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VERSION CONSOLIDÉE

colour inside

Safety requirements for electrical equipment for measurement, control, and laboratory use –
Part 1: General requirements

Règles de sécurité pour appareils électriques de mesurage, de régulation et de laboratoire –
Partie 1: Exigences générales

IEC 61010-1:2010-06+AMD1:2016-12 CSV(en-fr)

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TC 66/Publication 61010-1 (2010), Third edition/I-SH 01

SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR MEASUREMENT, CONTROL, AND LABORATORY USE –

Part 1: General requirements

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by IEC technical committee 66: Safety of measuring, control and laboratory equipment.

The text of this interpretation sheet is based on the following documents:

ISH	Report on voting
66/497A/ISH	66/505/RVD

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

IEC 61010-1:2010 contains a requirement in 6.8.3.1 pertaining to voltage testers for type tests as follows:

"The generator shall be able to supply a power of at least 500 VA."

This has given rise to the following questions:

How does one interpret the requirement for voltage testers in 6.8.3.1 of IEC 61010-1:2010? Specifically, this subclause requires that "The generator shall be able to supply a power of at least 500 VA." Does this requirement apply throughout the rated output range of the voltage tester? What is meant by the word "generator"? Is the "generator" the power supply within the voltage tester, or the voltage tester output, or something else?

Interpretation:

"A voltage tester used for type tests must be able to deliver at least 500 VA at its full-rated output voltage. It does not necessarily need to deliver 500 VA if set for lower voltages.

For example, a voltage tester that can deliver 100 mA at any test output voltage up to 5 000 V (and a current corresponding to 500 VA above 5 000 V) would meet the requirement.

The requirements for voltage testers used for routine (production line) tests are included in Annex F. The requirements of 6.8.3.1 do not apply to these voltage testers."

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR MEASUREMENT, CONTROL, AND LABORATORY USE –

Part 1: General requirements

FOREWORD

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This Consolidated version of IEC 61010-1 bears the edition number 3.1. It consists of the third edition (2010-06) [documents 66/414/FDIS and 66/423/RVD], its corrigenda 1 (2011-05) and 2 (2013-10) and its interpretation sheet (2013-02), and its amendment 1 (2016-12) [documents 66/612/FDIS and 66/620/RVD]. The technical content is identical to the base edition and its amendment.

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 61010-1 has been prepared by IEC technical committee 66: Safety of measuring, control and laboratory equipment.

It has the status of a group safety publication, as specified in IEC Guide 104.

This edition includes the following significant changes from the second edition, as well as numerous other changes.

- The scope of the standard has been expanded to include all locations where these products may be used, so that both professional and non-professional versions of these products are within the scope.
- The requirements for testing and measuring circuits (in various subclauses and the entirety of Clause 16) have been removed and included in a particular standard IEC 61010-2-030.
- Insulation requirements (6.7) have been completely rewritten.
  - Specific requirements have been added for solid insulation and thin-film insulation.
  - Subclause 6.7 now contains only the insulation requirements for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V, and for secondary circuits.
  - The insulation requirements for all other circuits have been moved to a new Annex K.
- Additional requirements for protection against mechanical HAZARDS (Clause 7) have been included.
- Surface temperature limits (Clause 10) have been modified to conform to the limits of EN 563.
- Radiation requirements (Clause 12) have been modified, and take into account a distinction between intended emission and unintended emission.
- Requirements for reasonably foreseeable misuse and ergonomic aspects have been added (Clause 16).
- A new clause (Clause 17) has been added to deal with HAZARDS and environments not covered by the standard, along with a new informative annex (Annex J) dealing with RISK assessment.
- A new informative annex (Annex E) addresses methods of reducing the POLLUTION DEGREE of a micro-environment.
- Requirements for the qualification of coatings for protection against POLLUTION have been added (Annex H).
- A new informative annex (Annex I) has been added to further explain how to determine the WORKING VOLTAGE of a MAINS CIRCUIT.

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

A list of all parts of the IEC 61010 series, under the general title: *Safety requirements for electrical equipment for measurement, control, and laboratory use*, may be found on the IEC website.

In this standard, the following print types are used:

– requirements and definitions: in roman type;
– NOTES: in smaller roman type;
– *conformity and tests: in italic type;*

– terms used throughout this standard which have been defined in Clause 3: SMALL ROMAN CAPITALS.

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

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

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INTRODUCTION

This International Standard specifies the safety requirements that are generally applicable to all equipment within its scope. For certain types of equipment, these requirements will be supplemented or modified by the special requirements of one, or more than one, particular part 2 of the standard which must be read in conjunction with the part 1 requirements.

SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR MEASUREMENT, CONTROL, AND LABORATORY USE –

Part 1: General requirements

1 Scope and object

1.1 Scope

1.1.1 Equipment included in scope

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

This part of IEC 61010 specifies general safety requirements for the following types of electrical equipment and their accessories, wherever they are intended to be used.

a) Electrical test and measurement equipment

This is equipment which by electromagnetic means tests, measures, indicates or records one or more electrical or physical quantities, also non-measuring equipment such as signal generators, measurement standards, power supplies for laboratory use, transducers, transmitters, etc.

NOTE 1 This includes bench-top power supplies intended to aid a testing or measuring operation on another piece of equipment. Power supplies intended to power equipment are within the scope of IEC 61558 (see 1.1.2 h)).

This standard also applies to test equipment integrated into manufacturing processes and intended for testing manufactured devices.

NOTE 2 Manufacturing test equipment is likely to be installed adjacent to and interconnected with industrial machinery in this application.

b) Electrical industrial process-control equipment

This is equipment which controls one or more output quantities to specific values, with each value determined by manual setting, by local or remote programming, or by one or more input variables.

c) Electrical laboratory equipment

This is equipment which measures, indicates, monitors, inspects or analyses materials, or is used to prepare materials, and includes in vitro diagnostic (IVD) equipment.

This equipment may also be used in areas other than laboratories; examples include self-test IVD equipment to be used in the home and inspection equipment to be used to check people or material during transportation.

1.1.2 Equipment excluded from scope

This standard does not apply to equipment within the scope of:

a) IEC 60065 (Audio, video and similar electronic apparatus);

b) IEC 60204 (Safety of machinery – Electrical equipment of machines);
c) IEC 60335 (Household and similar electrical appliances);
d) IEC 60364 (Electrical installations of buildings);
e) IEC 60439 (Low-voltage switchgear and controlgear assemblies);
f) IEC 60601 (Medical electrical equipment);
g) IEC 60950 (Information technology equipment including electrical business equipment, except as specified in 1.1.3);
h) IEC 61558 (Power transformers, power supply units and similar);
i) IEC 61010-031 (Hand-held probe assemblies);
j) IEC 61243-3 (Live working – Voltage detectors – Part 3: Two-pole low-voltage type).

1.1.3 Computing equipment

This standard applies only to computers, processors, etc. which form part of equipment within the scope of this standard or are designed for use exclusively with the equipment.

NOTE Computing devices and similar equipment within the scope of IEC 60950 and conforming to its requirements are considered to be suitable for use with equipment within the scope of this standard. However, some of the requirements of IEC 60950 for resistance to moisture and liquids are less stringent than those in this standard (see 5.4.4 second paragraph)).

1.2 Object

1.2.1 Aspects included in scope

The purpose of the requirements of this standard is to ensure that HAZARDS to the OPERATOR and the surrounding area are reduced to a tolerable level.

Requirements for protection against particular types of HAZARD are given in Clauses 6 to 13, as follows:

a) electric shock or burn (see Clause 6);
b) mechanical HAZARDS (see Clauses 7 and 8);
c) spread of fire from the equipment (see Clause 9);
d) excessive temperature (see Clause 10);
e) effects of fluids and fluid pressure (see Clause 11);
f) effects of radiation, including lasers sources, and sonic and ultrasonic pressure (see Clause 12);
g) liberated gases, explosion and implosion (see Clause 13).

Requirements for protection against HAZARDS arising from REASONABLY FORESEEABLE MISUSE and ergonomic factors are specified in Clause 16.

RISK assessment for HAZARDS or environments not fully covered above is specified in Clause 17.

NOTE Attention is drawn to the existence of additional requirements regarding the health and safety of labour forces.

1.2.2 Aspects excluded from scope

This standard does not cover:

a) reliable function, performance, or other properties of the equipment not related to safety;
b) effectiveness of transport packaging;

c) EMC requirements (see the IEC 61326 series);

d) protective measures for explosive atmospheres (see the IEC 60079 series).

1.3 Verification

This standard also specifies methods of verifying that the equipment meets the requirements of this standard, through inspection, TYPE TESTS, ROUTINE TESTS, and RISK assessment.

1.4 Environmental conditions

1.4.1 Normal environmental conditions

This standard applies to equipment designed to be safe at least under the following conditions:

a) indoor use;

b) altitude up to 2 000 m;

c) temperature 5 °C to 40 °C;

d) maximum relative humidity 80 % for temperatures up to 31 °C decreasing linearly to 50 % relative humidity at 40 °C;

e) MAINS supply voltage fluctuations up to ±10 % of the nominal voltage;

f) TRANSIENT OVERVOLTAGES up to the levels of OVERVOLTAGE CATEGORY II;

NOTE 1 These levels of transient overvoltage are typical for equipment supplied from the building wiring.

g) TEMPORARY OVERVOLTAGES occurring on the MAINS supply.

h) applicable POLLUTION DEGREE of the intended environment (POLLUTION DEGREE 2 in most cases).

NOTE 2 Manufacturers may specify more restricted environmental conditions for operation; nevertheless the equipment must be safe within these normal environmental conditions.

1.4.2 Extended environmental conditions

This standard applies to equipment designed to be safe not only in the environmental conditions specified in 1.4.1, but also in any of the following conditions as RATED by the manufacturer of the equipment:

a) outdoor use;

b) altitude above 2 000 m;

c) ambient temperatures below 5 °C or above 40 °C;

d) relative humidity above the levels specified in 1.4.1;

e) MAINS supply voltage fluctuations exceeding ±10 % of the nominal voltage;

f) WET LOCATION;

g) TRANSIENT OVERVOLTAGES up to the levels of OVERVOLTAGE CATEGORY III or IV (see Annex K).

2 Normative references

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

IEC 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60065, *Audio, video and similar electronic apparatus – Safety requirements*

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

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

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

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

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

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

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

IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

IEC 60332-2-2, *Tests on electric and optical fibre cables under fire conditions – Part 2-2: Test for vertical flame propagation for a single small insulated wire or cable – Procedure for diffusion flame*

IEC 60335-2-24, *Household and similar electrical appliances – Safety – Part 2-24: Particular requirements for refrigerating appliances, ice-cream appliances and ice-makers.*

IEC 60335-2-89, *Household and similar electrical appliances – Safety – Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor*

IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*
IEC 60364-4-44:2007/AMD1:2015

~~IEC 60405, *Nuclear instrumentation – Constructional requirements and classification of radiometric gauges*~~

IEC 60417, *Graphical symbols for use on equipment*

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

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

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

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

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

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

IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

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

IEC 61010-031, *Safety requirements for electrical equipment for measurement, control and laboratory use – Part 031: Safety requirements for hand-held probe assemblies for electrical measurement and test*

IEC 61180 (all parts), *High-voltage test techniques for low-voltage equipment*

IEC 61180-1, *High-voltage test techniques for low-voltage equipment – Part 1: Definitions, test and procedure requirements*

IEC 61180-2, *High-voltage test techniques for low-voltage equipment – Part 2: Test equipment*

IEC 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

IEC 61672-2, *Electroacoustics – Sound level meters – Part 2: Pattern evaluation tests*

IEC 62262, *Degrees of protection provided by enclosures for electrical equipment against external impacts (IK code)*

IEC 62471, *Photobiological safety of lamps and lamp systems*

IEC TR 62471-2, *Photobiological safety of lamps and lamp systems – Part 2: Guidance on manufacturing requirements relating to non-laser optical radiation safety*

IEC 62598, *Nuclear instrumentation – Constructional requirements and classification of radiometric gauges*

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

ISO/IEC Guide 51, *Safety aspects – Guidelines for their inclusion in standards*

ISO 306:~~1994~~ 2013, *Plastics – Thermoplastic materials – Determination of Vicat softening temperature (VST)*

ISO 361, *Basic ionizing radiation symbol*

ISO 3746, *Acoustics – Determination of sound power levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane*

ISO 7000, *Graphical symbols for use on equipment*

ISO 9614-1, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 1: Measurement at discrete points*

ISO 13857, *Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs*

EN 378-2, *Refrigerating systems and heat pumps – Safety and environmental requirements. Design, construction, testing, marking and documentation*

3 Terms and definitions

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

3.1 Equipment and states of equipment

3.1.1
FIXED EQUIPMENT
equipment fastened to a support, or otherwise secured in a specific location

[IEC 60050-826:2004, 826-16-07, modified]

3.1.2
PERMANENTLY CONNECTED EQUIPMENT
equipment that is electrically connected to a supply by means of a permanent connection which can be detached only by the use of a TOOL

3.1.3
PORTABLE EQUIPMENT
equipment intended to be carried by hand

3.1.4
HAND-HELD EQUIPMENT
PORTABLE EQUIPMENT intended to be supported by one hand during NORMAL USE

3.1.5
TOOL
external device, including keys and coins, used to aid a person to perform a mechanical function

3.1.6
DIRECT PLUG-IN EQUIPMENT
equipment with a MAINS plug that is attached to the equipment housing without the use of a MAINS supply cord so that the equipment is supported by the MAINS socket-outlet

3.2 Parts and accessories

3.2.1
TERMINAL
component provided for the connection of a device to external conductors

[IEC 60050-151:2001, 151-12-12, modified]

NOTE TERMINALS can contain one or several contacts and the term therefore includes sockets, connectors, etc.

3.2.2
FUNCTIONAL EARTH TERMINAL
TERMINAL by which electrical connection is made directly to a point of a measuring or control circuit or to a screening part and which is intended to be earthed for any functional purpose other than safety

NOTE For measuring equipment, this TERMINAL is often called the measuring earth TERMINAL.

3.2.3
PROTECTIVE CONDUCTOR TERMINAL
TERMINAL which is bonded to conductive parts of equipment for safety purposes and is intended to be connected to an external protective earthing system

3.2.4
ENCLOSURE
part providing protection of equipment against certain external influences and, in any direction, protection against direct contact

NOTE ENCLOSURES may also provide protection against the spread of fire (see 9.3.2 c)).

3.2.5
PROTECTIVE BARRIER
part providing protection against direct contact from any usual direction of access

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

NOTE Depending on its construction, a PROTECTIVE BARRIER can be called a casing, cover, screen, door, guard, etc.

A PROTECTIVE BARRIER can act alone; it is then only effective when it is in place. A PROTECTIVE BARRIER can also act in conjunction with an interlocking device with or without guard locking; in this case, protection is ensured whatever the position of the PROTECTIVE BARRIER.

3.3 Quantities

3.3.1
RATED (value)
quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment

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

3.3.2
RATING
set of RATED values and operating conditions

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

3.3.3
WORKING VOLTAGE
highest r.m.s. value of the a.c. or d.c. voltage across any particular insulation which can occur when the equipment is supplied at RATED voltage

NOTE 1 Transients and voltage fluctuations are not considered to be part of the WORKING VOLTAGE.

NOTE 2 Both open-circuit conditions and normal operating conditions are taken into account.

3.4 Tests

3.4.1
TYPE TEST
test of one or more samples of equipment (or parts of equipment) made to a particular design, to show that the design and construction meet one or more requirements of this standard

NOTE This is an amplification of the IEC 60050-151:2001, 151-16-16 definition to cover design as well as construction.

3.4.2
ROUTINE TEST
conformity test made on each individual item during or after manufacture

[IEC 60050-151:2001, 151-16-17]

3.5 Safety terms

3.5.1
ACCESSIBLE (of a part)
able to be touched with a standard test finger or test pin, when used as specified in 6.2

3.5.2
HAZARD
potential source of harm

3.5.3
HAZARDOUS LIVE
capable of rendering an electric shock or electric burn

3.5.4
MAINS
low-voltage electricity supply system to which the equipment concerned is designed to be connected for the purpose of powering the equipment

3.5.5
MAINS CIRCUIT
circuit which is intended to be directly connected to the MAINS for the purpose of powering the equipment

3.5.6
PROTECTIVE IMPEDANCE
component or assembly of components whose impedance, construction and reliability are suitable to provide protection against electric shock

3.5.7
PROTECTIVE BONDING
electrical connection of ACCESSIBLE conductive parts or protective screening to provide electrical continuity to the means for connection of an external protective conductor

3.5.8
NORMAL USE
operation, including stand-by, according to the instructions for use or for the obvious intended purpose

3.5.9
NORMAL CONDITION
condition in which all means for protection against HAZARDS are intact

3.5.10
SINGLE FAULT CONDITION
condition in which one means for protection against HAZARD is defective or one fault is present which could cause a HAZARD

NOTE If a SINGLE FAULT CONDITION results unavoidably in one or more other fault conditions, all the failures are considered as one SINGLE FAULT CONDITION [IEC Guide 104].

