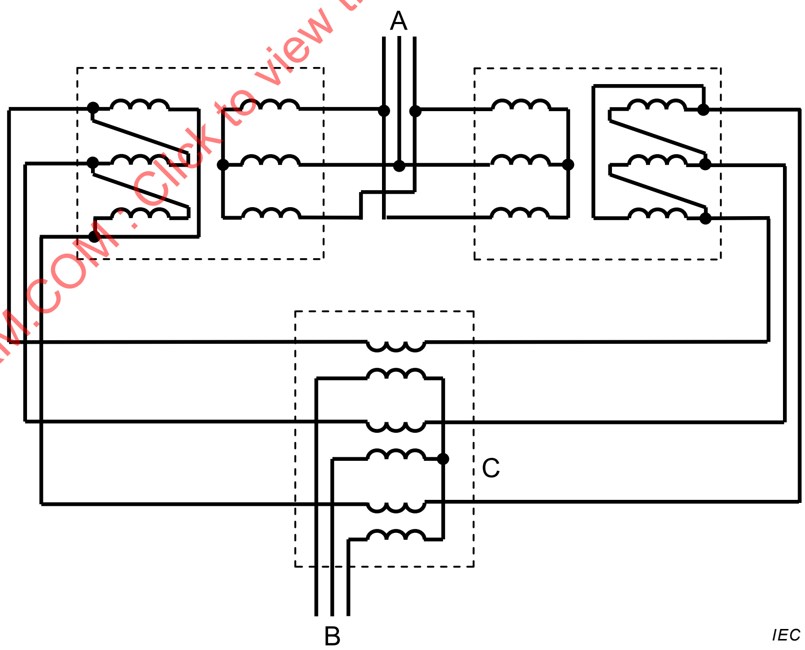
Key

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 ± 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 *T* 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:

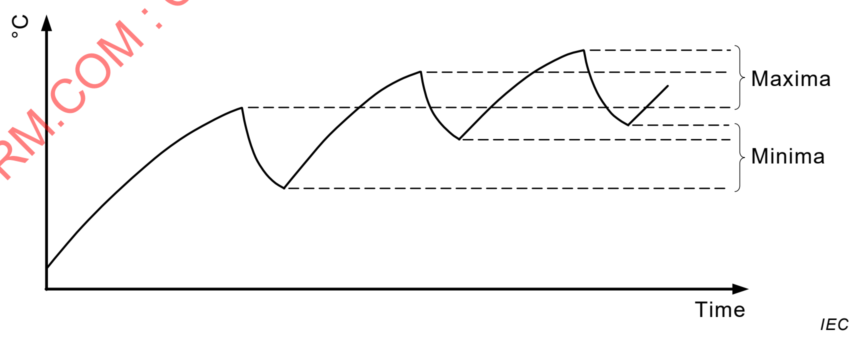
The graph of temperature versus time, while the power to the **transformer** is cycling on and off, is plotted for a period of test under consideration. The arithmetic average temperature (t_A) is determined by Formula (5):

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

where

t_{max} is the average of the maxima;

t_{min} is the average of the minima.



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 ± 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 ± 2) °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 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:

- *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 tumbeling barrel test. For the pull test, the pins, if distorted, shall be accurate into the vertical possition. The pin shall not break.*

   The pull force is applied within a heating cabinet at a temperature of (70 ± 2) °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

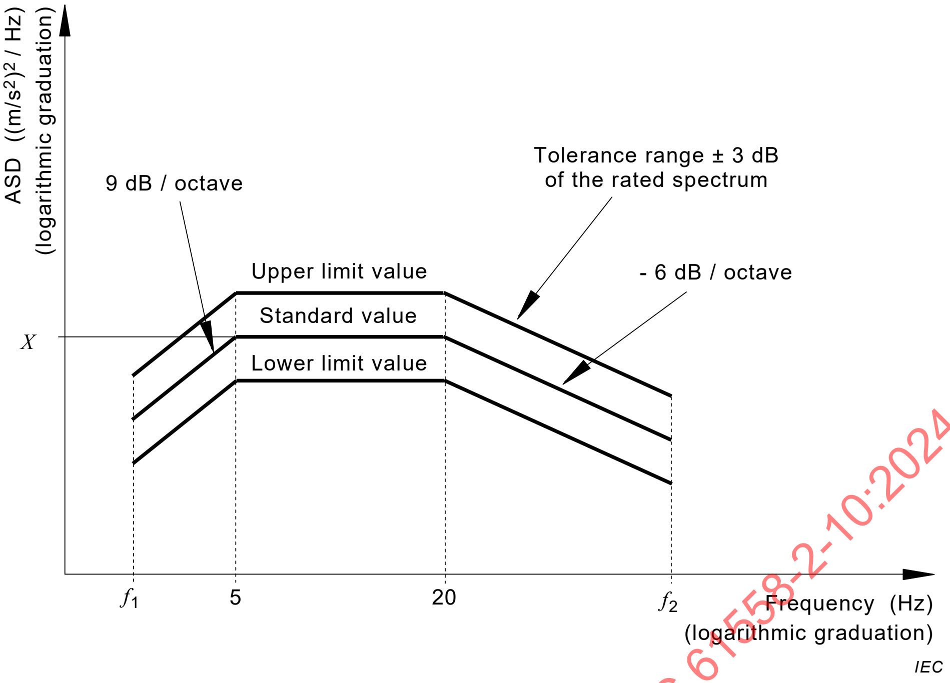


Figure 7 – Amplitude spectrum density for random testing

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

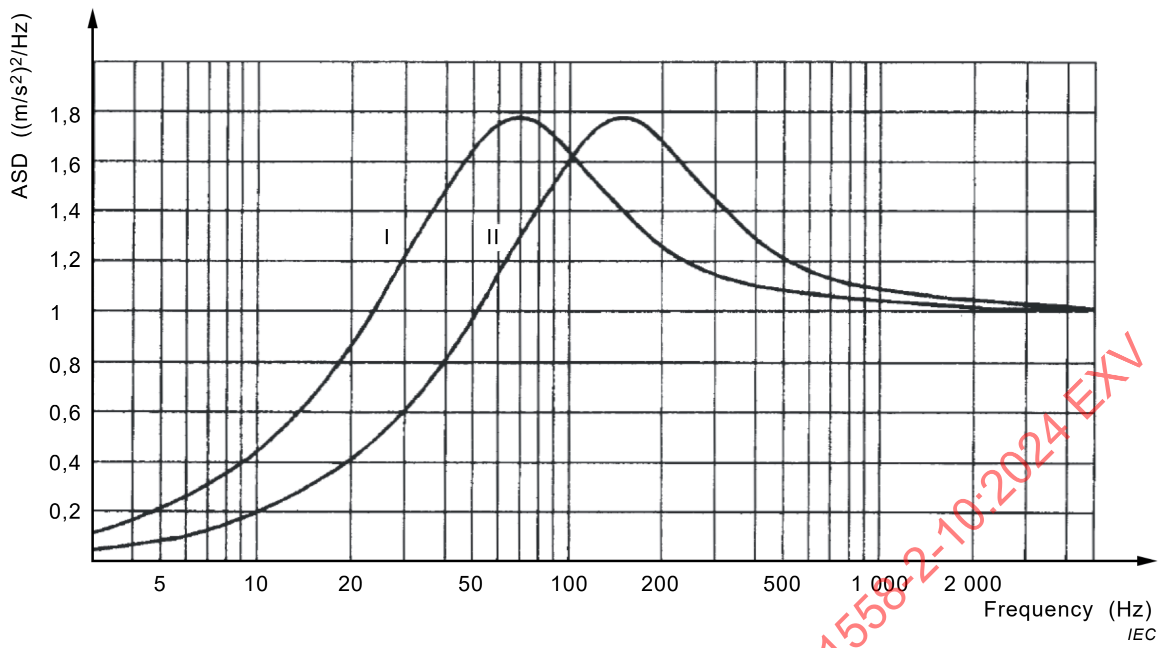
Frequency values		
For a mass ≤ 500 kg	$f_1 = 5$ Hz	$f_2 = 150$ Hz
For a mass > 500 kg and ≤ 1 250 kg	$f_1 = \frac{1\,250}{mass} x$ 2 Hz	$f_2 = \frac{1\,250}{mass} x$ 60 Hz
For a mass > 1 250 kg	$f_1 = 2$ Hz	$f_2 = 60$ Hz

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 ± 10) °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 (ø 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 ±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 $12{,}5_{0}^{+0{,}2}$ mm diameter applied with a force of 30N, with a relative tolerance of ±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 ± 0,3) N
First IP numeral 4	D	$1^{+0{,}05}_{0}$	(1 ± 0,1) 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 ±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 ±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 ±5 %, per hole, multiplied by number of holes (approximately 80 kN/m^2*).*

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.

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 Hz or 60 Hz. The value of the dielectric strength test voltage and the points of application are given in Table 103.

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

For **working voltages** up to and including 1 000 V the dielectric strength voltage shall not be less than the values shown in Table 14 of IEC 61558-1:2017.

Table 103 – Table of dielectric strength test voltages for working voltages above 1 000 V

Application of dielectric strength test voltage	Working voltage over 1 000 V, up to and including 15 000 V
Additional value for the corresponding transients of the different **overvoltage categories**	$U_{OVC\ I}$ = 500 V $U_{OVC\ II}$ = 750 V $U_{OVC\ III}$ = 1 000 V $U_{OVC\ IV}$ = 1 250 V
1) Between **live parts** of **input circuits** and **live parts** of **output circuits basic insulation**	2 × **working voltage** + U_{OVC}

2) Over **basic insulation** or **supplementary insulation** between: a) **live parts** of different polarity. Test is not applicable within the same winding b) **live parts** and the **body**, if intended to be connected to the **protective earthing** 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) **conductive parts** and the **body** f) each **input circuit** and all other **input circuits** connected together	2 × **working voltage** + U_{OVC}
Dielectric strength test voltages for **double** or **reinforced insulation** (e.g. for a **class II transformer insulation**) shall be twice the values for **basic insulation**.	

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.

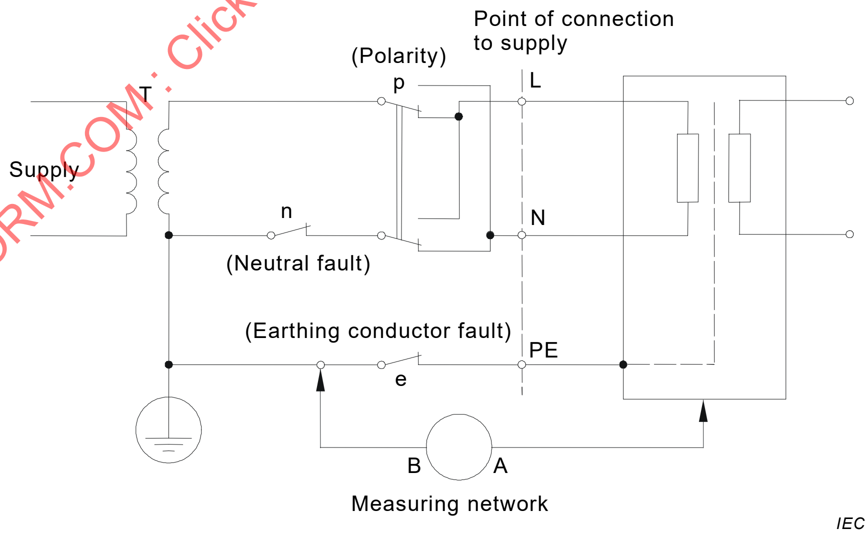


Figure 10 – Test configuration: single-phase equipment on star TN or TT system

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 Ω) 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: – **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

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, through other **conductive parts**, except by deliberate action.

Compliance is checked by inspection and measurements, taking Clause 18 and Clause 26 into consideration.

19.1.101 The **insulation** between **input** and **output winding(s)** shall consist of at least **basic insulation** (rated for the **working voltage**).

In addition, the following applies:

– for **class I transformers**, the **insulation** between the **input windings** and the **body**, and between the **output windings** and the **body**, shall consist of **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**).

19.1.102 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,** and between the **intermediate conductive parts** and the **output windings** shall consist of **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).

In addition, the following applies:

– 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 **input** and **output voltage**).

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}_{0}) *N/cm*^{2}.

The specimens are kept in the bomb at a temperature of (70^{+1}_{0}) *°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 ± 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.

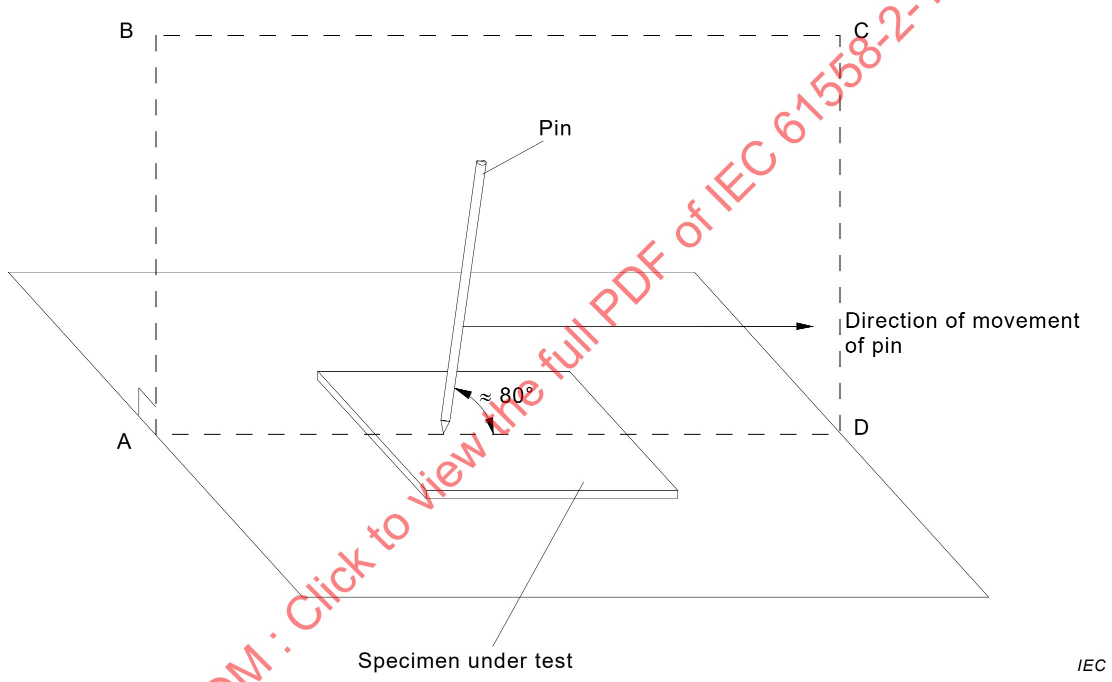
c) *Scratch test*

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 ± 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 ± 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;
– **supplemantary 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 fulfills 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 **transformer**s 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 mm^2 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.

19.101 Parts of **output circuits** can be connected to **protective earthing**.

19.102 There shall be no connection between the **output circuits** and the **body,** unless – for **associated transformers** – allowed by the relevant equipment standard.

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 ± 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.*

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 mm^2;
– exceed 2 m for cross-sectional areas greater than 0,5 mm^2.

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.

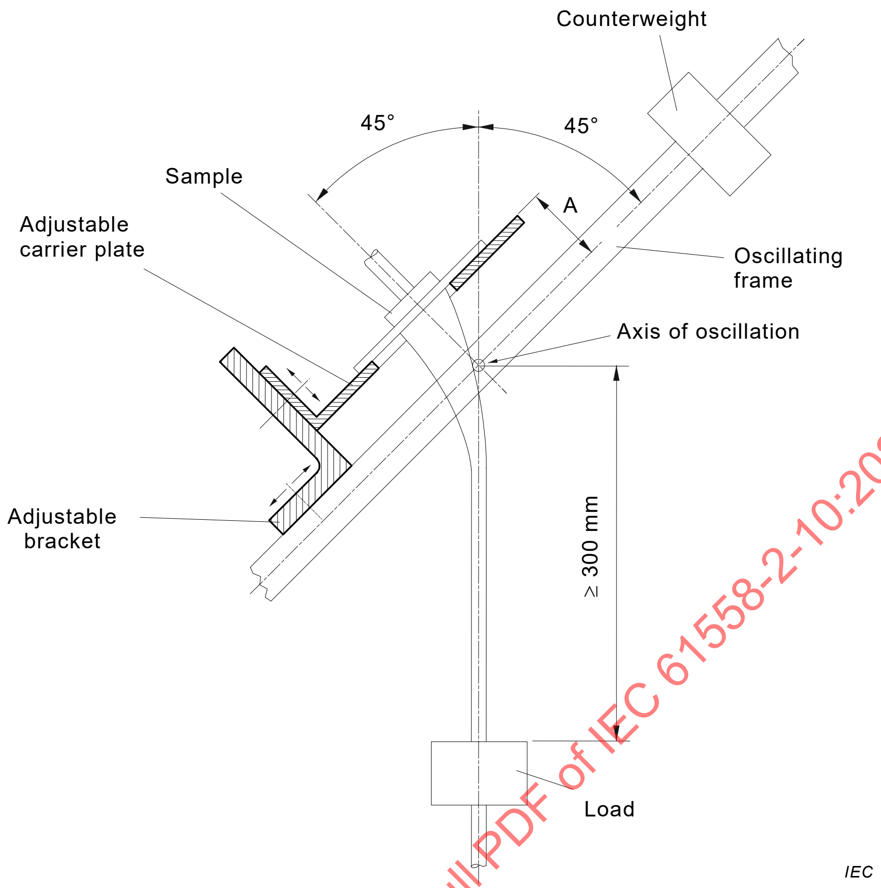


Figure 12 – Flexing test apparatus

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 **transformer**s, 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

For **working voltages** up to and including 1 000 V the **clearances, creepage distances** and distances through **insulation** shall not be less than the values shown in Table 20, Table 21 and Table 22 of IEC 61558-1:2017.

For **working voltages** above 1 000 V, up to and including 15 000 V the **clearances** and **creepage distances** shall not be less than the values shown in Table 104 and Table 105.

Compliance is checked by measurements in accordance with the provisions of 26.2 and 26.3.

NOTE 1 Table 20, Table 21 and Table 22 of IEC 61558-1:2017, and Table 104 and Table 105 of this document are applicable only 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 60664-12007 can be found in Annex R.

Clearance values are not required.