3.5.11
OPERATOR
person operating equipment for its intended purpose

3.5.12
RESPONSIBLE BODY
individual or group responsible for the safe use and maintenance of equipment

3.5.13
WET LOCATION
location where water or another conductive liquid may be present and is likely to cause reduced human body impedance due to wetting of the contact between the human body and the equipment, or wetting of the contact between the human body and the environment

3.5.14
REASONABLY FORESEEABLE MISUSE
use of a product in a way not intended by the supplier, but which may result from readily predictable human behaviour

3.5.15
RISK
combination of the probability of occurrence of harm and the severity of that harm

3.5.16
TOLERABLE RISK
RISK which is accepted in a given context based on the current values of society

[ISO/IEC Guide 51:1999, 3.7]

3.5.17
OVERVOLTAGE CATEGORY
numeral defining a TRANSIENT OVERVOLTAGE condition (see Annex K)

3.5.18
TRANSIENT OVERVOLTAGE
short duration overvoltage of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped

[IEC 60050-604, Amendment 1:1998, 604-03-13]

3.5.19
TEMPORARY OVERVOLTAGE
power frequency overvoltage of relatively long duration

[IEC 60050-604, Amendment 1:1998, 604-03-12]

3.6 Insulation

3.6.1
BASIC INSULATION
insulation of HAZARDOUS LIVE parts which provides basic protection

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

NOTE BASIC INSULATION may serve also for functional purposes.

3.6.2
SUPPLEMENTARY INSULATION
independent insulation applied in addition to BASIC INSULATION in order to provide protection against electric shock in the event of a failure of BASIC INSULATION

[IEC 60050-195:1998, 195-06-07, modified]

3.6.3
DOUBLE INSULATION
insulation comprising both BASIC INSULATION and SUPPLEMENTARY INSULATION

[IEC 60050-195:1998, 195-06-08]

3.6.4
REINFORCED INSULATION
insulation which provides protection against electric shock not less than that provided by DOUBLE INSULATION

NOTE REINFORCED INSULATION may be composed of several layers which cannot be tested singly as SUPPLEMENTARY INSULATION or BASIC INSULATION.

[IEC 60050-195:1998, 195-06-09, modified]

3.6.5
POLLUTION
addition of foreign matter, solid, liquid or gaseous (ionized gases), that may produce a reduction of dielectric strength or surface resistivity

3.6.6
POLLUTION DEGREE
numeral indicating the level of POLLUTION that may be present in the environment

3.6.7
POLLUTION DEGREE 1
no POLLUTION or only dry, non-conductive POLLUTION occurs, which has no influence

3.6.8
POLLUTION DEGREE 2
only non-conductive POLLUTION occurs except that occasionally a temporary conductivity caused by condensation is expected

3.6.9
POLLUTION DEGREE 3
conductive POLLUTION occurs, or dry, non-conductive POLLUTION occurs which becomes conductive due to condensation which is expected

NOTE In such conditions, equipment is normally protected against exposure to direct sunlight, precipitation, and full wind pressure, but neither temperature nor humidity is controlled.

3.6.10
POLLUTION DEGREE 4
continuous conductivity occurs due to conductive dust, rain or other wet conditions

3.6.11
CLEARANCE
shortest distance in air between two conductive parts

3.6.12
CREEPAGE DISTANCE
shortest distance along the surface of a solid insulating material between two conductive parts

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

4 Tests

4.1 General

Tests in this standard are TYPE TESTS to be carried out on samples of equipment or parts. Their only purpose is to check that the design and construction ensure conformity with this standard. In addition, manufacturers shall perform the ROUTINE TESTS of Annex F on 100 % of equipment produced which has both HAZARDOUS LIVE parts and ACCESSIBLE conductive parts.

The equipment shall at least meet the requirements of this standard. It is permissible to exceed the requirements. If, in this standard, a lower limit is specified for a conformity value, then the equipment may demonstrate a larger value. If an upper limit is specified for a conformity value, the equipment may demonstrate a lower value.

Tests on subassemblies that meet the requirements of the relevant standards specified in this standard, and used in accordance with them, need not be repeated during TYPE TESTS of the whole equipment.

Conformity with the requirements of this standard is checked by carrying out all applicable tests, except that a test may be omitted if examination of the equipment and design documentation demonstrates conclusively that the equipment would pass the test. Tests are carried out both under reference test conditions (see 4.3) and under fault conditions (see 4.4).

Where conformity statements in this standard require inspection, this may include examination of the equipment by measurement, examination of the markings on the equipment, examination of the instructions supplied with the equipment, examination of the data sheets of the materials or components from which the equipment is manufactured, etc. In each case, the inspection will either demonstrate that the equipment meets the applicable requirements, or will indicate that further testing is required.

Tests needed to support a RISK assessment (see Clause 17) are carried out in the combinations of conditions and operations determined during the RISK assessment.

If, when carrying out a conformity test, there is any uncertainty about the exact value of an applied or measured quantity (for example voltage) due to the tolerance:

a) manufacturers should ensure that at least the specified test value is applied;

b) test houses should ensure that no more than the specified test value is applied.

4.2 Sequence of tests

The sequence of tests is optional unless otherwise specified. The equipment under test shall be carefully inspected after each test. If the result of a test causes doubt whether any earlier tests would have been passed if the sequence had been reversed, these earlier tests shall be repeated.

4.3 Reference test conditions

4.3.1 Environmental conditions

Unless otherwise specified in this standard, the following environmental conditions shall exist in the test location:

a) a temperature of 15 °C to 35 °C;

b) a relative humidity of not more than 75 %, but not exceeding the limits of 1.4.1 d);

c) an air pressure of 75 kPa to 106 kPa;

d) no hoar-frost, dew, percolating water, rain, solar radiation, etc.

4.3.2 State of equipment

4.3.2.1 General

Unless otherwise specified, each test shall be carried out on the equipment assembled for NORMAL USE and under the least favourable combination of the conditions given in 4.3.2.2

to 4.3.2.13.

NOTE In case of doubt, tests should be performed in more than one combination of conditions.

If dimensions or mass make it unsuitable to carry out particular tests on completely assembled equipment, tests on sub-assemblies are allowed, provided it is verified that the assembled equipment will meet the requirements of this standard.

4.3.2.2 Position of equipment

The equipment shall be in any position of NORMAL USE and with any ventilation unimpeded. Equipment intended to be built into a wall, recess, cabinet, etc., shall be installed as specified in the manufacturer's instructions.

4.3.2.3 Accessories

Accessories and OPERATOR-interchangeable parts available from, or recommended by, the manufacturer for use with the equipment under test shall be either connected or not connected.

4.3.2.4 Covers and removable parts

Covers or parts which can be removed without using a TOOL shall be removed or not removed.

4.3.2.5 MAINS supply

The following requirements apply.

a) The supply voltage shall be between 90 % and 110 % of any RATED supply voltage for which the equipment can be set or, if the equipment is RATED for a greater fluctuation, at any supply voltage within the fluctuation range.
b) The frequency shall be any RATED frequency.
c) Equipment for both a.c. and d.c. shall be connected to an a.c. or d.c. supply.
d) Equipment for single-phase a.c. supply shall be connected both with normal and reverse polarity.
e) If the means of connection permits reversal, battery-operated and d.c. equipment shall be connected with both reverse and normal polarity.

4.3.2.6 Input and output voltages

Input and output voltages, including floating voltages but excluding the MAINS supply voltage, shall be set to any voltage within the RATED voltage range.

4.3.2.7 Earth TERMINALS

PROTECTIVE CONDUCTOR TERMINALS, if any, shall be connected to earth.

FUNCTIONAL EARTH TERMINALS shall be connected or not connected to earth.

4.3.2.8 Controls

Controls which an OPERATOR can adjust without the use of a TOOL shall be set to any position except that:

a) MAINS selection devices shall be set to the correct value;
b) combinations of settings shall not be made if they are prohibited by the manufacturer's marking on the equipment.

4.3.2.9 Connections

The equipment shall be connected for NORMAL USE, or not connected.

4.3.2.10 Load on motors

Load conditions of motor-driven parts of equipment shall be in accordance with the NORMAL USE.

4.3.2.11 Output

For equipment giving an electrical output:

a) the equipment shall be operated in such a way as to provide the RATED output power to the RATED load;

b) the RATED load impedance of any output shall be connected or not connected.

4.3.2.12 Duty cycle

Equipment for short-term or intermittent operation shall be operated for the longest RATED period and shall have the shortest RATED recovery period consistent with the manufacturer's instructions.

Equipment for short-term or intermittent operation that develops significant heat during the startup phase, and that relies on continued operation to dissipate that heat, shall also be operated for the shortest RATED period followed by the shortest RATED recovery period.

4.3.2.13 Loading and filling

Equipment intended to be loaded with a specific material in NORMAL USE shall be loaded with the least favourable quantity of the materials specified in the instructions for use, including not loaded (empty) if the instructions for use permit this in NORMAL USE.

NOTE If the specified material could cause a HAZARD during test, another material may be used provided that it can be shown that the result of the test is not affected.

4.4 Testing in SINGLE FAULT CONDITION

4.4.1 General

The following requirements apply.

a) Examination of the equipment and its circuit diagram will generally show the fault conditions which are liable to result in HAZARDS and which, therefore, shall be applied.

b) Fault tests shall be made as specified for checking conformity, unless it can be demonstrated that no HAZARD could arise from a particular fault condition.

c) The equipment shall be operated under the least favourable combination of reference test conditions (see 4.3). These combinations may be different for different faults and they shall be recorded for each test. If the environmental limits of the reference test conditions (see 4.3) do not allow realistic assessment of SINGLE FAULT CONDITIONS, the test shall be conducted at the least favourable RATED environmental conditions of the equipment.

4.4.2 Application of fault conditions

4.4.2.1 General

Fault conditions shall include those specified in 4.4.2.2 to 4.4.2.14. They shall be applied only one at a time and shall be applied in turn in any convenient order. Multiple simultaneous faults shall not be applied unless they are a consequence of an applied fault.

NOTE For example, fans may be stopped one fan at a time unless they share a common power or control source. In that case, the common fans should be stopped simultaneously by interrupting the power or control source.

After each application of a fault condition, the equipment or part shall pass the applicable tests of 4.4.4.

4.4.2.2 PROTECTIVE IMPEDANCE

The following requirements apply.

a) If a PROTECTIVE IMPEDANCE is formed by a combination of components, each component shall be short-circuited or disconnected, whichever is less favourable.

~~b) If a PROTECTIVE IMPEDANCE is formed by the combination of BASIC INSULATION and a current- or voltage-limiting device, both the BASIC INSULATION and the current- or voltage-limiting device shall be subjected to single faults, applied one at a time. BASIC INSULATION shall be bridged and the current- or voltage-limiting device shall be short-circuited or disconnected, whichever is less favourable.~~

~~c)~~b) If a PROTECTIVE IMPEDANCE is formed with a single component that meets the requirements of 6.5.4, it need not be short-circuited or disconnected.

4.4.2.3 Protective conductor

The protective conductor shall be interrupted, except for PERMANENTLY CONNECTED EQUIPMENT and equipment utilizing a connector meeting the requirements of IEC 60309.

4.4.2.4 Equipment or parts for short-term or intermittent operation

These shall be operated continuously if continuous operation could occur in a SINGLE FAULT CONDITION. Individual parts may include motors, relays, other electromagnetic devices and heaters.

4.4.2.5 Motors

Motors shall be stopped while fully energized or prevented from starting, whichever is less favourable.

One supply phase of any multi-phase motor shall be interrupted while the motor is operating at its intended full load.

4.4.2.6 Capacitors

Capacitors (except for self-healing capacitors) in the auxiliary winding circuits of motors shall be short-circuited.

4.4.2.7 MAINS transformers

4.4.2.7.1 General

The secondary windings of MAINS transformers shall be short-circuited as specified in 4.4.2.7.2, and overloaded as specified in 4.4.2.7.3.

A transformer damaged during one test may be repaired or replaced before the next test.

Tests for MAINS transformers tested as separate components are specified in 14.6.

4.4.2.7.2 Short circuit

Each untapped output winding, and each section of a tapped output winding, which is loaded in NORMAL USE, shall be tested in turn, one at a time, to simulate short circuits in the load.

Overcurrent protection devices remain fitted during the test. All other windings are loaded or not loaded, whichever load condition of NORMAL USE is less favourable.

4.4.2.7.3 Overload

Each untapped output winding, and each section of a tapped output winding, is overloaded in turn one at a time. The other windings are loaded or not loaded, whichever load condition of NORMAL USE is less favourable. If any overloads arise from testing in the fault conditions of 4.4, secondary windings shall be subjected to those overloads.

Overloading is carried out by connecting a variable resistor across the winding. The resistor is adjusted as quickly as possible and readjusted, if necessary, after 1 min to maintain the applicable overload. No further readjustments are then permitted.

If overcurrent protection is provided by a current-breaking device, the overload test current is the maximum current which the overcurrent protection device is just capable of passing for 1 h. Before the test, the device is replaced by a link with negligible impedance. If this value cannot be derived from the specification, it is to be established by test.

For equipment in which the output voltage is designed to collapse when a specified overload current is reached, the overload is slowly increased to a point just before the point which causes the output voltage to collapse.

In all other cases, the loading is the maximum power output obtainable from the transformer.

Transformers with overtemperature protection which meets the requirements of 14.3 during the short-circuit test of 4.4.2.7.2 need not be subjected to overload tests.

4.4.2.8 Outputs

Outputs shall be short-circuited one at a time.

4.4.2.9 Equipment for more than one supply

Equipment which is designed to be operated from more than one type of supply shall be simultaneously connected to these supplies, unless this is prevented by the construction.

4.4.2.10 Cooling

Equipment cooling shall be restricted as follows, one fault at a time:

a) air-holes with filters shall be closed;
b) forced cooling by motor-driven fans shall be stopped;
c) cooling by circulation of water or other coolant shall be stopped;
d) loss of cooling liquid shall be simulated.

4.4.2.11 Heating devices

In equipment incorporating heating devices, the following faults shall be applied one at a time:

a) timers which limit the heating period shall be overridden to energize the heating circuit continuously;
b) temperature controllers, except for overtemperature protection devices meeting the requirements of 14.3, shall be overridden to energize the heating circuit continuously.

4.4.2.12 Insulation between circuits and parts

Insulation between circuits and parts which is below the level specified for BASIC INSULATION shall be bridged to check against the spread of fire if the method of 9.1 a) is used.

4.4.2.13 Interlocks

Each part of an interlock system for the protection of the OPERATOR shall be short-circuited or open-circuited in turn if the system prevents access to HAZARDS when a cover, etc. is removed without the use of a TOOL.

4.4.2.14 Voltage selectors

Voltage selectors which an OPERATOR can set for different RATED supply voltages shall be set for each possible setting with the equipment connected to each of its RATED supply circuits.

4.4.3 Duration of tests

4.4.3.1 General

The equipment shall be operated until further change as a result of the applied fault is unlikely. Each test is normally limited to 1 h since a secondary fault arising from a SINGLE FAULT CONDITION will usually manifest itself within that time. If there is an indication that a HAZARD of electric shock, spread of fire or injury to persons may eventually occur, the test shall be continued for 4 h unless one of these HAZARDS arises before then.

4.4.3.2 Current limiting devices

If a device which interrupts or limits the current during operation is included to limit the temperature of parts which can easily be touched, the maximum temperature attained by those parts shall be measured, whether the device operates or not.

4.4.3.3 Fuses

If a fault is terminated by the opening of a fuse and if the fuse does not operate within approximately 1 s, the current through the fuse under the relevant fault condition shall be measured. The pre-arcing time/current characteristics of the fuse shall be evaluated to find out whether the minimum operating current is reached and what is the maximum time before the fuse operates. The current through the fuse may vary as a function of time.

If the minimum operating current of the fuse is not reached in the test, the equipment shall be operated for a period corresponding to the maximum fusing time or continuously for the duration specified in 4.4.3.1, with the fuse replaced with a short-circuit.

4.4.4 Conformity after application of fault conditions

4.4.4.1 General

Conformity with requirements for protection against electric shock after the application of single faults is checked as follows:

a) by making the measurements of 6.3.2 to check that no ACCESSIBLE conductive parts have become HAZARDOUS LIVE;

b) by performing a voltage test on DOUBLE INSULATION or REINFORCED INSULATION to check that the protection is still at least at the level of BASIC INSULATION. The voltage tests are made as specified in 6.7 and 6.8 (without humidity preconditioning) with the test voltage for BASIC INSULATION;

c) by measuring the temperature of transformer windings if the protection against electrical HAZARDS is achieved by DOUBLE INSULATION or REINFORCED INSULATION within the transformer. The temperatures of Table 20 shall not be exceeded.

4.4.4.2 Temperature

Conformity with requirements for temperature protection is checked by determining the temperature of the outer surface of the ENCLOSURE and of parts which can easily be touched (See Clause 10).