26.2.3 Uncemented insulationing 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.

26.2.101

Table 104 – Minimum clearances in air up to 2 000 m above sea level

Working voltage V	Overvoltage category			
	OVC I	OVC II	OVC III	OVC IV
1 000	3,0	5,5	8,0	14,0
1 500	5,5	8,0	11,0	18,0
3 000	8,0	11,0	18,0	25,0
6 000	25,0	33,0	40,0	60,0
10 000	40,0	60,0	75,0	90,0
15 000	75,0	90,0	130,0	170,0

The values from EN 50178 and IEC 62477-1 are also applicable.

Clearances for **double** or **reinforced insulation** (e.g. for a class II transformer insulation) shall be the next higher **overvoltage category.** If no higher **overvoltage category** exists use the next higher **working voltage** or 160 % of the **clearance** for **basic insulation**.

Table 105 – Minimum creepage distances for basic or supplementary insulation

Working voltage	Pollution degree						
	1	2			3		
	All material groups	Material group I	Material group II	Material group IIIa	Material group I	Material group II	Material group IIIa
V	mm	mm	mm	mm	mm	mm	mm
1 000	3,2	5,0	7,1	10,0	12,5	14,0	16,0
1 250	4,2	6,3	9,0	12,5	16,0	18,0	20,0
1 600	5,6	8,0	11,0	16,0	20,0	22,0	25,0
2 000	7,5	10,0	14,0	20,0	25,0	28,0	32,0
2 500	10,0	12,5	18,0	25,0	32,0	36,0	40,0
3 200	12,5	16,0	22,0	32,0	40,0	45,0	50,0
4 000	16,0	20,0	28,0	40,0	50,0	56,0	63,0
5 000	20,0	25,0	36,0	50,0	63,0	71,0	80,0
6 300	25,0	32,0	45,0	63,0	80,0	90,0	100,0
8 000	32,0	40,0	56,0	80,0	100,0	110,0	125,0
10 000	40,0	50,0	71,0	100,0	125,0	140,0	160,0
12 500	50,0	63,0	90,0	125,0	155,0	180,0	200,0
15 000	60,0	75,0	105,0	150,0	200,0	230,0	240,0

NOTE P1 = **pollution degree** 1; P2 = **pollution degree** 2; P3 = **pollution degree** 3.

The minimum values of **clearance** in this table are applicable in air up to 2 000 m above sea level.

Material group IIIb is not allowed.

Interpolation is allowed.

The values of IEC 60664-1:2020, Table F.5 are also applicable.

Creepage distance for **double** or **reinforced insulation** shall be twice the **creepage distance** for **basic insulation** from this tables.

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 ± 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 mm ± 0,005 mm thick shall be placed closely to the surface of the specimen and subjected to a pull force of (1 ± 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.

Dimensions in millimetres

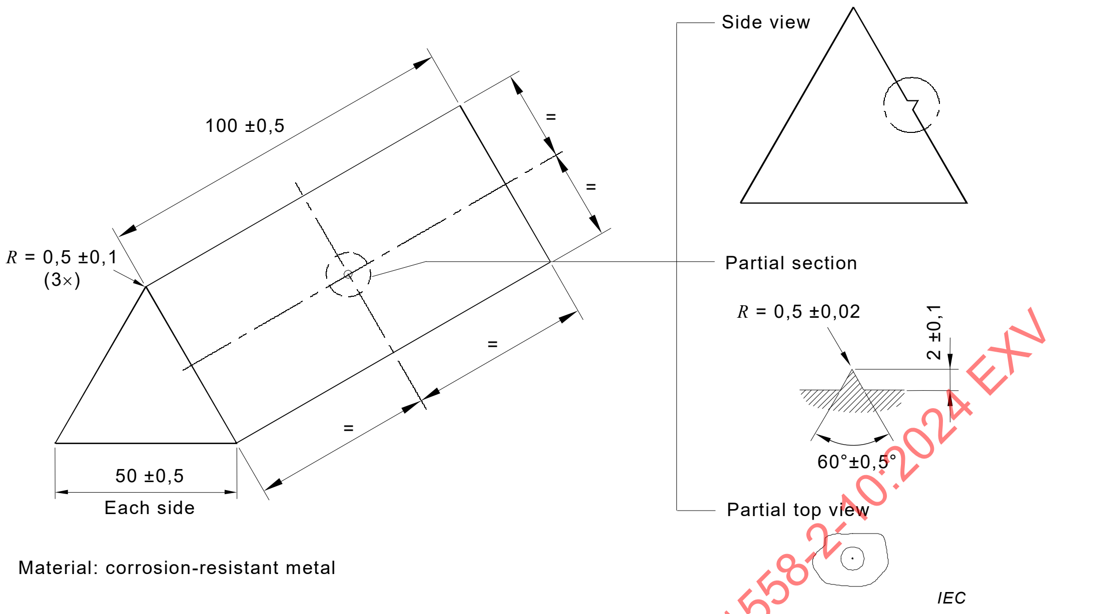


Figure 13a – Mandrel

Dimensions in millimetres

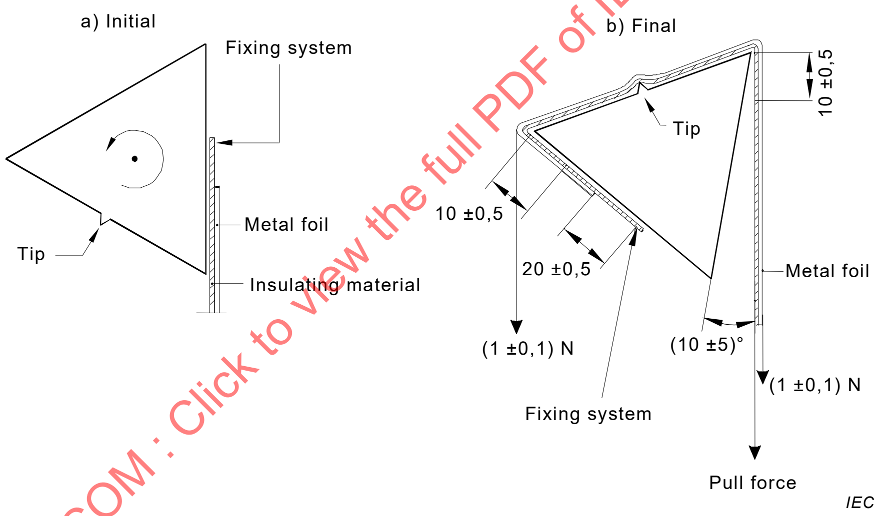


Figure 13b – Position of mandrel

Dimensions in millimetres

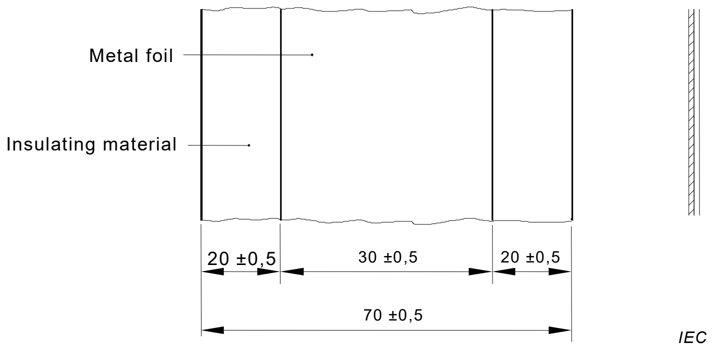


Figure 13c – Position of metal foil on paper

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 ≤ 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 ≤ 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 ≤ 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 ≤ 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 characteristical breakdown voltage [V/µm];

U_s is the allowed dielectric strength voltage for FIW [V] (duration of 60 s).

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		

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
0,56	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

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 ± 0,05) mm diameter shall be pressed against the surface with a force of (20 ± 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

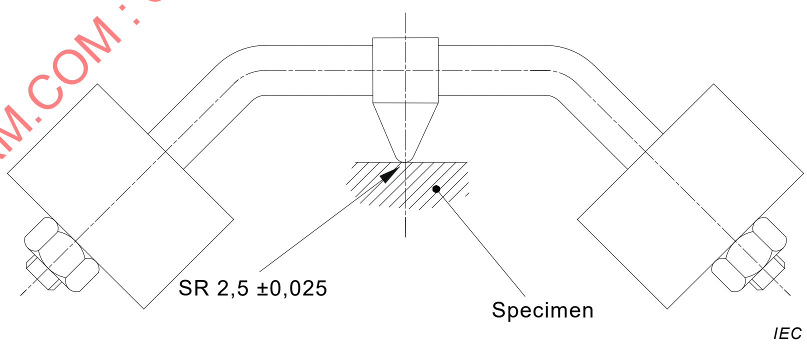


Figure 14 – Ball-pressure apparatus

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 ± 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 ± 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 ≤ 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 ± 5) °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 ± 5) °C.

After all the parts have been dried for 10 min in a heating cabinet at a temperature of (100 ± 5) °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.