4.4.4.3 Spread of fire

Conformity with requirements for protection against the spread of fire is checked by placing the equipment on white tissue-paper covering a softwood surface and covering the equipment with cheesecloth. No molten metal, burning insulation, flaming particles, etc. shall fall on the surface on which the equipment stands and there shall be no charring, glowing, or flaming of the tissue paper or cheesecloth. Melting of insulation material shall be ignored if no HAZARD could arise.

4.4.4.4 Other HAZARDS

Conformity with other requirements for protection against HAZARDS is checked as specified in Clauses 7 to 16.

5 Marking and documentation

5.1 Marking

5.1.1 General

Equipment shall bear markings as specified in 5.1.2 to 5.2. Except for marking of internal parts, these markings shall be visible from the exterior, or be visible after removing a cover or opening a door without the aid of a TOOL, if the cover or door is intended to be removed or opened by an OPERATOR. Markings applying to the equipment as a whole shall not be put on parts which can be removed by an OPERATOR without the use of a TOOL.

For rack- or panel-mounted equipment, markings are permitted to be on a surface that becomes visible after removal of the equipment from the rack or panel.

Letter symbols for quantities and units shall be as specified in IEC 60027. Graphic symbols shall be in accordance with Table 1 if applicable. There are no colour requirements for symbols. Graphic symbols shall be explained in the documentation.

NOTE 1 IEC or ISO symbols should be used if available.

NOTE 2 Markings should not be on the bottom of the equipment, except on HAND-HELD EQUIPMENT or where space is limited.

Conformity is checked by inspection.

5.1.2 Identification

The equipment shall, as a minimum, be marked with:

a) the name or trade mark of the manufacturer or supplier;

b) a model number, name or other means to identify the equipment. If equipment bearing the same distinctive designation (model number) is manufactured at more than one location, equipment from each manufacturing location shall be marked so that the location can be identified.

   NOTE The marking of factory location may be in code and need not be on the equipment exterior.

Conformity is checked by inspection.

5.1.3 MAINS supply

The equipment shall be marked with the following information.

a) Nature of supply:

1) a.c.: RATED MAINS frequency or range of frequencies;

2) d.c.: symbol 1 of Table 1.

NOTE 1 For information purposes it may be useful to mark

– equipment intended for a.c. with symbol 2 of Table 1;

– equipment suitable for both a.c. and d.c. with symbol 3 of Table 1;

– equipment for three-phase supply with symbol 4 of Table 1.

b) The RATED supply voltage(s) or the RATED range of supply voltages.

NOTE 2 RATED voltage fluctuations may also be marked.

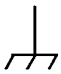
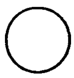
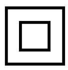
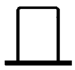
c) The maximum RATED power in watts (active power) or volt-amperes (apparent power), or the maximum RATED input current, with all accessories or plug-in modules connected. If the equipment can be used on more than one voltage range, separate values shall be marked for each voltage range unless the maximum and minimum values do not differ by more than 20 % of the mean value. The marked value shall not be less than 90 % of the maximum value.

d) Equipment which an OPERATOR can set for different RATED supply voltages shall be provided with means for the indication of the voltage for which the equipment is set. For PORTABLE EQUIPMENT the indication shall be visible from the exterior. If the equipment is so constructed that the supply voltage setting can be altered without the use of a TOOL, the action of changing the setting shall also change the indication.

e) Accessory MAINS socket-outlets accepting standard MAINS plugs shall be marked with the voltage if it is different from the MAINS supply voltage. If the outlet is for use only with specific equipment, it shall be marked to identify the equipment for which it is intended. If not, the maximum RATED current or power shall be marked, or symbol 14 of Table 1 placed beside the outlet with the full details included in the documentation.

Conformity is checked by inspection and by measurement of power or input current to check the ~~marking~~ requirements of 5.1.3 c) have been met. The measurement is made at each RATED voltage range with the equipment in the condition of maximum power or current consumption~~, but~~ as applicable with all accessories and plug-in modules connected. If the input current varies during the normal operating cycle, the steady-state current is taken as the mean indication of the highest measured r.m.s. value during a 1 min period of the normal operation cycle. To exclude any initial inrush current,~~ it~~ the measurement is not made until the current has stabilized (usually after 1 min). Transients are ignored.

Table 1 – Symbols

Number	Symbol	Reference	Description
1		IEC 60417-5031 (2002-10)	Direct current
2		IEC 60417-5032 (2002-10)	Alternating current
3		IEC 60417-5033 (2002-10)	Both direct and alternating current
4		IEC 60417-5032-1 (2002-10)	Three-phase alternating current
5		IEC 60417-5017 (2006-08)	Earth (ground) TERMINAL
6		IEC 60417-5019 (2006-08)	PROTECTIVE CONDUCTOR TERMINAL
7		IEC 60417-5020 (2002-10)	Frame or chassis TERMINAL
8			Not used
9		IEC 60417-5007 (2009-02)	On (Power)
10		IEC 60417-5008 (2009-02)	Off (Power)
11		IEC 60417-5172 (2003-02)	Equipment protected throughout by DOUBLE INSULATION or REINFORCED INSULATION
12			Caution, possibility of electric shock
13		IEC 60417-5041 (2002-10)	Caution, hot surface
14		ISO 7000-0434B (2004-01)	Caution [a]
15		IEC 60417-5268 (2002-10)	In position of a bi-stable push control
16		IEC 60417-5269 (2002-10)	Out position of a bi-stable push control
17		ISO 361	Ionizing radiation

[a] See 5.4.1 which requires manufacturers to state that documentation must be consulted in all cases where this symbol is marked.

5.1.4 Fuses

For any fuse which may be replaced by an OPERATOR, there shall be a marking beside the fuseholder, which will enable the OPERATOR to identify the correct replacement fuse (see 5.4.5).

Conformity is checked by inspection.

5.1.5 TERMINALS, connections and operating devices

5.1.5.1 General

If necessary for safety, an indication shall be given of the purpose of TERMINALS, connectors, controls, and indicators, including any connections for fluids such as gas, water and drainage. Where there is insufficient space, symbol 14 of Table 1 may be used.

NOTE 1 For additional information, see IEC 60445 and IEC 60447.

NOTE 2 Individual pins of multi-pin connectors need not be marked.

Push-buttons and actuators of emergency stop devices, and indicators used only to indicate a warning of danger or the need for urgent action, shall be coloured red and coded as specified in IEC 60073. If the meaning of colour relates to the safety of persons or the environment, supplementary means of coding shall be provided (see IEC 60073).

NOTE 3 National authorities may require that equipment used in certain environments meet the man-machine interface requirements pertinent to that environment.

Conformity is checked by inspection.

5.1.5.2 TERMINALS

TERMINALS for connection to the MAINS supply shall be identifiable.

The following TERMINALS shall be marked as follows:

a) FUNCTIONAL EARTH TERMINALS with symbol 5 of Table 1;

b) PROTECTIVE CONDUCTOR TERMINALS with symbol 6 of Table 1, except when the PROTECTIVE CONDUCTOR TERMINAL is part of an approved MAINS appliance inlet. The symbol shall be placed on the TERMINAL or close to it;

c) TERMINALS of ~~control~~ circuits which are permitted by 6.6.3 to be connected to ACCESSIBLE conductive parts, with symbol 7 of Table 1 unless connection is self-evident;

   NOTE This symbol may also be considered as a warning symbol in that it indicates that a HAZARDOUS LIVE voltage must not be connected to the TERMINAL. The symbol should also be used if it is likely that an OPERATOR could make such a connection inadvertently.

d) TERMINALS supplied from the interior of the equipment and which are HAZARDOUS LIVE, with the voltage, current, charge or energy value or range, or with symbol 14 of Table 1. This requirement does not apply to MAINS supply outlets where a standard MAINS socket outlet is used.

Conformity is checked by inspection.

5.1.6 Switches and circuit-breakers

If the power supply switch or circuit-breaker is used as the disconnecting device, the off-position shall be clearly marked.

NOTE It is recommended that the on-position also be marked.

Symbols 9 and 10 of Table 1 can, in some cases, also be suitable as the device identification (see 6.11.3.1 c)). A lamp alone is not considered to be a satisfactory marking.

If a push-button switch is used as the power supply switch, symbols 9 and 15 of Table 1 may be used to indicate the on-position, or symbols 10 and 16 to indicate the off-position, with the pair of symbols (9 and 15, or 10 and 16) close together.

Conformity is checked by inspection.

5.1.7 Equipment protected by DOUBLE INSULATION or REINFORCED INSULATION

Equipment which is only partially protected by DOUBLE INSULATION or REINFORCED INSULATION shall not be marked with symbol 11 of Table 1.

NOTE Equipment protected throughout by DOUBLE INSULATION or REINFORCED INSULATION may be marked with symbol 11 of Table 1.

Conformity is checked by inspection.

5.1.8 Field-wiring TERMINAL boxes

If the temperature of the TERMINALS or the ENCLOSURE of a field-wiring TERMINAL box or compartment exceeds 60 °C in NORMAL CONDITION at an ambient temperature of 40 °C, or at the maximum RATED ambient temperature if higher, there shall be a marking to warn the installer to consult the installation instructions before determining the temperature RATING of the cable to be connected to the TERMINALS. The marking shall be visible before and during connection, or be beside the TERMINALS. Symbol 14 is an acceptable marking.

Conformity, in case of doubt, is checked by measurement as specified in 10.3 a) and, if applicable, by inspection of markings.

5.2 Warning markings

Warning markings specified in ~~5.1.5.2 c), 6.1.2 b), 6.6.2, 7.3.2 b) 3), 7.4, 10.1 and 13.2.2~~ this standard shall meet the following requirements.

Warning markings shall be visible when the equipment is ready for NORMAL USE. If a warning applies to a particular part of the equipment, the marking shall be placed on or near that part.

The size of warning markings shall be as follows:

a) symbols shall be at least 2,75 mm high. Text shall be at least 1,5 mm high and contrast in colour with the background;

b) symbols or text moulded, stamped or engraved in a material shall be at least 2,0 mm high. If not contrasting in colour, they shall have a depth or raised height of at least 0,5 mm.

If it is necessary for the RESPONSIBLE BODY or OPERATOR to refer to the documentation to preserve the protection afforded by the equipment, the equipment shall be marked with symbol 14 of Table 1. Symbol 14 is not required to be used if other symbols which address the safety aspects are used and explained in the documentation.

If the instructions for use state that an OPERATOR is permitted to gain access, using a TOOL, to a part or location which in NORMAL USE may ~~be HAZARDOUS LIVE~~ present a HAZARD, there shall be a warning marking ~~which states~~ indicating that the equipment must be ~~isolated or disconnected from the HAZARDOUS LIVE voltage~~ placed in a safe state before access. Symbol 14 shall be used for this purpose with the warning text included in the documentation. Additional symbols may be used to indicate the nature of the HAZARD such as symbol 12, 13, or 17 as appropriate.

Symbols are the preferred marking method over text warnings. Supplemental text may be provided adjacent to the symbol.

Conformity is checked by inspection.

5.3 Durability of markings

Required markings shall remain clear and legible under conditions of NORMAL USE and shall resist the effects of the cleaning agents specified by the manufacturer.

Conformity is checked by performing the following test for durability of markings on the outside of the equipment. The markings are rubbed by hand, without undue pressure, for 30 s with a cloth soaked with each specified cleaning agent (or, if not specified, with 70 % isopropyl alcohol).

After the above treatment the markings shall be clearly legible and adhesive labels shall not have worked loose or become curled at the edges.

5.4 Documentation

5.4.1 General

The following documentation necessary for safety purposes, as needed by the OPERATOR or the RESPONSIBLE BODY, shall be provided with the equipment. Safety documentation for service personnel authorized by the manufacturer shall be made available to such personnel:

a) intended use of the equipment;

b) technical specification;

c) name and address of the manufacturer or supplier from whom technical assistance may be obtained;

d) the information specified in 5.4.2 to 5.4.6;

e) information about how to mitigate RISKS remaining after a RISK assessment has been performed (see Clause 17);

f) for equipment which for safety reasons requires specific accessories (for example probe assemblies) with specific characteristics, the documentation shall indicate that only accessories which meet the manufacturer's specifications shall be used;

g) if a HAZARD could be caused by an incorrect reading when measuring, indicating or detecting harmful or corrosive substances, or HAZARDOUS LIVE electrical quantities, the instructions shall provide guidance on how to determine that the equipment is functioning correctly;

h) instructions for lifting and carrying (see 7.5.1).

Warning symbols and warning statements that are marked on the equipment shall be explained in the documentation. In particular, the documentation shall include a statement that it must be consulted in all cases where symbol 14 of Table 1 is marked, in order to find out the nature of the potential HAZARDS and any actions which have to be taken to avoid them.

NOTE 1 Markings and text on equipment are considered equivalent to the documentation.

NOTE 2 If NORMAL USE involves the handling of harmful or corrosive substances, instruction should be given on correct use and safety provisions. If any harmful or corrosive substance is specified or supplied by the equipment manufacturer, the necessary information on its constituents and the correct disposal procedure should also be given.

Documentation may be provided on printed or electronic media, however printed information is required for all information necessary for safety that might not be available in electronic form at the time it is needed. The documentation shall be delivered with the equipment. Consideration shall be given to the ability of the RESPONSIBLE BODY to read the media.

Conformity is checked by inspection.

5.4.2 Equipment RATINGS

Documentation shall include the following:

a) the supply voltage or voltage range, frequency or frequency range, and power or current RATING;

b) a description of all input and output connections as required by 6.6.1 a);

c) the rating of the insulation of external circuits as required by 6.6.1 b);

d) a statement of the range of environmental conditions for which the equipment is designed ~~(see 1.4)~~ including:

   1) indoor or outdoor use,
   2) altitude,
   3) temperature,
   4) relative humidity,
   5) MAINS supply voltage fluctuations,
   6) OVERVOLTAGE CATEGORY, except for cord/plug-connected equipment,
   7) WET LOCATION, if applicable,
   8) POLLUTION DEGREE of the intended environment,

e) ~~a statement of the degree of ingress protection (IP), if the~~ for equipment ~~is~~ RATED for ingress protection according to IEC 60529 the information required in 11.6.1;

f) for equipment with an impact RATING less than 5 J, the information specified in 8.1 d).

Conformity is checked by inspection.

5.4.3 Equipment installation

The documentation shall include installation and specific commissioning instructions and, if necessary for safety, warnings against HAZARDS which could arise during installation or commissioning or as a result of improper installation or commissioning of the equipment. Such information includes, if applicable:

a) assembly, location and mounting requirements;

b) instructions for protective earthing;

c) connections to the supply;

d) for PERMANENTLY CONNECTED EQUIPMENT:

   1) supply wiring requirements;
   2) requirements for any external switch or circuit-breaker (see 6.11.3.1) and external overcurrent protection devices (see 9.6.2) and a recommendation that the switch or circuit-breaker be near the equipment;

e) ventilation requirements;

f) requirements and safety characteristics for special external services, for example: maximum and minimum temperature, pressure, or flow of air or cooling liquid;

g) instructions relating to sound level (see 12.5.1).

NOTE It is recommended to add a statement in the documentation for the installation that the safety of any system incorporating the equipment is the responsibility of the assembler of the system.

Conformity is checked by inspection.

5.4.4 Equipment operation

Instructions for use shall include, if applicable:

a) identification and description of operating controls and their use in all operating modes;

b) instructions not to position the equipment so that it is difficult to operate the disconnecting device;

c) instructions for interconnection to accessories and other equipment, including indication of suitable accessories, detachable parts and any special materials;

d) specifications of limits for intermittent operation;

e) explanations of symbols related to safety which are used on the equipment;

f) instructions for replacement of consumable materials;

g) instructions for cleaning and decontamination;

h) a statement listing potentially poisonous or injurious substances that can be liberated from the equipment, and possible quantities;

i) detailed instructions about RISK reduction procedures relating to flammable liquids (see 9.5 c));

j) details of methods of reducing the RISKS of burns from surfaces permitted to exceed the temperature limits of 10.1.

If equipment conforming to IEC 60950 is used with equipment conforming to this standard, and if there is a HAZARD due to moisture or liquids, the instructions for use shall specify any additional precautions necessary.

There shall be a statement in the instructions that, if the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

Conformity is checked by inspection.

5.4.5 Equipment maintenance and service

Instructions shall be provided to the RESPONSIBLE BODY in sufficient detail to permit safe maintenance ~~and~~, inspection and testing of the equipment, and to ensure continued safety of the equipment after the maintenance ~~and~~, inspection and test procedure.

If applicable, manufacturer's documentation shall instruct against replacing detachable MAINS supply cords by inadequately RATED cords.

For equipment using replaceable batteries, the specific battery type shall be stated.

The manufacturer shall specify any parts which are required to be examined or supplied only by the manufacturer or his agent.

The RATING and characteristics of replaceable fuses shall be stated.

Instructions on the following subjects shall be provided for service personnel, as necessary to permit safe servicing and continued safety of the equipment after servicing if the equipment is suitable to be serviced:

a) product-specific RISKS that may affect the service personnel;

b) protective measures for these RISKS;

c) verification of the safe state of the equipment after repair.