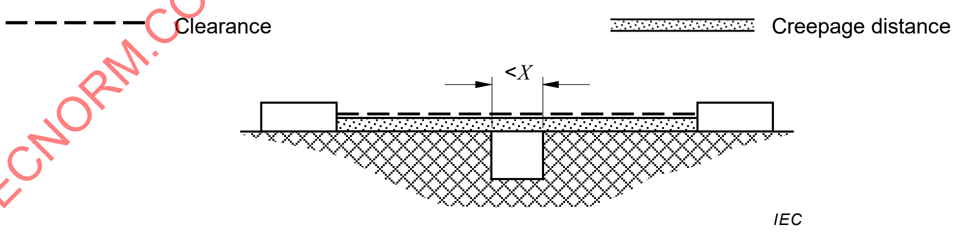
The methods of measuring **creepage distances** and **clearances** are indicated in Figure A.1 to Figure A.8. These cases do not differentiate between gaps and grooves or between types of insulation.

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);*

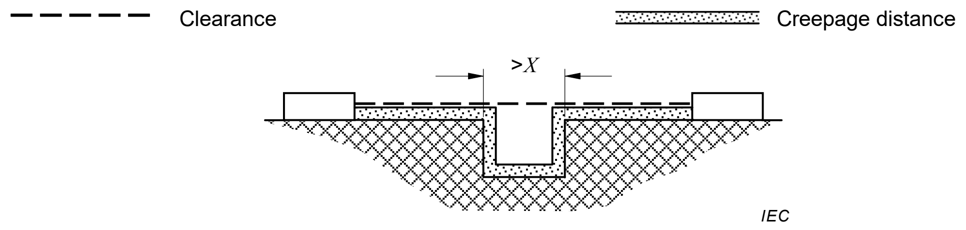
– ***creepage distances** and **clearances**, measured between parts which can assume different positions in relation to each other, are measured when these parts are in their most unfavourable position.*



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.

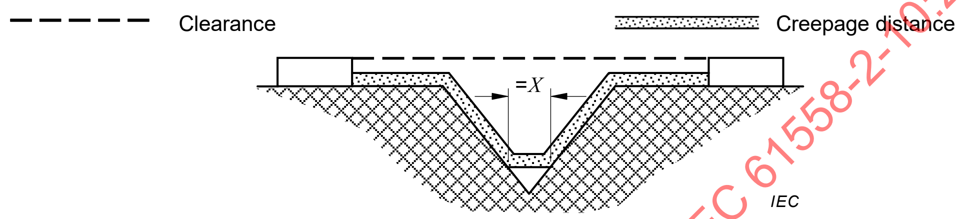
Figure A.1 – Example 1



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.

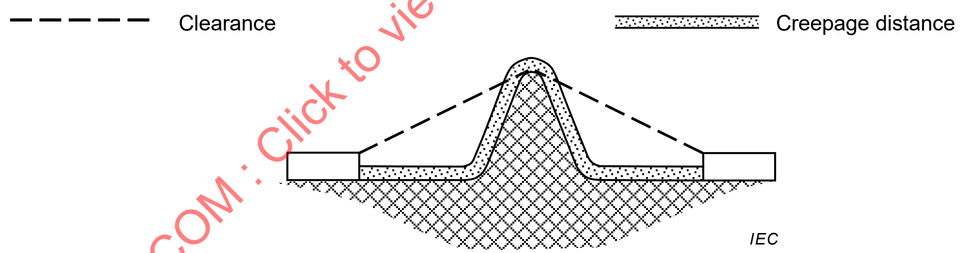
Figure A.2 – Example 2



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.

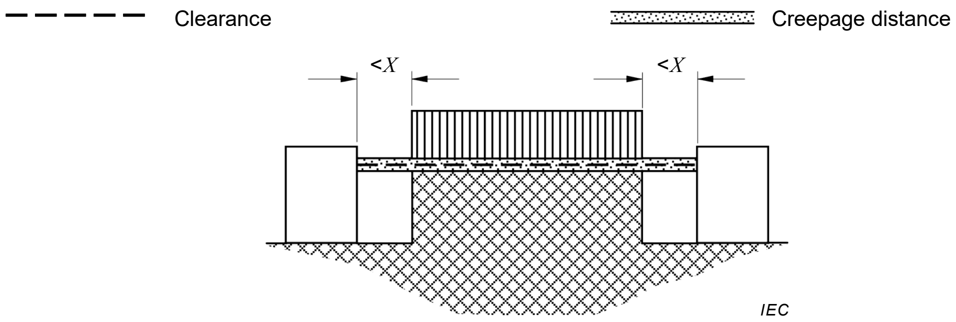
Figure A.3 – Example 3



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.

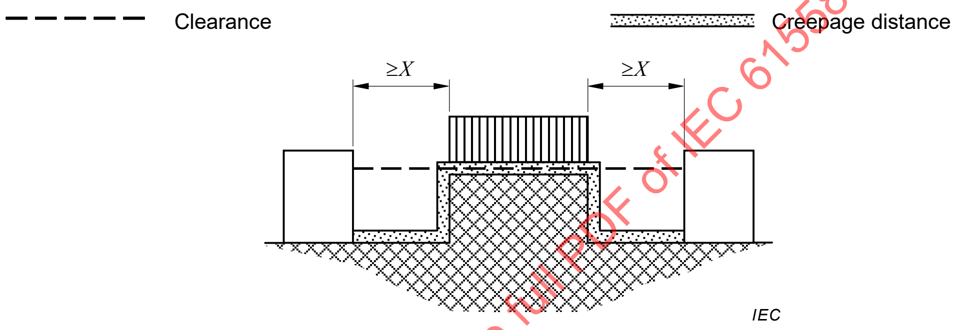
Figure A.4 – Example 4



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.

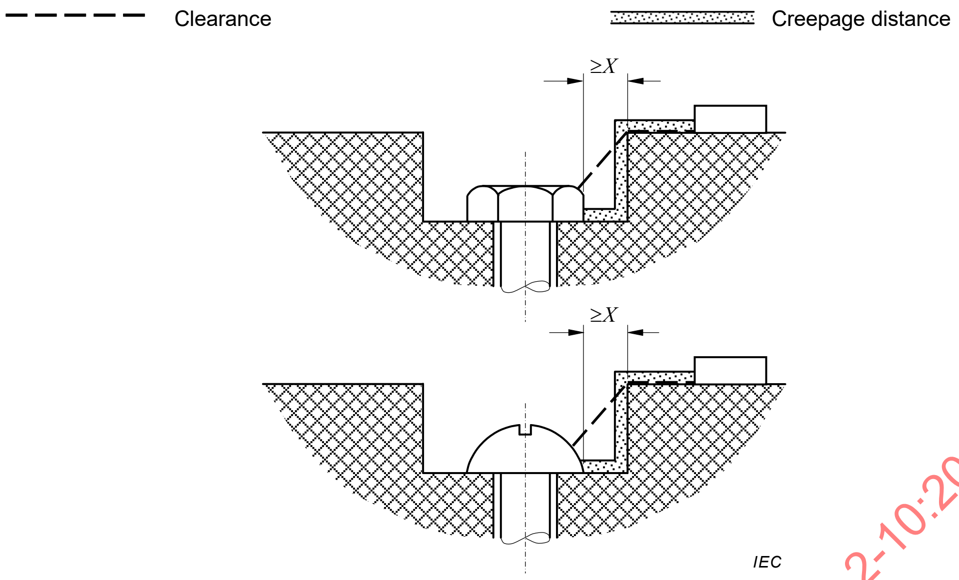
Figure A.5 – Example 5



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm wide on each side.

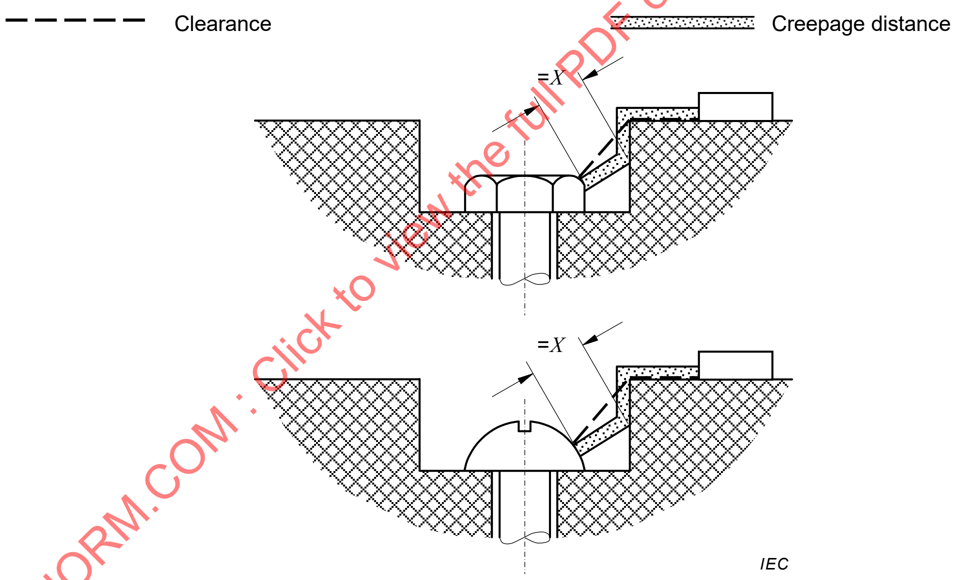
Rule: Clearance path is the "line of sight" distance. Creepage follows the contour of the groove.