NOTE Instructions for service personnel need not be supplied to the RESPONSIBLE BODY, but should be made available to service personnel.

Conformity is checked by inspection.

5.4.6 Integration into systems or effects resulting from special conditions

Aspects resulting from integration into systems or effects resulting from special ambient or application conditions shall be described in the documentation.

Conformity is checked by inspection of the documentation.

6 Protection against electric shock

6.1 General

6.1.1 Requirements

Protection against electric shock shall be maintained in NORMAL CONDITION and SINGLE FAULT CONDITION (see 6.4 and 6.5). ACCESSIBLE parts (see 6.2) shall not be HAZARDOUS LIVE (see 6.3). Voltage, current, charge or energy between an ACCESSIBLE part and earth, or between any two ACCESSIBLE parts on the same piece of equipment within a distance of 1,8 m (over a surface or through air), shall not exceed the levels of 6.3.1 in NORMAL CONDITION nor of 6.3.2 in SINGLE FAULT CONDITION.

Conformity is checked by the determination of ACCESSIBLE parts as specified in 6.2 and by the measurements of 6.3 to establish that the levels of 6.3.1 and 6.3.2 are not exceeded, followed by the tests of 6.4 to 6.11.

6.1.2 Exceptions

If it is not feasible for operating reasons to prevent the following parts being both ACCESSIBLE and HAZARDOUS LIVE, they are permitted to be ACCESSIBLE to an OPERATOR during NORMAL USE while they are HAZARDOUS LIVE:

a) parts of lamps and lamp sockets after lamp removal;
b) parts intended to be replaced by an OPERATOR (for example, batteries) and which may be HAZARDOUS LIVE during the replacement or other OPERATOR action, but only if they are ACCESSIBLE only by means of a TOOL and have a warning marking (see 5.2);

If any of the parts in a) and b) receives a charge from an internal capacitor, they shall not be HAZARDOUS LIVE 10 s after interruption of the supply.

If a charge is received from an internal capacitor, conformity is checked by the measurements of 6.3 to establish that the levels of 6.3.1 c) are not exceeded.

6.2 Determination of ACCESSIBLE parts

6.2.1 General

Unless obvious, determination of whether a part is ACCESSIBLE is made as specified in 6.2.2 to 6.2.4 in all positions of NORMAL USE. Test fingers (see Annex B) and pins are applied without force unless a force is specified. Parts are considered to be ACCESSIBLE if they can be touched with any part of a test finger or test pin, or if they could be touched in the absence of a covering which is not considered to provide suitable insulation (see ~~6.9.1~~ 6.9.2).

If, in NORMAL USE, an OPERATOR is intended to perform any actions (with or without a TOOL) that could increase the accessibility of parts, such actions are taken before performing the examinations of 6.2.2 to 6.2.4.

NOTE Examples of such actions include:

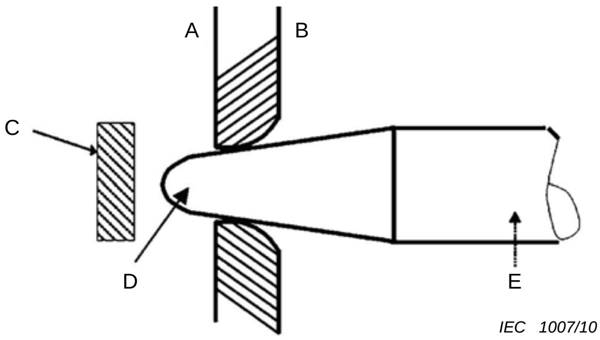
a) removing covers;
b) opening doors;
c) adjusting controls;
d) replacing consumable material;
e) removing parts.

Rack-mounted and panel-mounted equipment is installed as specified in the manufacturer's instructions before making the examinations of 6.2.2 to 6.2.4. For such equipment, the OPERATOR *is assumed to be in front of the panel.*

6.2.2 Examination

The jointed test finger (see Figure B.2) is applied in every possible position. If a part could become ACCESSIBLE *by applying a force, the rigid test finger (see Figure B.1) is applied with a force of 10 N. The force is exerted by the tip of the test finger so as to avoid wedge and lever action. The test is applied to all outer surfaces, including the bottom. However, on equipment accepting plug-in modules the tip of the jointed test finger is inserted only to a depth of 180 mm from the opening in the equipment.*

The test finger is likewise applied to all openings in the ENCLOSURE*, including holes and* TERMINALS*. In these cases, the* ACCESSIBLE *parts of the* ENCLOSURE *are considered to include any part of the test finger which can be inserted into the hole or* TERMINAL *(see Figure 1).*



Key

A inside of equipment

B outside of equipment

C HAZARDOUS LIVE part

D tip of test finger is considered to be ACCESSIBLE

E test finger

Figure 1 – Measurements through openings in ENCLOSURES

6.2.3 Openings above parts that are HAZARDOUS LIVE

A metal test pin 100 mm long and 4 mm in diameter is inserted into any openings above parts which are HAZARDOUS LIVE*. The test pin is suspended freely and allowed to penetrate up to 100 mm.*

The additional safety measures of 6.5.1 for protection in SINGLE FAULT CONDITION *are not required solely because a part is* ACCESSIBLE *only by this test.*

NOTE This exception is permitted because the insertion of an object similar to this test pin is considered to be a SINGLE FAULT CONDITION and one means of protection is sufficient.

This test is not applied to TERMINALS*.*

6.2.4 Openings for pre-set controls

A metal test pin 3 mm in diameter is inserted through holes intended to give access to pre-set controls which require the use of a screwdriver or other TOOL*. The test pin is applied in every* *possible direction through the hole. Penetration shall not exceed three times the distance from the* ENCLOSURE *surface to the control shaft or 100 mm, whichever is smaller.*

6.3 Limit values for ACCESSIBLE parts

6.3.1 Levels in NORMAL CONDITION

Voltages above the levels of a) are deemed to be HAZARDOUS LIVE if any of the levels of b) or c) are exceeded at the same time.

a) The a.c. voltage levels are ~~33~~ 30 V r.m.s., ~~46,7~~ 42,4 V peak and the d.c. voltage level is ~~70~~ 60 V. For equipment intended for use in WET LOCATIONS, the a.c. voltage levels are 16 V r.m.s., 22,6 V peak and the d.c.voltage level is 35 V.

b) The current levels are:

1) 0,5 mA r.m.s. for sinusoidal waveforms, 0,7 mA peak for non-sinusoidal waveforms or mixed frequencies, or 2 mA d.c., when measured with the measuring circuit of Figure A.1. If the frequency does not exceed 100 Hz, the measuring circuit of Figure A.2 can be used. The measuring circuit of Figure A.4 is used for equipment intended for use in WET LOCATIONS.

2) 70 mA r.m.s. when measured with the measuring circuit of Figure A.3. This relates to possible burns at higher frequencies.

c) The levels of capacitive charge or energy are:

1) 45 μC charge for voltages up to 15 kV peak or d.c.; line A of Figure 3 shows the capacitance versus voltage where the charge is 45 μC.

2) 350 mJ stored energy for voltages above 15 kV peak or d.c.

6.3.2 Levels in SINGLE FAULT CONDITION

Voltages above the levels of a) are deemed to be HAZARDOUS LIVE if any of the levels of b) or c) are exceeded at the same time.

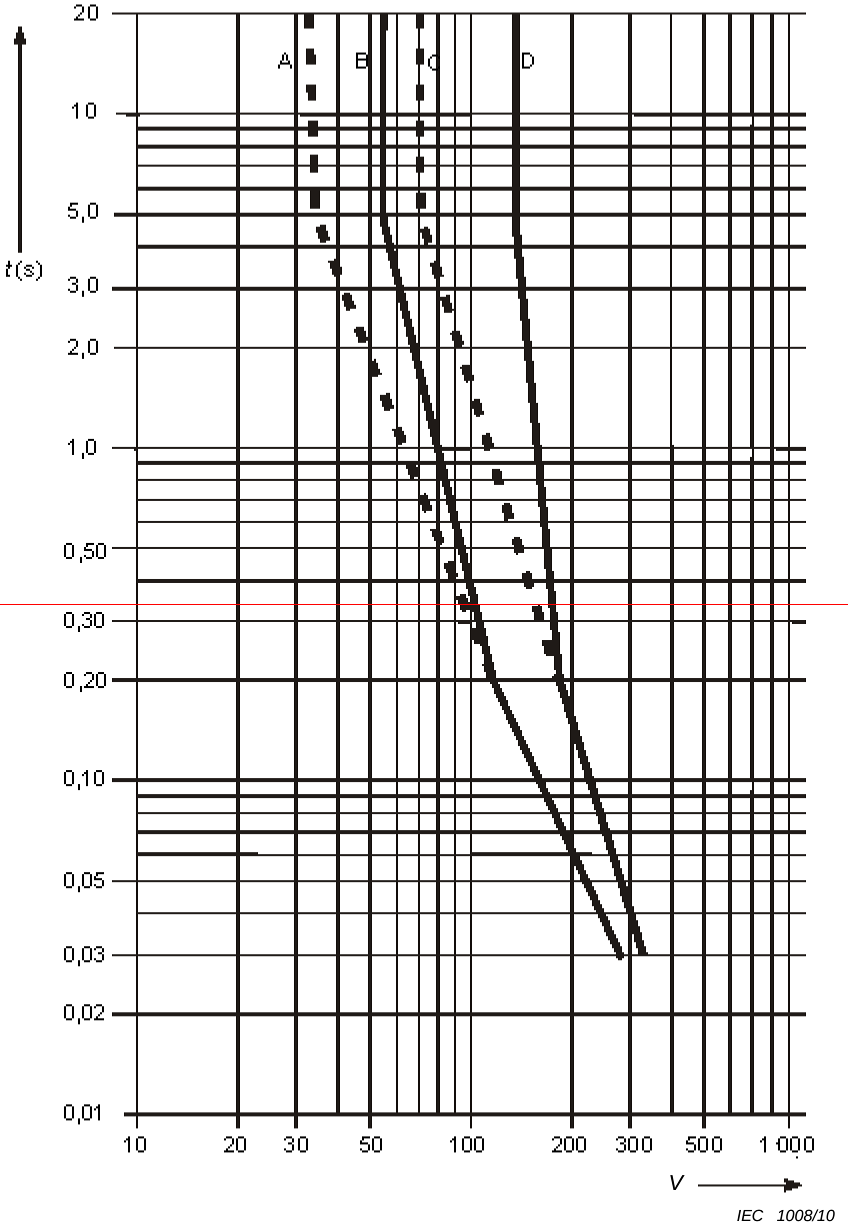
a) The a.c. voltage levels are ~~55~~ 50 V r.m.s., ~~78~~ 70 V peak and the d.c. voltage level is ~~140~~ 120 V. For equipment intended for use in WET LOCATIONS, the a.c. voltage levels are 33 V r.m.s, 46,7 V peak and the d.c. voltage level is 70 V . For voltages of short duration, the duration versus voltage levels are those of Figure 2, measured across a 50 kΩ resistor.

b) The current levels are:

1) 3,5 mA r.m.s. for sinusoidal waveforms, 5 mA peak for non-sinusoidal waveforms or mixed frequencies, or 15 mA d.c., when measured with the measuring circuit of Figure A.1. If the frequency does not exceed 100 Hz, the measuring circuit of Figure A.2 can be used. The measuring circuit of Figure A.4 is used for equipment intended for use in WET LOCATIONS;

2) 500 mA r.m.s. when measured with the measuring circuit of Figure A.3. This relates to possible burns at higher frequencies.

c) The capacitance level is line B of Figure 3.


20
10
5,0
3,0
2,0
1,0
0,50
0,30
0,20
0,10
0,05
0,03
0,02
0,01
t (s)
A
B
C
D
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30
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200
300
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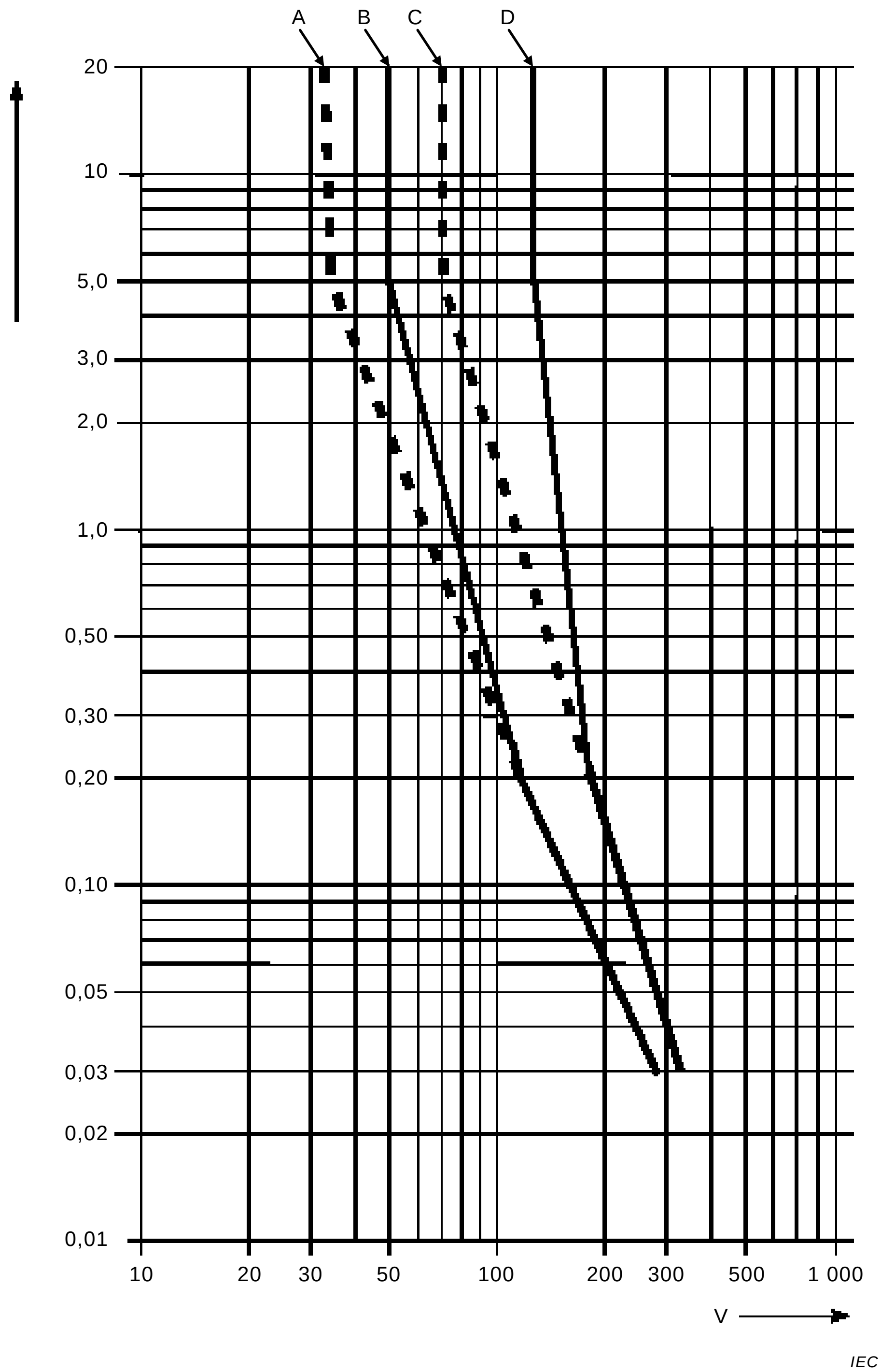


Key

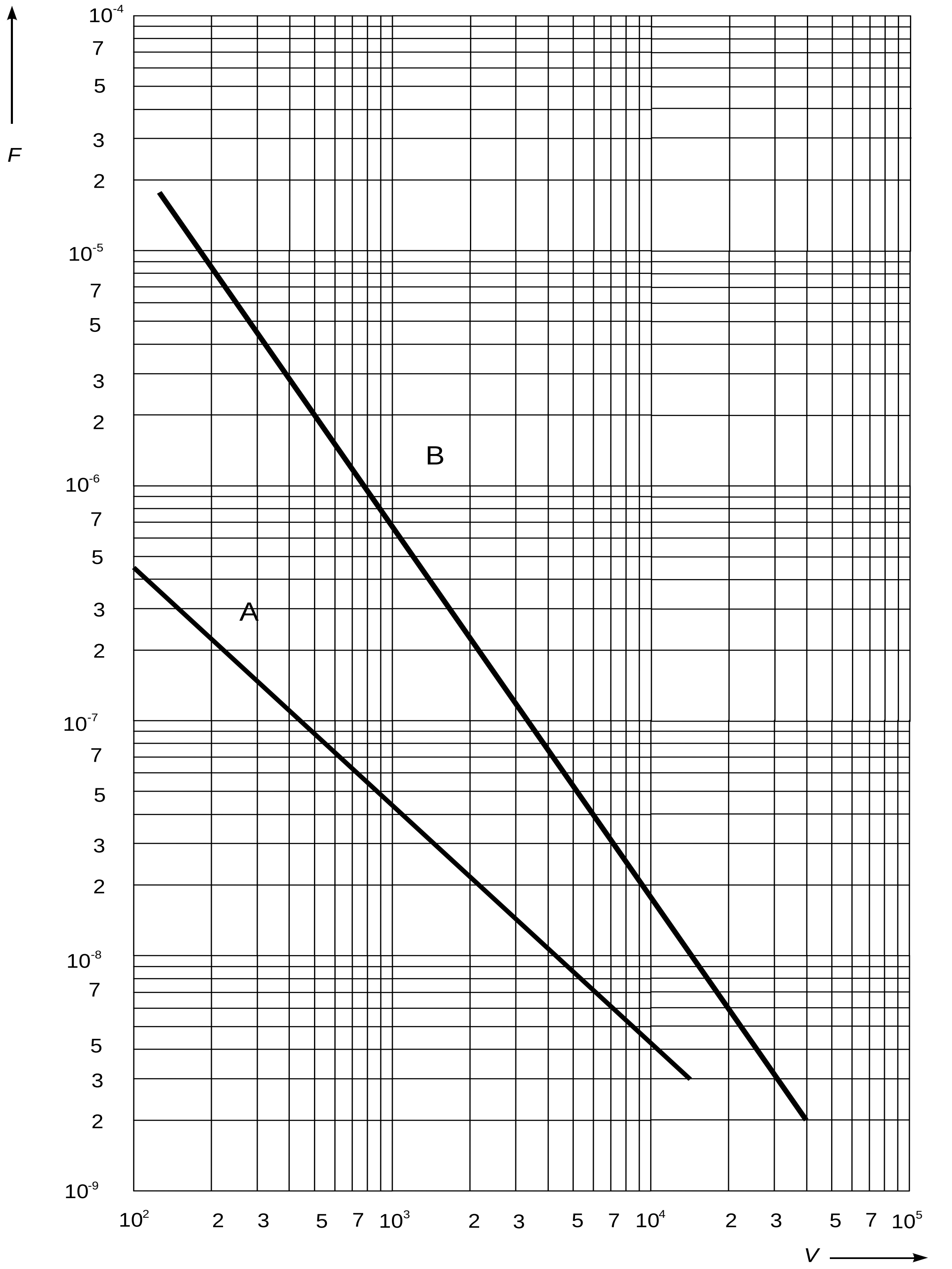
A a.c. voltage level in WET LOCATIONS

B a.c. voltage level in dry locations

C d.c. voltage level in WET LOCATIONS

D d.c. voltage level in dry locations

Figure 2 – Maximum duration of short-term ACCESSIBLE voltages in SINGLE FAULT CONDITION (see 6.3.2 a))



Key

A NORMAL CONDITION

B SINGLE FAULT CONDITION

Figure 3 – Capacitance level versus voltage in NORMAL CONDITION and SINGLE FAULT CONDITION (see 6.3.1 c) and 6.3.2 c))

6.4 Primary means of protection

6.4.1 General

ACCESSIBLE parts shall be prevented from becoming HAZARDOUS LIVE by one or more of the following means (see Annex D):

a) ENCLOSURES or PROTECTIVE BARRIERS (see 6.4.2);

b) BASIC INSULATION (see 6.4.3);

c) impedance (see 6.4.4).

Conformity is checked by inspection and as specified in 6.4.2. to 6.4.4.

6.4.2 ENCLOSURES and PROTECTIVE BARRIERS

ENCLOSURES and PROTECTIVE BARRIERS shall meet the rigidity requirements of 8.1.

If ENCLOSURES or PROTECTIVE BARRIERS provide protection by insulation, they shall meet the requirements of BASIC INSULATION.

If ENCLOSURES or PROTECTIVE BARRIERS provide protection by limiting access, CLEARANCES and CREEPAGE DISTANCES between ACCESSIBLE parts and HAZARDOUS LIVE parts shall meet the requirements of 6.7 and the applicable requirements for BASIC INSULATION.

Conformity is checked as specified in 6.7 and 8.1.

6.4.3 BASIC INSULATION

CLEARANCES, CREEPAGE DISTANCES and solid insulation forming BASIC INSULATION between ACCESSIBLE parts and HAZARDOUS LIVE parts shall meet the requirements of 6.7.

Conformity is checked as specified in 6.7.

6.4.4 Impedance

An impedance used as a primary means of protection shall meet all the following requirements:

a) it shall limit the current or voltage to not more than the applicable level of 6.3.2;

b) it shall be RATED for the maximum WORKING VOLTAGE and for the amount of power that it will dissipate;

c) CLEARANCE and CREEPAGE DISTANCE between terminations of the impedance shall meet the applicable requirements of 6.7 for BASIC INSULATION.

Conformity is checked by inspection, by measuring the voltage or current to confirm that they do not exceed the levels of 6.3.2, and by measuring CLEARANCE and CREEPAGE DISTANCE as specified in 6.7.

6.5 Additional means of protection in case of SINGLE FAULT CONDITIONS

6.5.1 General

ACCESSIBLE parts shall be prevented from becoming HAZARDOUS LIVE in SINGLE FAULT CONDITION. The primary means of protection (see 6.4) shall be supplemented by one of a), b), c) or d). Alternatively one of the single means of protection e) or f) shall be used. See Figure 4 and Annex D.

a) PROTECTIVE BONDING (see 6.5.2);

b) SUPPLEMENTARY INSULATION (see 6.5.3);

c) automatic disconnection of the supply (see 6.5.5);

d) current- or voltage-limiting device (see 6.5.6);

e) REINFORCED INSULATION (see 6.5.3);

f) PROTECTIVE IMPEDANCE (see 6.5.4).

Conformity is checked by inspection and as specified in 6.5.2 to 6.5.6.

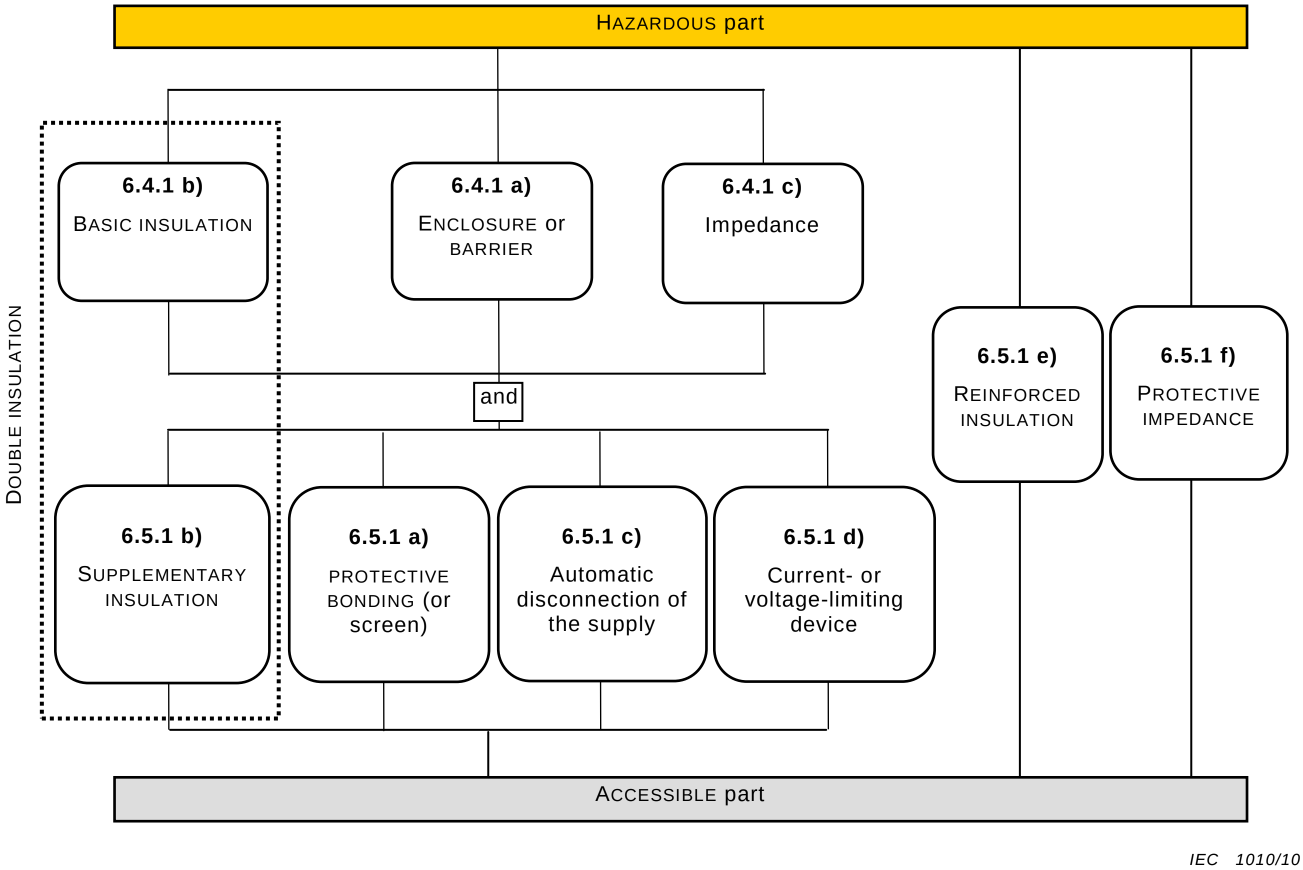


Figure 4 – Acceptable arrangement of protective means against electric shock

6.5.2 PROTECTIVE BONDING

6.5.2.1 General

ACCESSIBLE conductive parts shall be bonded to the PROTECTIVE CONDUCTOR TERMINAL if they could become HAZARDOUS LIVE in case of a single fault of the primary means of protection specified in 6.4. Alternatively, such ACCESSIBLE parts shall be separated from parts which are HAZARDOUS LIVE by a conductive protective screen bonded to the PROTECTIVE CONDUCTOR TERMINAL.

Conformity is checked as specified in 6.5.2.2 to 6.5.2.6.

6.5.2.2 Integrity of PROTECTIVE BONDING

The integrity of PROTECTIVE BONDING shall be assured as specified below.

a) PROTECTIVE BONDING shall consist of directly connected structural parts or discrete conductors, or both. It shall withstand all thermal and dynamic stresses to which it could be subjected before one of the overcurrent protective means specified in 9.6 disconnects the equipment from the supply.

b) Soldered connections subject to mechanical stress shall be mechanically secured independently from the soldering. Such connections shall not be used for other purposes such as fixing constructional parts.

c) Screw connections shall be secured against loosening.

d) If a part of the equipment is removable by an OPERATOR, the PROTECTIVE BONDING for the remainder of the equipment shall not be interrupted (except for a part that also carries the MAINS input connection to the whole equipment).

e) Unless they are specifically designed for electrical inter-connection and meet the requirements of 6.5.2.4, movable conductive connections, for example, hinges, slides, etc., shall not be the sole PROTECTIVE BONDING path.

f) The exterior metal braid of cables shall not be regarded as PROTECTIVE BONDING, even if connected to the PROTECTIVE CONDUCTOR TERMINAL.

g) If power from the MAINS supply is passed through equipment for use by other equipment, means shall also be provided for passing the protective conductor through the equipment to protect the other equipment. The impedance of the protective conductor path through the equipment shall not exceed that specified in 6.5.2.4.

h) Protective conductors may be bare or insulated. Insulation shall be green-and-yellow, except in the following cases:

   1) for earthing braids, either green-and-yellow or colourless-transparent;

   2) for internal protective conductors, and other conductors connected to the PROTECTIVE CONDUCTOR TERMINAL in assemblies such as ribbon cables, busbars, flexible printed wiring, etc., any colour may be used provided that no HAZARD is likely to arise from non-identification of the protective conductor.

Equipment using PROTECTIVE BONDING shall be provided with a TERMINAL that is suitable for connection to a protective conductor and meets the requirements of 6.5.2.3.

Conformity is checked by inspection.

6.5.2.3 PROTECTIVE CONDUCTOR TERMINAL

PROTECTIVE CONDUCTOR TERMINALS shall meet the following requirements.

a) The contact surfaces shall be metal.

   NOTE 1 Materials of PROTECTIVE BONDING systems should be chosen to minimize electro-chemical corrosion between the TERMINAL and the protective conductor, or any other metal in contact with them.

b) The integral protective conductor connection of an appliance inlet shall be regarded as the PROTECTIVE CONDUCTOR TERMINAL.

c) For equipment provided with a rewirable flexible cord and for PERMANENTLY CONNECTED EQUIPMENT, the PROTECTIVE CONDUCTOR TERMINAL shall be located near the MAINS supply TERMINALS.

d) If the equipment does not require connection to a MAINS supply, but nevertheless has a circuit or part which is required to be protectively earthed, the PROTECTIVE CONDUCTOR TERMINAL shall be located near the TERMINALS of that circuit for which protective earthing is necessary. If this circuit has external TERMINALS, the PROTECTIVE CONDUCTOR TERMINAL shall also be external.

e) PROTECTIVE CONDUCTOR TERMINALS for MAINS CIRCUITS shall be at least equivalent in current-carrying capacity to the MAINS supply TERMINALS.

f) Plug-in type PROTECTIVE CONDUCTOR TERMINALS combined with other TERMINALS and intended to be connected and disconnected without the use of a TOOL, shall be designed so that the protective conductor connection makes first and breaks last with respect to the other connections. Examples include plugs and appliance couplers for MAINS cords and connector assemblies of plug-in units.

g) If the PROTECTIVE CONDUCTOR TERMINAL is also used for other bonding purposes, the protective conductor shall be applied first and secured independently of other connections. The protective conductor shall be connected in such a way that it is unlikely to be removed during servicing that does not require disconnection of the protective conductor.

h) For equipment in which the protective conductor is required for protection against a single fault in a measuring circuit, the following shall apply:

   1) the PROTECTIVE CONDUCTOR TERMINAL and protective conductor shall have at least the current RATING of the measuring TERMINALS;

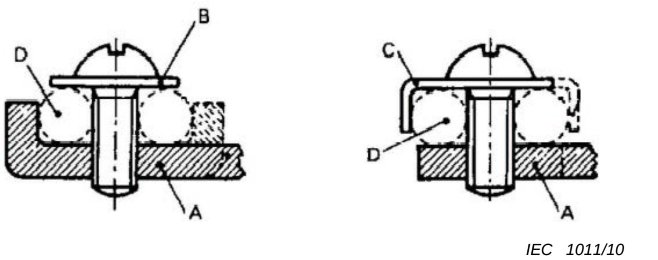
   2) the PROTECTIVE BONDING shall not be interrupted by any switching or interrupting device.

i) FUNCTIONAL EARTH TERMINALS (for example, measuring earth TERMINALS) shall allow a connection which is independent from the connection of the protective conductor.

NOTE 2 Equipment may be equipped with FUNCTIONAL EARTH TERMINALS, irrespective of the protective means taken.

j) If the PROTECTIVE CONDUCTOR TERMINAL is a binding screw assembly (see Figure 5), it shall be of a suitable size for the bond wire, but with a thread size no smaller than 4,0 mm, with at least three turns of the screw engaged.

k) The contact pressure required for a bonding connection shall not be capable of being reduced by deformation of materials forming part of the connection.



Key

A fixed part

B washer or clamping plate

C anti-spread device

D conductor space

Figure 5 – Examples of binding screw assemblies

Conformity is checked by inspection. Conformity for j) is also checked by the following test.

The binding screw assembly is to be tightened and loosened three times, together with the least favourable conductor to be secured, using the tightening torques specified in Table 2. All parts of the binding screw assembly shall withstand this test without mechanical failure.

Table 2 – Tightening torque for binding screw assemblies

Thread size mm	4,0	5,0	6,0	8,0	10,0
Tightening torque N·m	1,2	2,0	3,0	6,0	10,0

6.5.2.4 Impedance of PROTECTIVE BONDING of plug-connected equipment

The impedance between the PROTECTIVE CONDUCTOR TERMINAL and each ACCESSIBLE part for which PROTECTIVE BONDING is specified shall not exceed 0,1 Ω. If the equipment has a non-detachable power cord, the impedance between the protective conductor plug pin of the MAINS cord and each ACCESSIBLE part for which PROTECTIVE BONDING is specified shall not exceed 0,2 Ω.

Conformity is checked by applying a test current for 1 min and then calculating impedance. The test current is the greater of

a) 25 A a.c. r.m.s. at RATED MAINS frequency or d.c.,

b) a current equal to twice the RATED current of the equipment.

If the equipment contains overcurrent protection devices for all poles of the MAINS supply, and if the wiring on the supply side of the overcurrent protection devices cannot become connected to ACCESSIBLE conductive parts in the case of a single fault, the test current need not be more than twice the RATED current of the internal overcurrent protection devices.

6.5.2.5 Impedance of PROTECTIVE BONDING of PERMANENTLY CONNECTED EQUIPMENT

PROTECTIVE BONDING of PERMANENTLY CONNECTED EQUIPMENT shall be of low impedance.