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 tappings with the highest voltage difference between adjacent windings;
- one of the medium rated output, with medium voltages and medium number of tappings;
- 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)

Annex D

(void)

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.*

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 ≤ (CTI);
- material group II 400 ≤ (CTI) < 600;
- material group IIIa 175 ≤ (CTI) < 400;
- material group IIIb 100 ≤ (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)

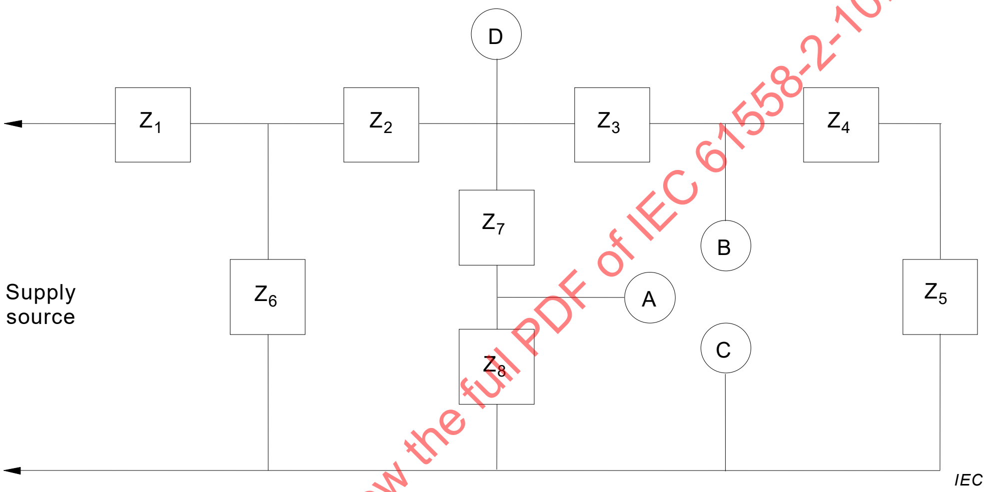
H.4.1 For **live parts** of different polarity separated by **basic insulation** only, **creepage distances** and **clearances** smaller than those specified in Clause 26 are allowed, provided the requirements of Clause H.3 are met if these **creepage distances** and **clearances** are short-circuited 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/mm^2. The dimensions and mounting holes of the attachment surface shall conform with the values stated in Table I.1.

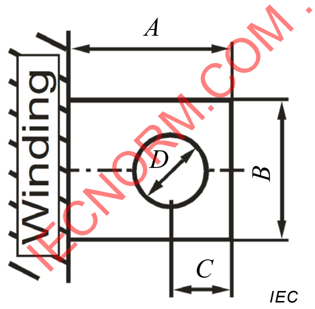
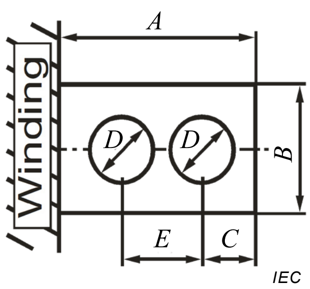
For higher current values or by constructional reasons, rectangular cross-section connectors can be used in parallel connection if the same value of the cross-section dimension is met.

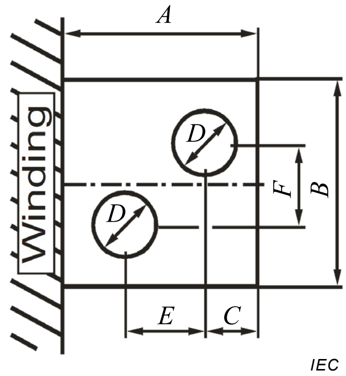
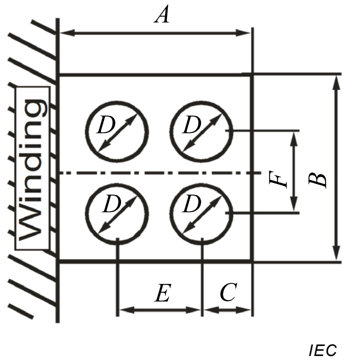
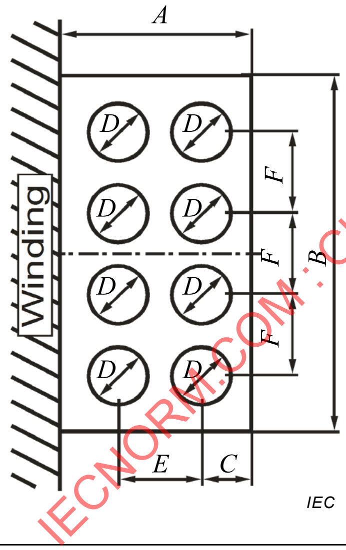
NOTE These values can be reduced when the rectangular cross-section connectors are cooled by additional methods and the attachment is ensured. Methods are for example liquid cooling.

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

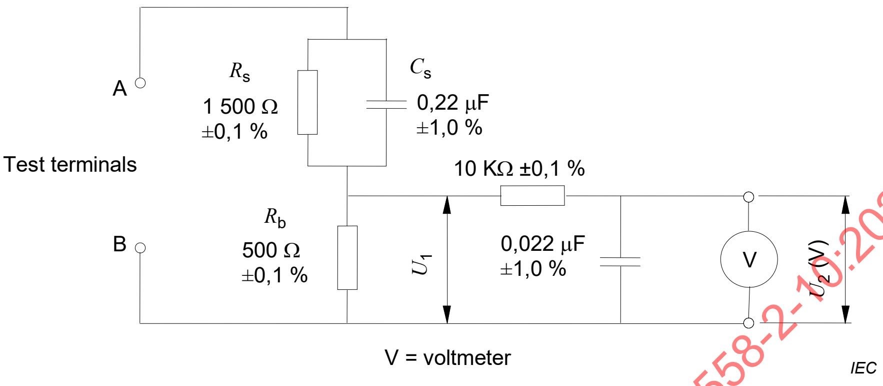
<table>
<tr><th>Dimensions</th><th>Current
A</th><th>A
mm</th><th>B
mm</th><th>C
mm</th><th>D
mm</th><th>E
mm</th><th>F
mm</th><th>Mounting Screws</th></tr>
<tr><td rowspan="6">
</td><td>≤ 145</td><td>15</td><td>12</td><td>6</td><td>5,5</td><td rowspan="6">/</td><td rowspan="6">/</td><td>M5</td></tr>
<tr><td>≤ 215</td><td>18</td><td>15</td><td>7,5</td><td>6,6</td><td>M6</td></tr>
<tr><td>≤ 365</td><td>23</td><td>20</td><td>10</td><td>9</td><td>M8</td></tr>
<tr><td>≤ 430</td><td>28</td><td>25</td><td>12,5</td><td>11</td><td>M10</td></tr>
<tr><td>≤ 760</td><td>35</td><td>30</td><td>15</td><td>11</td><td>M10</td></tr>
<tr><td>≤ 950</td><td>45</td><td>40</td><td>20</td><td>13,5</td><td>M12</td></tr>
<tr><td>
</td><td>≤ 1 130</td><td>85</td><td>50</td><td>20</td><td>13,5</td><td>40</td><td>/</td><td>M12</td></tr>
</table>

<table>
<tr><th>Dimensions</th><th>Current
[A]</th><th>A
[mm]</th><th>B
[mm]</th><th>C
[mm]</th><th>D
[mm]</th><th>E
[mm]</th><th>F
[mm]</th><th>Mounting Screws</th></tr>
<tr><td></td><td>≤ 1 305</td><td>65</td><td>60</td><td>17</td><td>13,5</td><td>26</td><td>26</td><td>M12</td></tr>
<tr><td rowspan="3"></td><td>≤ 1 645</td><td>85</td><td>80</td><td>20</td><td>13,5</td><td>40</td><td>40</td><td>M12</td></tr>
<tr><td>≤ 1 975</td><td>85</td><td>100</td><td>20</td><td>13,5</td><td>40</td><td>50</td><td>M12</td></tr>
<tr><td>≤ 2 305</td><td>85</td><td>120</td><td>20</td><td>13,5</td><td>40</td><td>60</td><td>M12</td></tr>
<tr><td rowspan="2"></td><td>≤ 2 940</td><td>85</td><td>160</td><td>20</td><td>13,5</td><td>40</td><td>40</td><td>M12</td></tr>
<tr><td>≤ 3 565</td><td>85</td><td>200</td><td>20</td><td>13,5</td><td>40</td><td>50</td><td>M12</td></tr>
<tr><td colspan="9">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.</td></tr>
</table>

Annex J
(normative)

Measuring network for touch-currents



Source: Figure 4 of IEC 60990:2016.

True RMS reading		Input capacitance:	≤ 200 pF
Uncertainty:	≤ 2 %	Supply frequency range:	15 Hz to 1 MHz
Input resistance:	0,1 MΩ		

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 mm^2 to 19,6 mm^2).

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/mm^2, 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 **transformer**s 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.

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.