Conformity is checked by applying a test current of twice the value of the overcurrent protection means specified in the equipment installation instructions for the building supply MAINS CIRCUIT for 1 min between the PROTECTIVE CONDUCTOR TERMINAL and each ACCESSIBLE conductive part for which PROTECTIVE BONDING is required. The voltage between them shall not exceed 10 V a.c. r.m.s. or d.c.

If the equipment contains overcurrent protection devices for all poles of the MAINS supply, and if the wiring on the supply side of the overcurrent protection devices cannot become connected to ACCESSIBLE conductive parts in the case of a single fault, the test current need not be more than twice the RATED current of the internal overcurrent protection devices.

6.5.2.6 Transformer PROTECTIVE BONDING screen

If the transformer is fitted with a screen for PROTECTIVE BONDING purposes that is separated only by BASIC INSULATION from a winding that is connected to a HAZARDOUS LIVE circuit, the screen shall satisfy the requirements of 6.5.2.2 a) and b), and be of low impedance.

Conformity is checked by inspection and by one of the following tests:

a) a test current of twice the value of the overcurrent protection means of the winding is applied for 1 min between the screen and the PROTECTIVE CONDUCTOR TERMINAL. The voltage between them shall not exceed 10 V a.c. r.m.s. or d.c.;

b) the test of 6.5.2.4 using test current twice the value of the overcurrent protection means of the winding. The impedance shall not exceed 0,1 Ω.

NOTE If test a) or b) is carried out, a specially prepared sample transformer having an extra lead-out wire from the free end of the screen is used to ensure that the current during the test passes through the screen.

6.5.3 SUPPLEMENTARY INSULATION and REINFORCED INSULATION

CLEARANCES, CREEPAGE DISTANCES and solid insulation forming SUPPLEMENTARY INSULATION or REINFORCED INSULATION shall meet the applicable requirements of 6.7.

Conformity is checked as specified in 6.7.

6.5.4 PROTECTIVE IMPEDANCE

A PROTECTIVE IMPEDANCE shall limit the current or voltage to the levels of 6.3.1 in NORMAL CONDITION and 6.3.2 in SINGLE FAULT CONDITION.

Insulation between the terminations of the PROTECTIVE IMPEDANCE shall meet the requirements of 6.7 for DOUBLE INSULATION or REINFORCED INSULATION.

A PROTECTIVE IMPEDANCE shall be one or more of the following:

a) an appropriate single component which shall be constructed, selected and tested so that safety and reliability for protection against electric shock is assured. In particular, the component shall be:
   1) RATED for twice the maximum WORKING VOLTAGE;
   2) if a resistor, RATED for twice the power dissipation for the maximum WORKING VOLTAGE.
b) a combination of components.

A PROTECTIVE IMPEDANCE shall not be a single electronic device that employs electron conduction in a vacuum, gas or semiconductor

Conformity is checked by inspection, by measuring the current or voltage to confirm that they do not exceed the applicable levels of 6.3 and by measuring CLEARANCES and CREEPAGE DISTANCES as specified in 6.7. Conformity of a single component is checked by inspection of its RATINGS.

6.5.5 Automatic disconnection of the supply

An automatic disconnection device shall meet both the following requirements.

a) It shall be RATED to disconnect the load within the time specified in Figure 2.
b) It shall be RATED for the maximum RATED load conditions of the equipment.

Conformity is checked by inspection of the device specification. In case of doubt, the device is tested to check that it disconnects the supply within the required time.

6.5.6 Current- or voltage-limiting device

A current- or voltage-limiting device shall meet all the following requirements:

a) it shall be RATED to limit the current or voltage to the levels not exceeding the values of 6.3.2;
b) it shall be RATED for the maximum WORKING VOLTAGE and, if applicable, for the maximum operational current;
c) CLEARANCE and CREEPAGE DISTANCE between the terminations of the current or voltage-limiting device shall meet the applicable requirements of 6.7 for SUPPLEMENTARY INSULATION.

Conformity is checked by inspection, by measuring the voltage or current to confirm that they do not exceed the levels of 6.3.2, and by measuring CLEARANCES and CREEPAGE DISTANCES as specified in 6.7.

6.6 Connections to external circuits

6.6.1 General

In NORMAL CONDITION and in SINGLE FAULT CONDITION of the equipment, no ACCESSIBLE parts of the equipment and no ACCESSIBLE parts of an external circuit shall become HAZARDOUS LIVE as a result of connecting the external circuit to the equipment.

NOTE 1 External circuits are all circuits connected to TERMINALS of the equipment.

NOTE 2 For connection to MAINS supply source, see 6.10.

Protection shall be achieved by separation of circuits, unless short-circuiting of the separation could not cause a HAZARD.

The manufacturer's instructions or equipment markings shall include the following information, if applicable, for each external TERMINAL:

a) RATED conditions at which the TERMINAL has been designed to operate while maintaining safety (maximum RATED input/output voltage, specific type of connector, designated use, etc.);
b) RATING of the insulation required for the external circuit to conform to the requirements for protection against electric shock, arising from the connection to the TERMINAL, in NORMAL CONDITION and SINGLE FAULT CONDITION.

Conformity is checked by:

1) *inspection;*
2) *the determinations of 6.2;*
3) *the measurements of 6.3 and 6.7;*
4) *the voltage test of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7).*

6.6.2 TERMINALS for external circuits

ACCESSIBLE conductive parts of TERMINALS that receive a charge from an internal capacitor shall not be HAZARDOUS LIVE 10 s after interruption of the supply.

Conformity is checked by inspection, and by the determination of ACCESSIBLE conductive parts as specified in 6.2 and in case of doubt by measurement of the remaining voltage or charge.

6.6.3 Circuits with TERMINALS which are HAZARDOUS LIVE

These circuits shall not be connected to ACCESSIBLE conductive parts, except for circuits which are not MAINS CIRCUITS, and which are designed to be operated with one TERMINAL contact at earth potential. In such cases, the ACCESSIBLE conductive parts shall not be HAZARDOUS LIVE.

If such a circuit is also designed to be operated with one ACCESSIBLE TERMINAL contact (signal low) floating at a voltage which is not HAZARDOUS LIVE, this TERMINAL contact is permitted to be connected to a common FUNCTIONAL EARTH TERMINAL or system (for example, a coaxial screening system). This common FUNCTIONAL EARTH TERMINAL or system is also permitted to be connected to other ACCESSIBLE conductive parts.

Conformity is checked by inspection.

6.6.4 TERMINALS for stranded conductors

TERMINALS for stranded conductors that are intended to be connected during installation, maintenance, or operation of the equipment shall be located or shielded so that there is no possibility of accidental contact between HAZARDOUS LIVE parts of different polarity or between such parts and other ACCESSIBLE parts, even if a strand of a conductor escapes from a TERMINAL. ~~Unless it is self-evident (which is preferable) TERMINALS shall be marked to show whether or not they are connected to ACCESSIBLE conductive parts (see 5.1.5.2 c)).~~ This requirement does not apply to connections that are only to be made at the manufacturing facility.

Conformity is checked by inspection after fully inserting a stranded conductor *a) with the maximum length of insulation removed as specified by the equipment manufacturer, or*

b) with an 8 mm length of insulation removed if no specification is given by the equipment manufacturer.

With one of the strands free, the free strand shall not touch parts of different polarity or other ACCESSIBLE parts, when bent in every possible direction, without tearing back the insulation or making sharp bends.

TERMINALS of circuits carrying HAZARDOUS LIVE voltage or current shall be anchored, fitted or designed so that conductors will not work loose when they are tightened, loosened or when connections are made.

Conformity is checked by manual test and inspection.

6.7 Insulation requirements

6.7.1 The nature of insulation

6.7.1.1 General

Insulation between circuits and ACCESSIBLE parts (see 6.2) or between separate circuits consists of a combination of CLEARANCES, CREEPAGE DISTANCES and solid insulation. When used to provide protection against a HAZARD, the insulation needs to withstand the electric stresses that are caused by the voltages that may appear on the MAINS supply or in the equipment.

Electric stresses originating from MAINS include:

a) WORKING VOLTAGE across the insulation. This WORKING VOLTAGE is normally the line-to-neutral voltage of the MAINS supply (also see Annex I);

b) TRANSIENT OVERVOLTAGES that may occasionally appear on the line conductors. The magnitude of the overvoltages depends on the OVERVOLTAGE CATEGORY and the line-to-neutral voltage of the MAINS supply;

c) short-term TEMPORARY OVERVOLTAGES that may occur between the line conductor and earth in electrical installations. These TEMPORARY OVERVOLTAGES may have a value of the line-to-neutral voltage of the MAINS supply plus 1 200 V, and may last up to 5 s;

d) long-term TEMPORARY OVERVOLTAGES that may occur between the line conductor and earth in electrical installations. These TEMPORARY OVERVOLTAGES may have a value of the line-to neutral voltage of the MAINS supply plus 250 V and may last longer than 5 s.

NOTE See IEC 60364-4-44, Clause 442 for additional information on these TEMPORARY OVERVOLTAGES.

The requirements for insulation depend on:

1) the required level of insulation (BASIC INSULATION, SUPPLEMENTARY INSULATION, or REINFORCED INSULATION);

2) the maximum TRANSIENT OVERVOLTAGE that may appear on the circuit, either as a result of an external event (such as a lightning strike or a switching transient), or as the result of the operation of the equipment;

3) the maximum WORKING VOLTAGE (including steady-state and recurring peak voltages);

4) the POLLUTION DEGREE of the micro-environment;

5) the maximum TEMPORARY OVERVOLTAGE that may occur in a MAINS CIRCUIT because of a fault in the MAINS distribution system.

6.7.1.2 CLEARANCES

Required CLEARANCES depend on the factors in 6.7.1.1 a) to d) as well as the RATED altitude for operation. If the equipment is RATED to operate at an altitude greater than 2 000 m, all CLEARANCES shall be multiplied by the applicable factor of Table 3.

Table 3 – Multiplication factors for CLEARANCES of equipment RATED for operation at altitudes up to 5 000 m

RATED operating altitude m	Multiplication factor
Up to 2 000	1,00
2 001 to 3 000	1,14
3 001 to 4 000	1,29
4 001 to 5 000	1,48

See Annex C for details of how to measure CLEARANCES.

6.7.1.3 CREEPAGE DISTANCES

Required CREEPAGE DISTANCES depend on the factors in 6.7.1.1 a) to d) as well as the Comparative Tracking Index (CTI) of the insulating material.

Materials are separated into four groups according to their CTI values, as follows:

Material group I $600 \leq CTI$

Material group II $400 \leq CTI < 600$

Material group IIIa $175 \leq CTI < 400$

Material group IIIb $100 \leq CTI < 175$

These CTI values refer to values obtained, in accordance with IEC 60112, on samples of the relevant material specifically made for the purpose and tested with solution A. For materials where the CTI value is not known, material group IIIb is assumed.

For glass, ceramics, or other inorganic insulating materials which do not track, there are no requirements for CREEPAGE DISTANCES.

A CREEPAGE DISTANCE may be split in several portions of different materials and/or have different POLLUTION DEGREES if one of the CREEPAGE DISTANCES is dimensioned to withstand the total voltage or if the total distance is dimensioned according to the material having the lowest CTI and the highest POLLUTION DEGREE.

See Annex C for details of how to measure CREEPAGE DISTANCES.

6.7.1.4 Solid insulation

The requirements for solid insulation depend on the factors in 6.7.1.1 a) to d).

The term “solid insulation” is used to describe many different types of construction, including monolithic blocks of insulating material and insulation subsystems composed of multiple insulating materials, organized in layers or otherwise.

The electric strength of a thickness of solid insulation is considerably greater than that of the same thickness of air. The insulating distances through solid insulation are therefore typically smaller than the distances through air. As a result, electric fields in solid insulation are typically higher, and often are less homogeneous.

Solid insulation material may contain gaps or voids. When a solid insulation system is constructed from layers of solid materials, there are also likely to be gaps or voids between layers. These voids will perturb the electric field so that a disproportionately large part of the electric field is located in the void, potentially causing ionization within the void, resulting in partial discharge. These partial discharges will influence the adjacent solid insulation and may reduce its service life.

Solid insulation is not a renewable medium: damage is cumulative over the life of the equipment. Solid insulation is also subject to ageing and to degradation from repeated high voltage testing.

6.7.1.5 Requirements for insulation according to type of circuit

Requirements for insulation in particular types of circuits are specified as follows:

a) in 6.7.2 for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II with a nominal supply voltage up to 300 V;

NOTE 1 See Annex I for nominal voltages of MAINS supplies.

b) in 6.7.3 for secondary circuits separated from the circuits in a) only by means of a transformer;

c) in K.1 for MAINS CIRCUITS of OVERVOLTAGE CATEGORY III or IV or for OVERVOLTAGE CATEGORY II over 300 V;

d) in K.2 for secondary circuits separated from the circuits in c) only by means of a transformer

e) in K.3 for circuits that have one or more of the following characteristics:

1) the maximum possible TRANSIENT OVERVOLTAGE is limited by the supply source or within the equipment to a known level below the level assumed for the MAINS CIRCUIT;
2) the maximum possible TRANSIENT OVERVOLTAGE is above the level assumed for the MAINS CIRCUIT;
3) the WORKING VOLTAGE is the sum of voltages from more than one circuit, or is a mixed voltage;
4) the WORKING VOLTAGE includes a recurring peak voltage that may include a periodic non-sinusoidal waveform or a non-periodic waveform that occurs with some regularity;
5) the WORKING VOLTAGE has a frequency above 30 kHz.

NOTE 2 Requirements for insulation of measuring circuits are specified in IEC 61010-2-030.

NOTE 3 See K.3 for requirements for switching circuits such as a switching power supply.

NOTE 4 The assumed transient overvoltage level for mains is equal to the required rated impulse voltage of equipment in Table 443.2 of IEC 60364-4-44:2007/AMD1:2015.

6.7.2 Insulation for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II with a nominal supply voltage up to 300 V

6.7.2.1 CLEARANCES and CREEPAGE DISTANCES

CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS shall meet the values of Table 4 taking the following into account.

a) The values in Table 4 are for BASIC INSULATION and SUPPLEMENTARY INSULATION. Values for REINFORCED INSULATION shall be twice the values for BASIC INSULATION.

b) Minimum CLEARANCE for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION for POLLUTION DEGREE 3 is 0,8 mm.

c) If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCES shall be multiplied by the applicable factor of Table 3.

Conformity is checked by inspection and measurement.

TABLE 4 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V

Voltage line-to-neutral a.c. r.m.s. or d.c.	Values for CLEARANCE	Values for CREEPAGE DISTANCE								
		Printed wiring board material		Other insulating material						
		POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
		All material groups	Material groups I, II, IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
≤150	0,5	0,5	0,5	0,5	0,8	1,1	1,6	2,0	2,2	2,5
>150 ≤ 300	1,5	1,5	1,5	1,5	1,5	2,1	3,0	3,8	4,1	4,7

Linear interpolation of the CREEPAGE DISTANCES is allowed.

Coatings that meet the requirements of Annex H when applied to the outer surfaces of printed wiring boards reduce the POLLUTION DEGREE of the coated area to POLLUTION DEGREE 1.

Conformity of coatings is checked as specified in Annex H.

6.7.2.2 Solid insulation

6.7.2.2.1 General

Solid insulation of MAINS CIRCUITS shall withstand the electric and mechanical stresses that may occur in NORMAL USE, in all RATED environmental conditions (see 1.4), during the intended life of the equipment.

NOTE The manufacturer should take the expected life of the equipment into account when selecting insulating materials.

Conformity is checked by inspection, and by the a.c. test of 6.8.3.1 ~~with a duration of at least 1 min, or for MAINS CIRCUITS stressed only by d.c.,~~ or the ~~1 min~~ d.c. test of 6.8.3.2, using the applicable voltage from Table 5 for 1 min.

Table 5 – Test voltages for solid insulation in MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V

Voltage line-to-neutral a.c. r.m.s. or d.c.	1 min a.c. test voltage		1 min d.c. test voltage	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION
V	V	V	V	V
≤ 150	1 350	2 700	1 900	3 800
>150 ≤ 300	1 500	3 000	2 100	4 200

Solid insulation shall also meet the following requirements, as applicable:

a) for solid insulation used as an ENCLOSURE or PROTECTIVE BARRIER, the requirements of Clause 8;

b) for moulded and potted parts, the requirements of 6.7.2.2.2;

c) for inner layers of printed wiring boards, the requirements of 6.7.2.2.3;

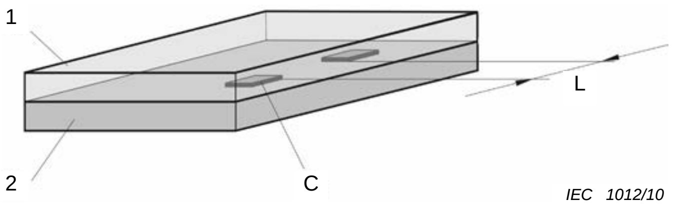
d) for thin-film insulation, the requirements of 6.7.2.2.4.