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

1 A tube of a specified thickness for **supplementary insulation** or at least three layers of tape (see Clause 26).

2 Formed part of thickness as specified for **supplementary insulation** in Clause 26

3 Last turn of winding prevented from being displaced. For example, adhesive bonding tape or a bonding agent.

CR **creepage distance**

CL **clearance**

B **basic insulation**

S **supplementary insulation**

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

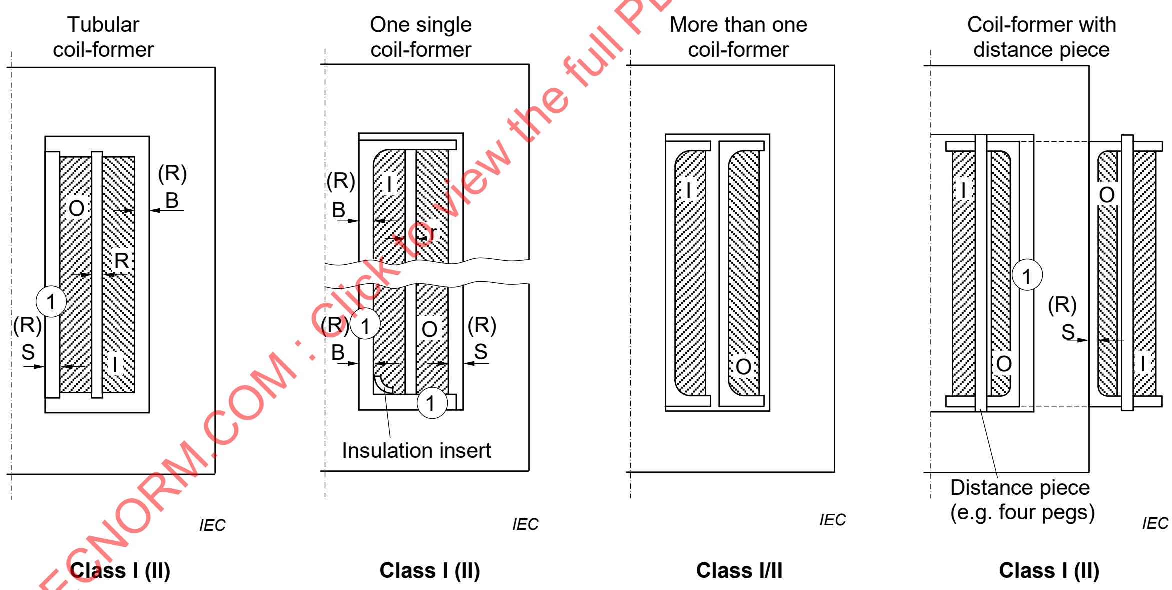
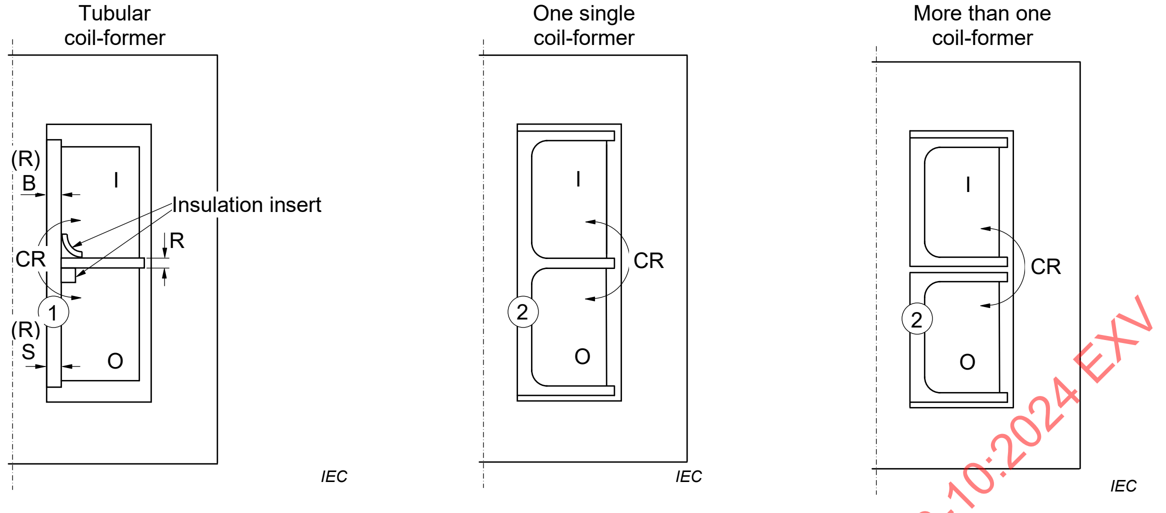


Figure M.1 – Examples for concentric type constructions

M.2.2 Side-by-side type

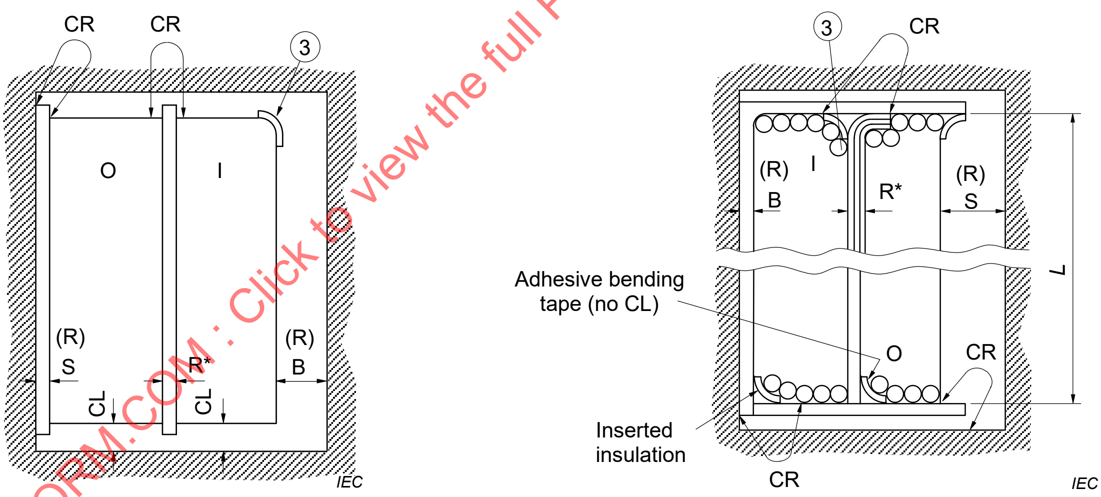


Class I (II) **Class I/II** **Class I/II**

Figure M.2 – Examples for side-by-side type constructions

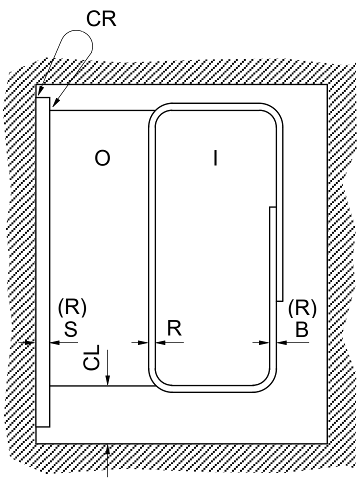
M.3 Windings

M.3.1 Without screen



Class I (II) **Class I (II)**

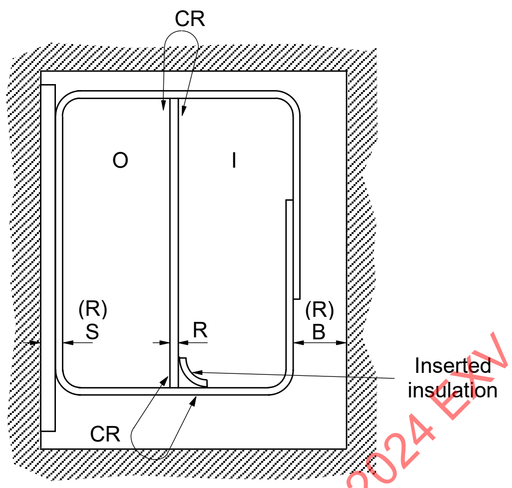
Figure M.3 – Examples for winding constructions without screen



Input or output winding wrapped with insulating material

IEC

Class I (II)



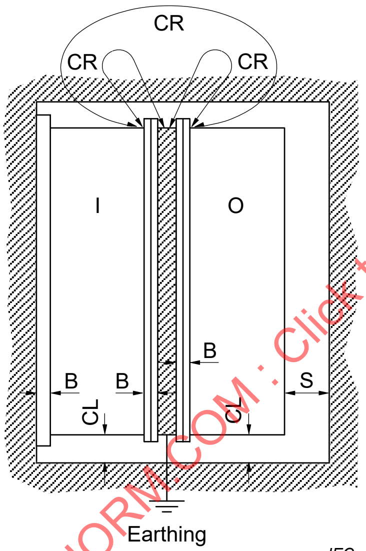
Input and output winding wrapped with insulating material (no CR)

IEC

Class I (II)

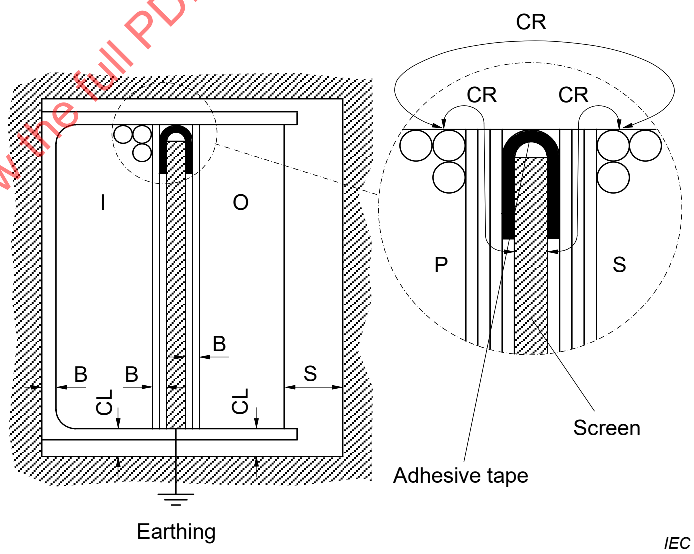
Figure M.4 – Examples for wrapped winding constructions

M.3.2 With screen



IEC

Class I



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):

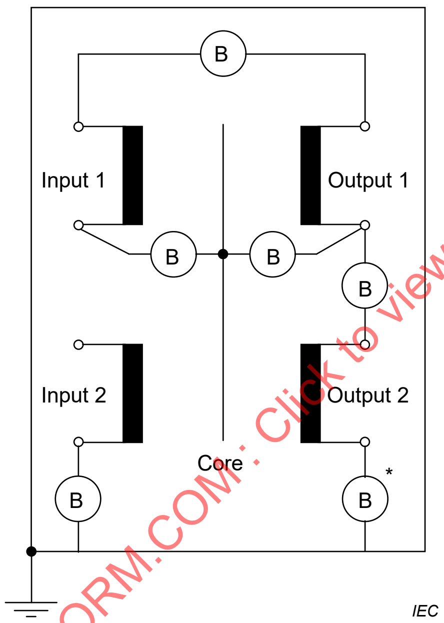
(F) functional insulation (e.g. for polyfilar windings according to Table 20, Table 21 and Table 22)

(B) basic insulation

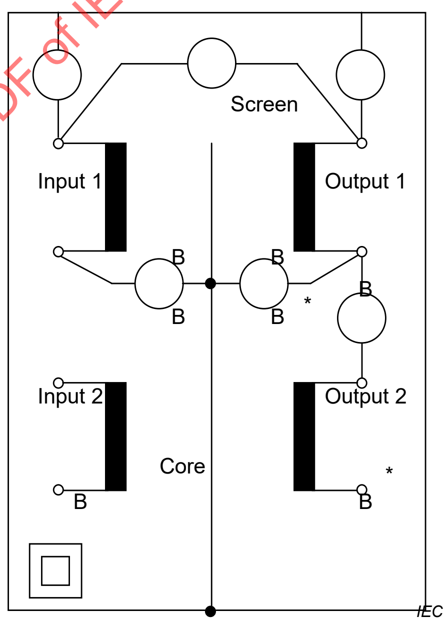
(B)* basic insulation (for the level of the applied voltage to the output winding)

(S) supplementary insulation

(D) double or reinforced insulation

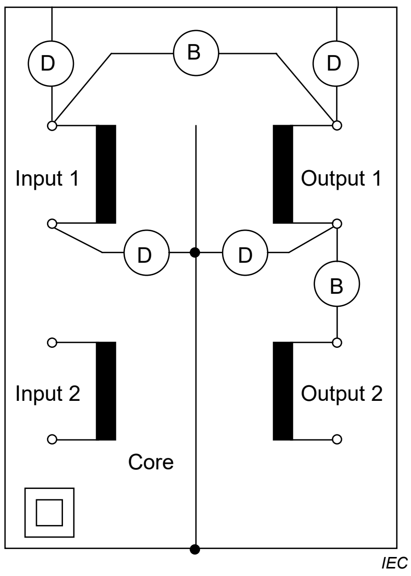


a) Transformer of **class I** construction

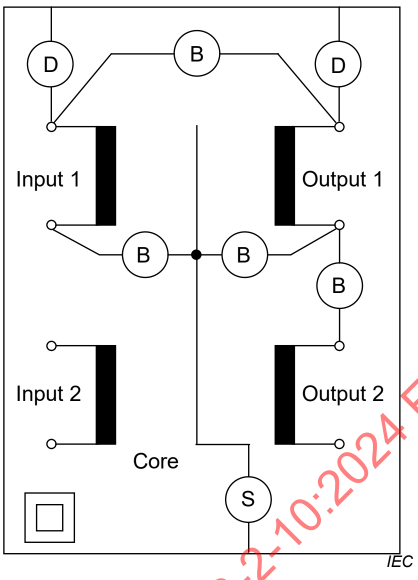


b) Transformer of **class I** construction with earthed metal screen

Figure N.1 – Transformer of class I construction with metal enclosure



a) **Core connected to the body**



b) **Core not connected to the body**

Figure N.2 – Transformer of class II construction with metal enclosure

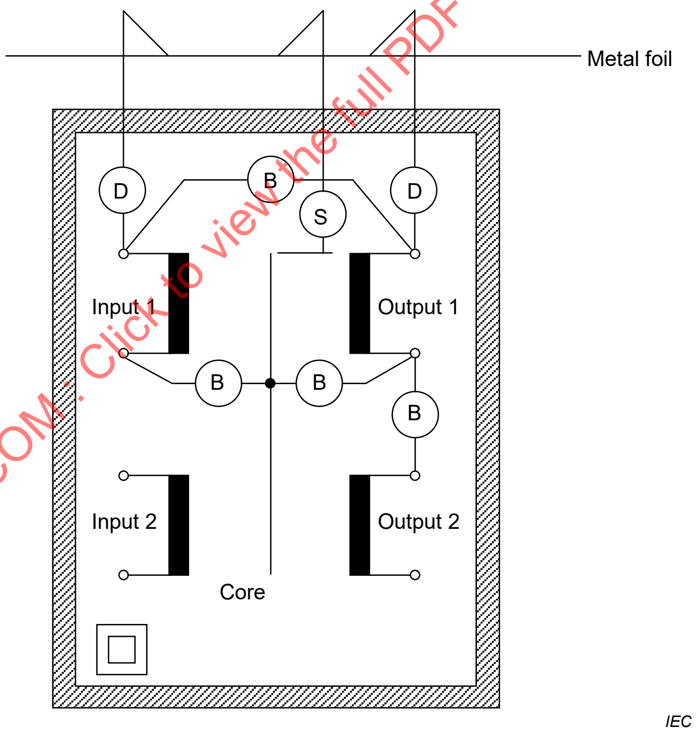


Figure N.3 – Transformer of class II construction with enclosure of insulating material

Annex O

(void)

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):

Ⓕ functional insulation (e.g. for polyfilar windings according to Table 20, Table 21 and Table 22)

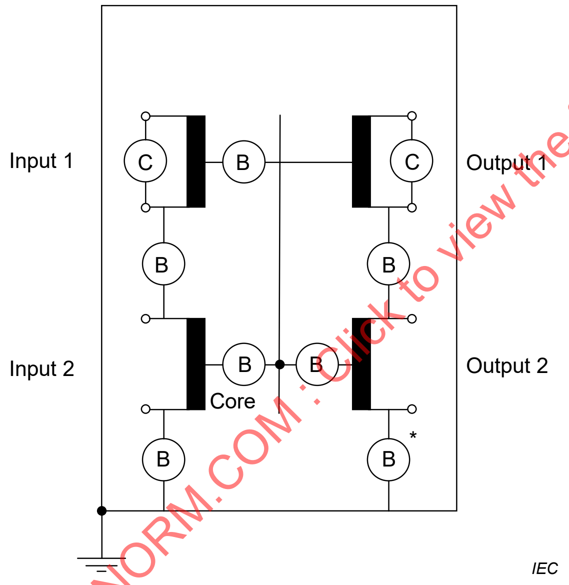
Ⓑ basic insulation

Ⓑ* basic insulation (for the level of the applied voltage to the output winding)

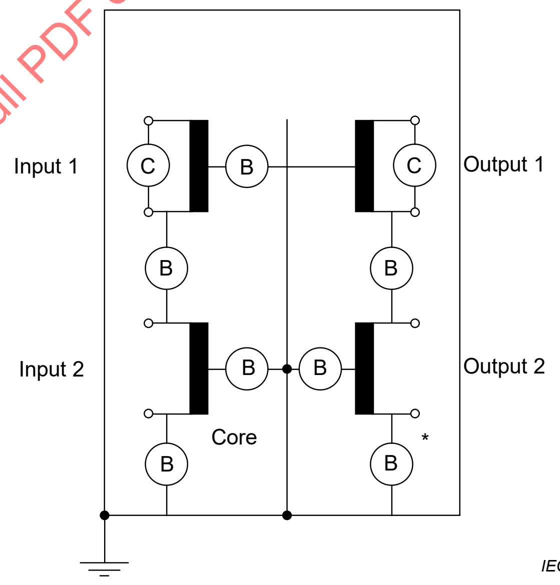
Ⓢ supplementary insulation

Ⓓ double or reinforced insulation

Ⓒ between terminals for the connections (see Table 23)