Conformity is checked as specified in 6.7.2.2.2 to 6.7.2.2.4, and in Clause 8, as applicable.

6.7.2.2.2 Moulded and potted parts

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located on an interface between the same two layers moulded together shall be separated by at least 0,4 mm (see Figure 6, item L) after the moulding is completed.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key

1 Layer 1

2 Layer 2

C Conductor

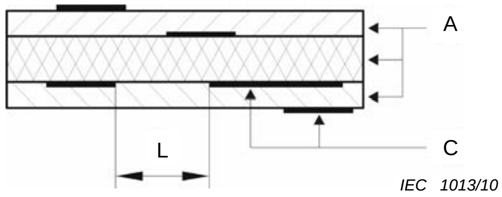
L Distance between conductors

Figure 6 – Distance between conductors on an interface between two layers

6.7.2.2.3 Inner insulating layers of printed wiring boards

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers shall be separated by at least 0,4 mm (see Figure 7, item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key

L Distance between adjacent conductors

A Layers

C Conductors

Figure 7 – Distance between adjacent conductors along an interface of two inner layers

REINFORCED INSULATION of inner insulating layers of printed wiring boards shall also have adequate electric strength through the respective layers. One of the following methods shall be used:

a) the thickness of the insulation is at least 0,4 mm;

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation is assembled from at least two separate layers of printed wiring board materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of Table 5 for BASIC INSULATION;

Conformity is checked by inspection of the manufacturer's specifications.

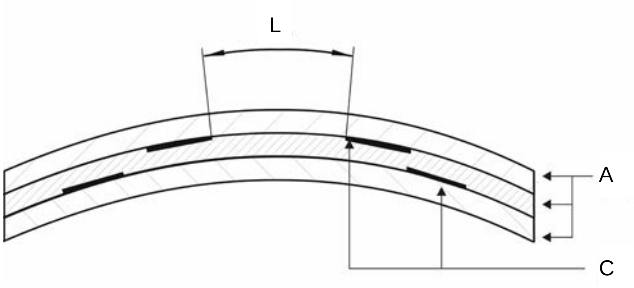
c) the insulation is assembled from at least two separate layers of printed wiring board materials, and the combination of layers is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of Table 5 for REINFORCED INSULATION.

Conformity is checked by inspection of the manufacturer's specifications.

6.7.2.2.4 Thin-film insulation

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers (see Figure 8, item L).shall be separated by the applicable CLEARANCE and CREEPAGE DISTANCE of 6.7.2.1.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key

L Distance between adjacent conductors

A Layers of thin-film material such as tape and polyester film

C Conductors

NOTE There may be air present between the layers

Figure 8 – Distance between adjacent conductors located between the same two layers

REINFORCED INSULATION through the layers of thin-film insulation shall also have adequate electric strength. One of the following methods shall be used:

a) the thickness through the insulation is at least 0,4 mm;

Conformity is checked by inspection and either by measurement of the part or by inspection of the manufacturer's specifications.

b) the insulation consists of at least two separate layers of thin-film materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of Table 5 for BASIC INSULATION;

Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation consists of at least three separate layers of thin-film materials, any two of which have been tested to exhibit adequate electric strength.

Conformity is checked by the a.c. test of 6.8.3.1 ~~with a duration of at least 1 min, or for MAINS CIRCUITS stressed only by d.c,~~ or the ~~1 min~~ d.c. test of 6.8.3.2 applied to two of the three layers using the applicable voltage for REINFORCED INSULATION of Table 5 for 1 min.

NOTE For the purposes of this test a special sample may be assembled with only two layers of the material.

6.7.3 Insulation for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V

6.7.3.1 General

In this standard, secondary circuits are circuits where separation from MAINS CIRCUITS is achieved by a transformer in which the primary windings are separated from the secondary windings by REINFORCED INSULATION, DOUBLE INSULATION, or a screen connected to the PROTECTIVE CONDUCTOR TERMINAL.

NOTE These circuits are assumed to be subjected to lower TRANSIENT OVERVOLTAGE levels than the MAINS CIRCUIT.

6.7.3.2 CLEARANCES

CLEARANCES for secondary circuits shall meet a) or b):

a) for BASIC INSULATION and SUPPLEMENTARY INSULATION, meet the values of Table 6, or for REINFORCED INSULATION meet twice the values of Table 6;

b) pass the voltage test of 6.8 using the applicable test voltage from Table 6.

The following adjustments apply:

1) values for test voltages for REINFORCED INSULATION are 1,6 times the values for BASIC INSULATION;

2) if the equipment is RATED to operate at an altitude greater than 2 000 m, the values for CLEARANCES are multiplied by the applicable factor of Table 3;

3) minimum CLEARANCE is 0,2 mm for POLLUTION DEGREE 2 and 0,8 mm for POLLUTION DEGREE 3.

Conformity is checked by inspection and measurement and for b) by the a.c. test of 6.8.3.1 with a duration of at least 5 s, or by the 1 min d.c. test of 6.8.3.2, using the applicable test voltage from Table 6. The value of the d.c. test voltage is $\sqrt{2}$ *times the a.c. r.m.s. test voltage.*

Table 6 – CLEARANCES and test voltages for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V

Secondary WORKING VOLTAGE		MAINS voltage, line-to-neutral, OVERVOLTAGE CATEGORY II			
		≤ 150 V a.c. r.m.s.		> 150 V ≤ 300 V a.c. r.m.s.	
a.c. r.m.s. V	d.c. or a.c. peak V	CLEARANCE mm	Test voltage V a.c. r.m.s.	CLEARANCE mm	Test voltage V a.c. r.m.s.
16	22,6	0,10	500	~~0,50~~ 0,48	~~840~~ 830
~~33~~ 30	~~46,7~~ 42,4	0,11	510	~~0,52~~ 0,50	~~850~~ 840
50	70	0,12	520	0,53	860
100	140	0,13	540	0,61	900
150	210	0,16	580	0,69	940
300	420	0,39	770	0,94	1 040
600	840	1,01	1 070	1,61	1 450
1 000	1 400	1,92	1 630	2,52	1 970
1 250	1 750	2,50	1 960	3,16	2 280
1 600	2 240	3,39	2 390	4,11	2 730
2 000	2 800	4,49	2 890	5,30	3 230
2 500	3 500	6,02	3 520	6,91	3 850
3 200	4 480	8,37	4 390	9,16	4 660
4 000	5 600	10,9	5 320	11,6	5 610
5 000	7 000	14,0	6 590	14,9	6 960
6 300	8 820	18,2	8 270	19,1	8 620
8 000	11 200	23,9	10 400	24,7	10 700
10 000	14 000	30,7	12 900	31,6	13 300
12 500	17 500	39,6	16 100	40,5	16 400
16 000	22 400	52,5	20 400	53,5	20 700
20 000	28 000	67,9	25 300	68,9	25 600
25 000	35 000	87,9	31 600	89,0	32 000
32 000	44 800	117	40 400	118	40 700
40 000	56 000	151	50 300	153	50 800
50 000	70 000	196	62 800	198	63 400
63 000	88 200	258	79 400	260	80 000
Linear interpolation is allowed.					

6.7.3.3 CREEPAGE DISTANCES

CREEPAGE DISTANCES for BASIC INSULATION or SUPPLEMENTARY INSULATION for secondary circuits shall meet the applicable values of Table 7, based on the WORKING VOLTAGE which stresses the insulation. Values for REINFORCED INSULATION are twice the values for BASIC INSULATION.

Conformity is checked by inspection and measurement.

Coatings that meet the requirements of Annex H when applied to the outer surfaces of printed wiring boards reduce the POLLUTION DEGREE of the coated area to POLLUTION DEGREE 1.

Conformity of coatings is checked as specified in Annex H.

Table 7 – CREEPAGE DISTANCES for secondary circuits

Secondary WORKING VOLTAGE a.c. r.m.s. or d.c.	Printed wiring board material		Other insulating material						
	POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
	All material groups	Material groups I, II or IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III[b]
V	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	0,025	0,04	0,08	0,40	0,40	0,40	1,00	1,00	1,00
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05
16	0,025	0,04	0,10	0,45	0,45	0,45	1,10	1,10	1,10
20	0,025	0,04	0,11	0,48	0,48	0,48	1,20	1,20	1,20
25	0,025	0,04	0,125	0,50	0,50	0,50	1,25	1,25	1,25
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3
40	0,025	0,04	0,16	0,56	0,80	1,10	1,4	1,6	1,8
50	0,025	0,04	0,18	0,60	0,85	1,20	1,5	1,7	1,9
63	0,040	0,063	0,20	0,63	0,90	1,25	1,6	1,8	2,0
80	0,063	0,10	0,22	0,67	0,95	1,3	1,7	1,9	2,1
100	0,10	0,16	0,25	0,71	1,00	1,4	1,8	2,0	2,2
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4
160	0,25	0,40	0,32	0,80	1,1	1,6	2,0	2,2	2,5
200	0,40	0,63	0,42	1,00	1,4	2,0	2,5	2,8	3,2
250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0
320	0,75	1,6	0,75	1,60	2,2	3,2	4,0	4,5	5,0
400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0
630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0
800	2,4	4,0	2,4	4,0	5,6	8,0	10,0	11	12,5
1 000	3,2 [a]	5,0 [a]	3,2	5,0	7,1	10,0	12,5	14	16
1 250			4,2	6,3	9,0	12,5	16	18	20
1 600			5,6	8,0	11	16	20	22	25
2 000			7,5	10,0	14	20	25	28	32
2 500			10,0	12,5	18	25	32	36	40
3 200			12,5	16	22	32	40	45	50
4 000			16	20	28	40	50	56	63
5 000			20	25	36	50	63	71	80
6 300			25	32	45	63	80	90	100
8 000			32	40	56	80	100	110	125
10 000			40	50	71	100	125	140	160
12 500			50	63	90	125			
16 000			63	80	110	160			
20 000			80	100	140	200			
25 000			100	125	180	250			
32 000			125	160	220	320			
40 000			160	200	280	400			
50 000			200	250	360	500			
63 000			250	320	450	600			

[a] For voltages above 1 000 V, CREEPAGE DISTANCES on printed wiring board material are the same as for other insulators of the same Material Group.

[b] Material group IIIb is not recommended for application in POLLUTION DEGREE 3 above 630 V.

Linear interpolation is allowed.

6.7.3.4 Solid insulation

6.7.3.4.1 General

Solid insulation in secondary circuits shall withstand the electrical and mechanical stresses that may occur in NORMAL USE, in all RATED environmental conditions (see 1.4), during the intended life of the equipment.

NOTE The manufacturer should take the expected life of the equipment into account when selecting insulating materials.

Conformity is checked by both of the following tests:

a) by the voltage test of 6.8.3.1 for 5 s using the applicable test voltage of Table 6 for BASIC INSULATION or SUPPLEMENTARY INSULATION. For REINFORCED INSULATION the values are multiplied by 1,6;

b) additionally, if the WORKING VOLTAGE exceeds 300 V, by the voltage test of 6.8.3.1 for 1 min with a test voltage of 1,5 times the WORKING VOLTAGE for BASIC INSULATION or SUPPLEMENTARY INSULATION and twice the WORKING VOLTAGE for *REINFORCED INSULATION.*

Solid insulation shall also meet the following requirements, as applicable:

1) for solid insulation used as an ENCLOSURE or PROTECTIVE BARRIER, the requirements of Clause 8;
2) for moulded and potted parts, the requirements of 6.7.3.4.2;
3) for inner insulating layers of printed wiring boards, the requirements of 6.7.3.4.3;
4) for thin-film insulation, the requirements of 6.7.3.4.4.

Conformity is checked as specified in 6.7.3.4.2 to 6.7.3.4.4 and Clause 8, as applicable.

6.7.3.4.2 Moulded and potted parts

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers shall be separated by the applicable minimum distance of Table 8 (see Figure 6 item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

Table 8 – Minimum values for distance or thickness (see 6.7.3.4.2 to 6.7.3.4.4)

Peak value of the a.c. or d.c. WORKING VOLTAGE or recurring peak voltage	Minimum value	Peak value of the a.c. or d.c. WORKING VOLTAGE or recurring peak voltage	Minimum value
kV	mm	kV	mm
>0,046 7 ≤ 0,33	0,05	>8,0 ≤ 10	3,5
>0,33 ≤ 0,8	0,1	>10 ≤ 12	4,5
>0,8 ≤ 1,0	0,15	>12 ≤15	5,5
>1,0 ≤ 1,2	0,2	>15 ≤ 20	8
>1,2 ≤ 1,5	0,3	>20 ≤ 25	10
>1,5 ≤ 2,0	0,45	>25 ≤ 30	12,5
>2,0 ≤ 2,5	0,6	>30 ≤ 40	17
>2,5 ≤ 3,0	0,8	>40 ≤ 50	22
>3,0 ≤ 4,0	1,2	>50 ≤ 60	27
>4,0 ≤ 5,0	1,5	>60 ≤ 80	35
>5,0 ≤ 6,0	2	>80 ≤ 100	45
>6,0 ≤ 8,0	3		

6.7.3.4.3 Inner insulating layers of printed wiring boards

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers shall be separated by the applicable minimum distance of Table 8 (see Figure 7, item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

REINFORCED INSULATION of inner insulating layers of printed wiring boards shall also have adequate electric strength through the respective layers. One of the following methods shall be used:

a) the thickness of the insulation is at least the applicable minimum distance of Table 8;

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation is assembled from at least two separate layers of printed wiring board materials, each of which is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of Table 6 for BASIC INSULATION;

   Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation is assembled from at least two separate layers of printed wiring board materials, and the combination of layers is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of Table 6 multiplied by 1,6.

   Conformity is checked by inspection of the manufacturer's specifications.

6.7.3.4.4 Thin-film insulation

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers (see Figure 8, item L) shall be separated by at least the applicable CLEARANCE and CREEPAGE DISTANCE of 6.7.3.2 and 6.7.3.3.

Conformity is checked by measurement or by inspection of the part or the manufacturer's specifications.

REINFORCED INSULATION through the layers of thin-film insulation shall also have adequate electric strength. One of the following methods shall be used:

a) the thickness of the insulation is at least the applicable value of Table 8;

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation consists of at least two separate layers of thin-film materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of Table 6 for BASIC INSULATION;

   Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation consists of at least three separate layers of thin-film materials, any two of which have been tested to exhibit adequate electric strength.

   Conformity is checked by the a.c. test of 6.8.3.1 with a duration of at least 1 min, or, for circuits stressed only by d.c., the 1 min d.c. test of 6.8.3.2, using the applicable test voltage from Table 6 multiplied by 1,6, applied to two of the three layers.

   NOTE For the purposes of this test a special sample may be assembled with only two layers of the material.

6.8 Procedure for voltage tests

6.8.1 General

The following test procedures apply to type testing, and deterioration of the test specimen may occur. Further use of the test specimen may not be appropriate.

Test equipment for the voltage tests is specified in IEC 61180-1 and IEC 61180-2.

ACCESSIBLE insulating parts of the ENCLOSURE are covered with metal foil everywhere except around TERMINALS. For test voltages up to 10 kV a.c. peak or d.c., the distance from foil to TERMINAL is not more than 20 mm. For higher voltages it is the minimum to prevent flashover. For guidance to these minimum distances, see Table 9.

NOTE The distances of Table 9 will prevent flashover between foil and TERMINALS.

Table 9 – Distances between TERMINALS and foil

Test voltage	Distance
kV	mm
10	20
20	45
30	70
50	130
70	195
100	290

ACCESSIBLE parts of controls with parts made of insulating material are wrapped in metal foil or have soft conductive material pressed against them.

The foil is applied after the humidity preconditioning (if applicable) and connected to the low TERMINAL of the test voltage generator.

When verifying a CLEARANCE within equipment, it is necessary to ensure that the specified voltage appears at the CLEARANCE. PROTECTIVE IMPEDANCE, impedances and voltage-limiting devices in parallel with the insulation to be tested may be disconnected.

The equipment is not energized during the tests.

When verifying CLEARANCES, the values for test voltages given in 6.7 apply to tests performed at 2 000 m. For other test site altitudes, the corrections of Table 10 are applied for CLEARANCES but not for tests of solid insulation.

NOTE 1 The electric testing of CLEARANCES will also stress the associated solid insulation.

NOTE 2 Where two or more protective means are used in combination (see 6.5.1), the voltages specified for REINFORCED INSULATION might be applied to parts of circuits which are not required to withstand these voltages. To test the complete equipment appropriately it may be necessary to test subassemblies separately.

Table 10 – Correction factors according to test site altitude for test voltages for CLEARANCES

	Correction factors			
Test voltage peak	**≥327 V < 600 V**	**≥600 V < 3 500 V**	**≥3 500 V < 25 kV**	**≥25 kV**
Test voltage r.m.s.	**≥231 V < 424 V**	**≥424 V < 2 475 V**	**≥2 475 V < 17,7 kV**	**≥17,7 kV**
Test site altitude m				
0	1,08	1,16	1,22	1,24
500	1,06	1,12	1,16	1,17
1 000	1,04	1,08	1,11	1,12
2 000	1,00	1,00	1,00	1,00
3 000	0,96	0,92	0,89	0,88
4 000	0,92	0,85	0,80	0,79
5 000	0,88	0,78	0,71	0,70
Linear interpolation is allowed.				