a) **Core not connected to the body**



b) **Core connected to the body**

Figure P.1 – Transformer of class I construction

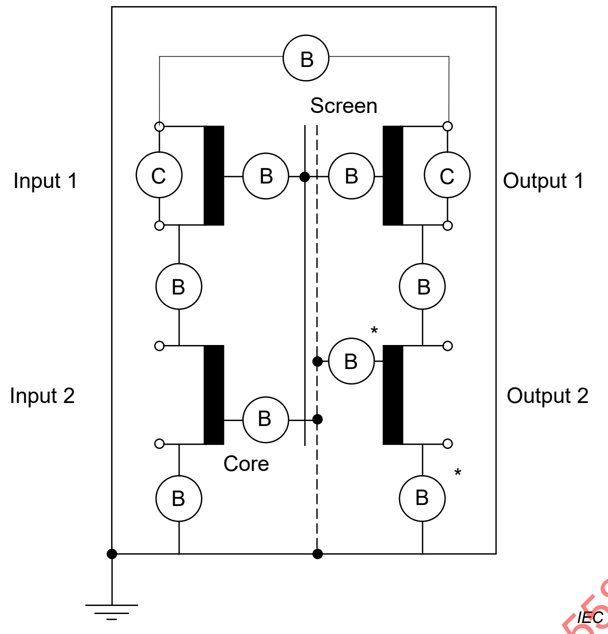
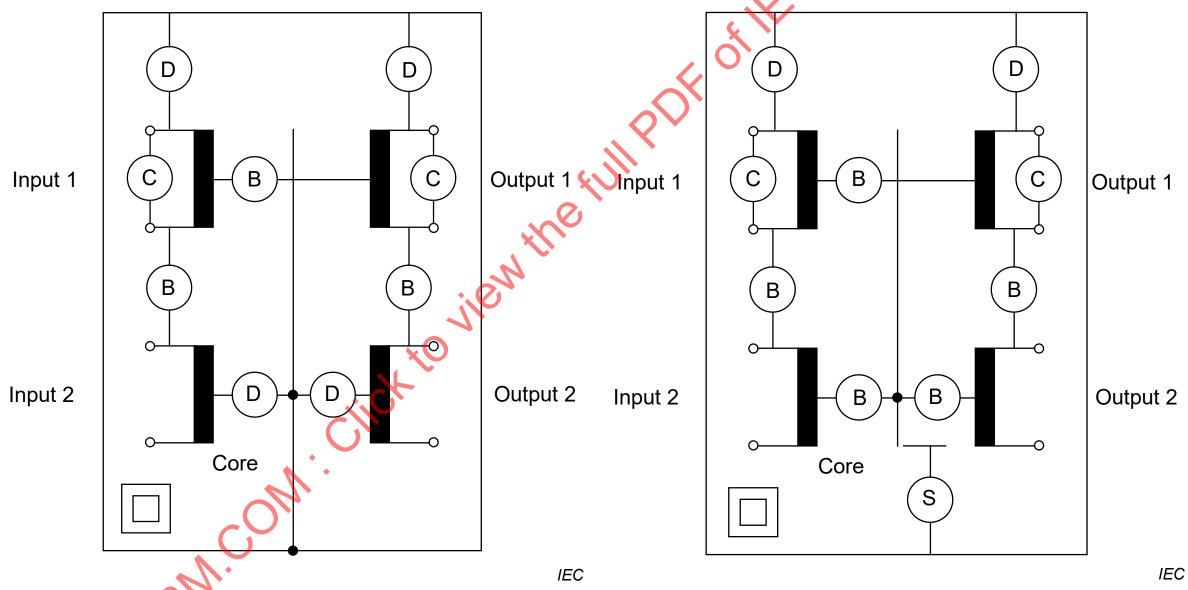


Figure P.2 – Transformer of class I construction with earthed metal screen



a) Core connected to the body

b) Core not connected to the body

Figure P.3 – Transformer of class II construction with metal enclosure

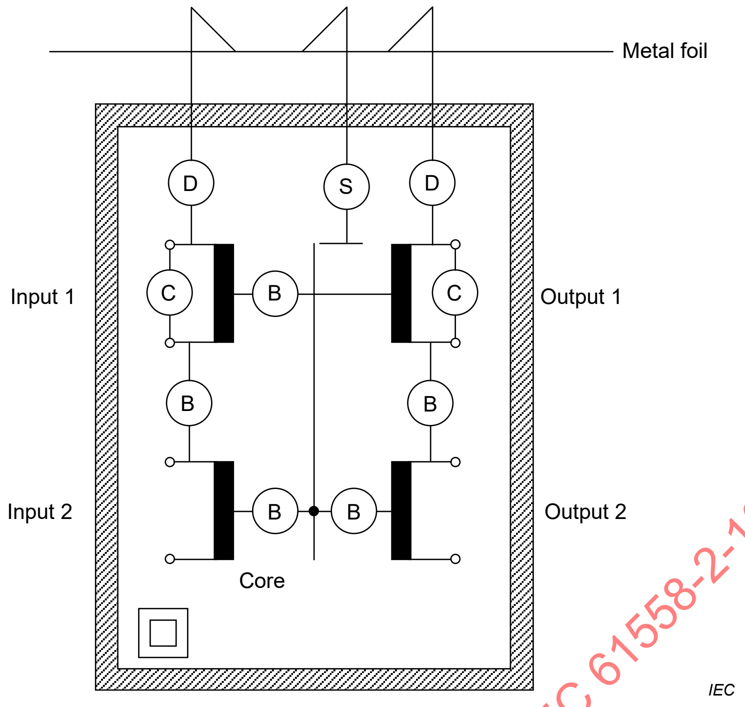


Figure P.4 – Transformer of class II construction with enclosure of insulating material

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 characteristics 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 adeguate 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 adeguate 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 adeguate 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 continously 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 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 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 V AC	Double or reinforced insulation V AC	Basic insulation V AC	Double or reinforced insulation V AC	Basic insulation V AC	Double or reinforced insulation V AC	Basic insulation V AC	Double or reinforced insulation V AC	Basic insulation 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.

Annex S

(void)

Annex T

(void)

Annex U

(void)

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)

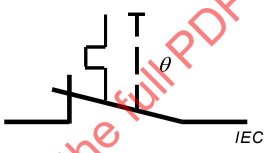


Figure V.1 – Restored by manual operation

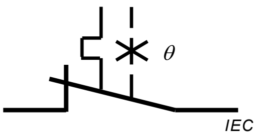


Figure V.2 – Restored by disconnection of the supply

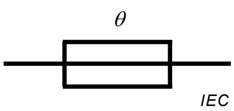


Figure V.3 – Thermal link (see 3.3.5)

V.3 Self-resetting thermal cut-out (see 3.3.3)

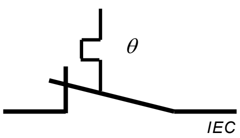


Figure V.4 – Self-resetting thermal cut-out

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.

Bibliography

IEC 60038:2009, *IEC standard voltages*

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

IEC 60050-195:1998, *International Electrotechnical Vocabulary (IEV) – Part 195: Earthing and protection against electric shock*

IEC 60050-421:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 421: Power transformers and reactors*

IEC 60050-581:2008, *International Electrotechnical Vocabulary (IEV) – Part 581: Electromechanical components for electronic equipment*

IEC 60051 (all parts), *Direct acting indicating analogue electrical measuring instruments and their accessories*

IEC 60076-11:2018, *Power transformers – Part 11: Dry-type transformers*

IEC 60204-1:2016, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*
IEC 60204-1:2016/AMD1:2021

IEC 60317-43, *Specifications for particular types of winding wires – Part 43: Aromatic polyimide tape wrapped round copper wire, class 240*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60584-1:2013, *Thermocouples – Part 1: EMF specifications and tolerances*

IEC 60695-10-2:2014, *Fire hazard testing – Part 10-2: Abnormal heat – Ball pressure test method*

IEC 60738-1:2006, *Thermistors – Directly heated positive temperature coefficient – Part 1: Generic specification*

IEC 60998-1:2002, *Connecting devices for low-voltage circuits for household and similar purposes – Part 1: General requirements*

IEC 61000-3-2:2014, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*

IEC 61000-3-3:2013, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase and not subject to conditional connection*

IEC 61050:1991, *Transformers for tubular discharge lamps having a no-load output voltage exceeding 1000 V (generally called neon-transformers) – General and safety requirements*
IEC 61050:1991/AMD1:1994

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

IEC 61347-2-10:2000, *Lamp controlgear – Part 2-10: Particular requirements for electronic invertors and convertors for high-frequency operation of cold start tubular discharge lamps (neon tubes)*
IEC 61347-2-10:2000/AMD1:2008

IEC 61558 (all parts), *Safety of transformers, reactors, power supply units and combinations thereof*

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

IEC 61558-2-4, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V – Part 2-4: Particular requirements and tests for isolating transformers and power supply units incorporating isolating transformers*

IEC 61558-2-6, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V – Part 2-6: Particular requirements and tests for safety isolating transformers and power supply units incorporating safety isolating transformers*

IEC 61558-2-16:2021, *Safety of transformers, reactors, power supply units and combinations thereof – Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units for general applications*

IEC 61558-2-23, *Safety of transformers, reactors, power supply units and combinations thereof – Part 2-23: Particular requirements and tests for transformers and power supply units for construction sites*

IEC 62041:2010, *Safety of transformers, reactors, power supply units and combinations thereof – EMC requirements*

IEC 62103[2]:2003, *Electronic equipment for use in power installations*

IEC 62477-1:2022, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

IEC Guide 104, *The preparation of safety publications and the use of basic safety publications and group safety publications*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 14 (all parts), *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus*

ISO/IEC 18004, *Information technology – Automatic identification and data capture techniques – QR Code bar code symbology specification*

ISO 3:1973, *Preferred numbers – Series of preferred numbers*

ISO 4046-4:2016, *Paper, board, pulps and related terms – Vocabulary – Part 4: Paper and board grades and converted products*

IEEE 101:1987, *IEEE guide for the statistical analysis of thermal life test data*

2 This publication was withdrawn and replaced with IEC 62477-1:2022.