6.8.2 Humidity preconditioning

Unless otherwise specified in this standard, the equipment is subjected to humidity preconditioning before the voltage tests. The equipment is not energized during preconditioning.

This treatment need not be applied to parts that are clearly unlikely to be influenced by humidity and temperature.

Parts which can be removed without the use of a TOOL are removed and subjected to humidity preconditioning together with the main part.

Preconditioning is carried out in a humidity chamber containing air with a humidity of 93 % RH ± 3 % RH. The temperature of the air in the chamber is maintained at 40 °C ± 2 °C.

Before applying humidity, the equipment is brought to a temperature of 42 °C ± 2 °C, normally by keeping it at this temperature for at least 4 h before the humidity preconditioning.

The air in the chamber is stirred and the chamber is designed so that condensation will not precipitate on the equipment.

The equipment remains in the chamber for 48 h, after which it is removed and allowed a recovery period of 2 h under the environmental conditions of 4.3.1, with the covers of non-ventilated equipment removed.

The tests are performed and completed within 1 h of the end of the recovery period after humidity preconditioning. Parts that have been removed are re-assembled or not, whichever is less favourable.

6.8.3 Test procedures

6.8.3.1 The a.c. voltage test

~~The generator shall be able to supply a power of at least 500 VA.~~ The voltage tester shall have a regulated output capable of maintaining the test voltage throughout the test. The waveform of the ~~power frequency~~ test voltage shall be substantially sinusoidal. This requirement is fulfilled if the ratio between the peak value and the r.m.s. value is $\sqrt{2} \pm 3$ %.

The a.c. voltage test is performed at the RATED MAINS frequency, but for equipment RATED for MAINS frequencies including 50 Hz and 60 Hz, a test at either 50 Hz or at 60 Hz is sufficient.

The test voltage is raised uniformly from 0 V to the specified value within 5 s and held at that value for at least the specified time.

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test.

6.8.3.2 The ~~1 min~~ d.c. voltage test

The d.c. test voltage shall be substantially free of ripple. This requirement is fulfilled if the ratio between the peak value of the voltage and the average value is 1,0 ± 3 %.

The d.c. test voltage is raised uniformly from 0 V to the specified value within 5 s and held at that value for at least ~~1 min~~ the specified time.

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test.

6.8.3.3 The impulse voltage ~~withstand~~ test

The test shall be conducted for five impulses of each polarity with an interval of at least 1 s between impulses. The impulse voltage test is carried out with a 1,2/50 μs waveform (see Figure 1 of IEC 61180-1). The wave shape of each impulse shall be observed (see Note 1).

When verifying CLEARANCES within equipment by an impulse voltage test, it is necessary to ensure that the specified impulse voltage appears at the CLEARANCE. PROTECTIVE IMPEDANCE and voltage-limiting devices in parallel with the insulation to be tested shall be disconnected.

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test, but partial discharges are allowed. Partial discharge will be indicated by a step in the resulting wave shape which will occur earlier in successive impulses. Breakdown on the first impulse may either indicate a complete failure of the insulation system or the operation of overvoltage limiting devices in the equipment.

NOTE 1 If there are overvoltage limiting devices in the equipment, care must be taken to examine the waveshape to ensure that their operation is not taken to indicate insulation failure. Distortions of the impulse voltage which do not change from impulse to impulse may be caused by operation of an overvoltage limiting device and do not indicate a (partial) breakdown of solid insulation.

NOTE 2 Partial discharges in voids can lead to partial notches of extremely short durations in the waveform which may be repeated in the course of an impulse.

6.9 Constructional requirements for protection against electric shock

6.9.1 General

If a failure could cause a HAZARD:

a) the security of wiring connections subject to mechanical stresses shall not depend on soldering;

b) screws securing removable covers shall be captive if their length determines a CLEARANCE or CREEPAGE DISTANCE between ACCESSIBLE conductive parts and HAZARDOUS LIVE parts;

c) accidental loosening or freeing of the wiring, screws, etc., shall not cause ACCESSIBLE parts to become HAZARDOUS LIVE;

d) CLEARANCES and CREEPAGE DISTANCES between the ENCLOSURE and HAZARDOUS LIVE parts shall not be reduced below the values for BASIC INSULATION by loosening of parts or wires.

NOTE Screws or nuts with lock washers are not regarded as likely to become loose, nor are wires which are mechanically secured by more than soldering alone.

Conformity is checked by inspection and by measurement of CLEARANCES and CREEPAGE DISTANCES.

6.9.2 Insulating materials

The following shall not be used as insulation for safety purposes:

a) materials which can easily be damaged (for example, lacquer, enamel, oxides, anodic films);

b) non-impregnated hygroscopic materials (for example, paper, fibres, fibrous materials).

Conformity is checked by inspection.

6.9.3 Colour coding

Green-and-yellow insulation shall not be used except for:

a) protective earth conductors;

b) PROTECTIVE BONDING conductors;

c) potential equalization conductors for safety purposes;

d) functional earth conductors.

Conformity is checked by inspection.

6.10 Connection to the MAINS supply source and connections between parts of equipment

6.10.1 MAINS supply cords

The following requirements apply to non-detachable MAINS supply cords and to detachable MAINS supply cords supplied with the equipment.

Cords shall be RATED for the maximum current for the equipment and the cable used shall meet the requirements of IEC 60227 or IEC 60245. Cords certified or approved by a recognized testing authority are regarded as meeting this requirement.

If a cord is likely to contact hot external parts of the equipment, it shall be made of suitably heat-resistant material.

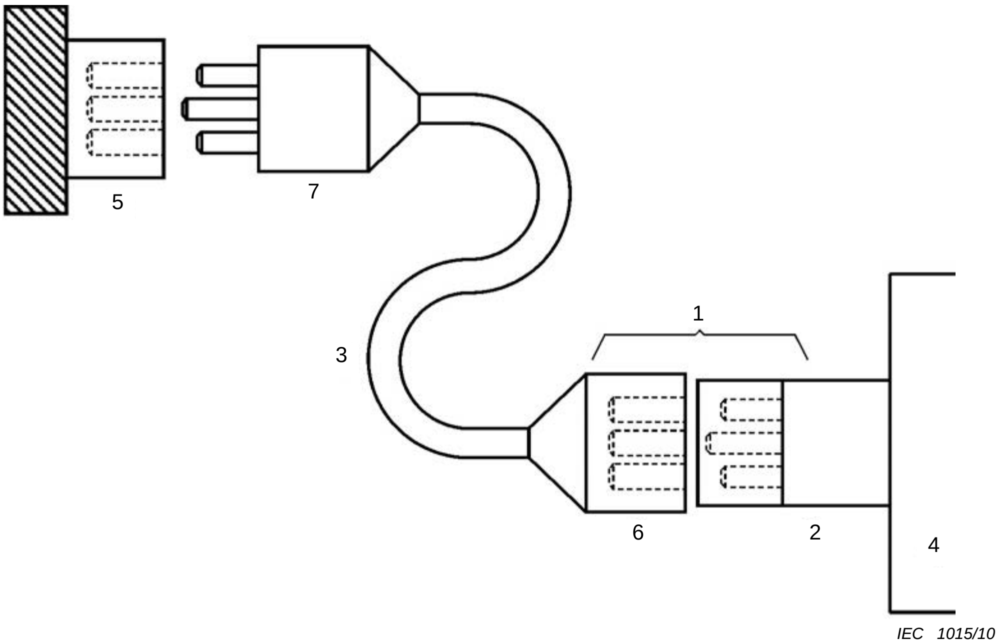
If the cord is detachable, both the cord and the appliance inlet shall have adequate temperature RATINGS.

Conductors coloured green-and–yellow shall be used only for connection to PROTECTIVE CONDUCTOR TERMINALS.

Detachable MAINS supply cords with MAINS connectors according to IEC 60320 shall either meet the requirements of IEC 60799, or shall be RATED at least for the current RATING of the MAINS connector fitted to the cord.

Figure 9 explains the terminology for MAINS supply cords.

Conformity is checked by inspection and, where necessary, by measurement.



Key

1	Appliance coupler	5	Fixed mains socket-outlet
2	Appliance inlet	6	Mains connector
3	Cable	7	Mains plug
4	Equipment		

Figure 9 – Detachable MAINS supply cords and connections

6.10.2 Fitting of non-detachable MAINS supply cords

6.10.2.1 Cord entry

MAINS supply cords shall be protected against abrasion and sharp bends at the point where the cord enters the equipment, by one of the following means:

a) an inlet or bushing with a smoothly rounded opening;

b) a reliably fixed flexible cord guard made of insulating material protruding beyond the inlet opening by at least five times the overall diameter of a cord with the largest cross-sectional area which can be fitted. For flat cords, the larger cross-sectional dimension is taken as the overall diameter.

Conformity is by inspection, and if needed by measurement of dimensions.

6.10.2.2 Cord anchorage

The cord anchorage shall relieve the conductors of the cord from strain, including twisting, where they are connected within the equipment, and shall protect the insulation of the conductors from abrasion. The protective earth conductor, if any, shall be the last to take the strain if the cord slips in its anchorage.

Cord anchorages shall meet the following requirements:

a) the cord shall not be clamped by a screw which bears directly on the cord;
b) knots in the cord shall not be used;
c) it shall not be possible to push the cord into the equipment to an extent which could cause a HAZARD;
d) failure of the cord insulation in a cord anchorage which has metal parts shall not cause ACCESSIBLE conductive parts to become HAZARDOUS LIVE.
e) it shall not be possible to loosen the cord anchorage without the use of a TOOL.
f) it shall be designed so that cord replacement does not cause a HAZARD, and it shall be clear how the relief from strain is provided.

A compression bushing shall not be used as a cord anchorage unless it is suitable for use with the MAINS supply cord supplied with it or specified for it by the manufacturer.

Conformity is checked by inspection and by the following push-pull test:

For each combination of cord and bushing, the cord is pushed into the equipment manually, as far as possible. It is then subjected 25 times to a steady pull of the value shown in Table 11, applied for 1 s each time in the least favourable direction. Immediately afterwards it is subjected for 1 min to a torque of the value shown in Table 11. The torque shall be applied as close as possible to the external end of the cord anchorage or bushing.

Table 11 – Values for physical tests on cord anchorages

Mass of equipment kg	**Force for pull test** N	**Torque for torque test** N·m
≤1	30	0,10
>1 ≤ 4	60	0,25
>4	100	0,35

After the tests:

1) *the cord shall not have been damaged;*
2) *the cord shall not have been displaced longitudinally by more than 2 mm;*
3) *there shall be no signs of strain at the point where the anchorage clamps the cord;*
4) *CLEARANCES and CREEPAGE DISTANCES shall not have been reduced below the applicable values;*
5) *the cord shall pass the a.c. voltage test of 6.8.3.1 (without humidity preconditioning) with a duration of at least 1 min as follows:*
   i) *for equipment with a protective earth conductor, the test is made between the protective conductor and the line and neutral conductors joined together, with the test*

voltage from Table 5 or Table K.8 for BASIC INSULATION *for the appropriate line-to-neutral voltage;*

ii) *for equipment without a protective earth conductor, the test is made between* ACCESSIBLE *conductive parts of the equipment and the line and neutral conductors joined together, with the test voltage from Table 5 or Table K.8 for* REINFORCED INSULATION *for the appropriate line-to-neutral voltage.*

6.10.3 Plugs and connectors

Plugs and connectors for connecting equipment to the MAINS supply, including appliance couplers used to connect detachable MAINS supply cords, shall conform to the relevant specifications for plugs, socket-outlets and connectors.

If the equipment is designed to be supplied only at voltages below the level of 6.3.2 a) in NORMAL CONDITION or SINGLE FAULT CONDITION, or from a source used solely to supply that equipment, the plugs of the power supply cord shall not fit into the socket-outlets of MAINS supply systems at voltages above the RATED supply voltage of the equipment. MAINS-type plugs and sockets shall not be used for purposes other than connection of a MAINS supply.

If plug pins of cord-connected equipment receive a charge from an internal capacitor, the pins shall not be HAZARDOUS LIVE 5 s after disconnection of the supply.

On equipment with accessory MAINS socket-outlets:

a) if the outlet can accept a standard MAINS supply plug, there shall be a marking as specified in 5.1.3 e);
b) if the outlet has a TERMINAL contact for a protective earth conductor, the input MAINS supply connection to the equipment shall include a protective earth conductor connected to a PROTECTIVE CONDUCTOR TERMINAL.

Conformity is checked by inspection. For plugs receiving a charge from an internal capacitor, the measurements of 6.3 are made to establish that the levels of 6.3.1 c) are not exceeded.

6.11 Disconnection from supply source

6.11.1 General

Except as specified in 6.11.2, equipment shall be provided with a means for disconnecting it from each electrical supply source, whether external or internal to the equipment. The disconnecting means shall disconnect all current-carrying conductors.

NOTE Equipment may also be provided with a switch or other disconnecting device for functional purposes.

Conformity is checked as specified in 6.11.3.1 to 6.11.4.3.

6.11.2 Exceptions

A disconnecting device is not required if a short circuit or overload cannot cause a HAZARD.

NOTE Examples include:

a) equipment intended for supply only from a low energy source such as a small battery or signal powered equipment;

b) equipment intended only for connection to an impedance protected supply. Such a supply is one having an impedance of such value that, if the equipment is subjected to an overload or short circuit, the RATED supply conditions are not exceeded and no HAZARD can arise;

c) equipment which constitutes an impedance protected load. Such a load is a component without discrete overcurrent or thermal protection, and of such impedance that the RATING is not exceeded if the circuit of which the component is a part is subjected to an overload or short circuit.

Conformity is checked by inspection. In case of doubt, a short circuit or overload is applied to check that no HAZARD can arise.

6.11.3 Requirements according to type of equipment

6.11.3.1 PERMANENTLY CONNECTED EQUIPMENT and multi-phase equipment

PERMANENTLY CONNECTED EQUIPMENT and multi-phase equipment shall employ a switch or circuit-breaker as the means for disconnection.

If a switch is not part of the equipment, documentation for equipment installation shall specify that:

a) a switch or circuit-breaker must be included in the installation;

b) it must be suitably located and easily reached;

c) it must be marked as the disconnecting device for the equipment.

Conformity is checked by inspection.

6.11.3.2 Single-phase cord-connected equipment

Single-phase cord-connected equipment shall have one of the following as a disconnecting device:

a) a switch or circuit-breaker;

b) an appliance coupler which can be disconnected without the use of a TOOL;

c) a separable plug, without a locking device, to mate with a socket-outlet in the building.

Conformity is checked by inspection.

6.11.4 Disconnecting devices

6.11.4.1 General

If a disconnecting device is part of the equipment, it shall be located electrically as close as practicable to the supply. Power-consuming components shall not be electrically located between the supply source and the disconnecting device, except that electromagnetic interference suppression circuits are permitted to be located on the supply side of the disconnecting device.

Conformity is checked by inspection.

6.11.4.2 Switches and circuit-breakers

An equipment ~~switch or~~ circuit-breaker employed as a disconnecting device shall meet the relevant requirements of ~~IEC 60947-1 and IEC 60947-3~~ IEC 60947-2 and be suitable for the application.

An equipment switch employed as a disconnecting device shall meet the relevant requirements of IEC 60947-3, and be suitable for the application.

If a switch or a circuit-breaker is used as a disconnecting device, it shall be marked to indicate this function. If there is only one device – one switch or one circuit-breaker – symbols 9 and 10 of Table 1 are sufficient if the symbols are marked on or adjacent to the switch or circuit-breaker.

A switch shall not be incorporated in a MAINS supply cord.

A switch or circuit-breaker shall not interrupt a protective earth conductor.

Conformity is checked by inspection.

6.11.4.3 Appliance couplers and plugs

If an appliance coupler or separable plug is used as the disconnecting device, it shall be readily identifiable and easily reached by the OPERATOR. For single-phase PORTABLE EQUIPMENT, a plug on a cord of length not greater than 3 m is considered to be easily reached. The protective earth conductor of an appliance coupler shall be connected before the supply conductors and disconnected after them.

Conformity is checked by inspection.

7 Protection against mechanical HAZARDS

7.1 General

The equipment shall not cause a mechanical HAZARD in NORMAL USE, or cause a HAZARD in a SINGLE-FAULT CONDITION that might not be easily noticed. Mechanical HAZARDS include, but are not limited to, the following:

a) sharp edges which could cause cuts (see 7.2);

b) moving parts that could crush body parts or penetrate the skin (see 7.3);

c) unstable equipment that could fall on a person while in use or while being moved (see 7.4);

d) falling equipment, resulting from breakage of the carrying device (see 7.5), wall mounting bracket (see 7.6) or other support part (see 7.5); and

e) expelled parts from the equipment (see 7.7).

NOTE If the equipment consists of two or more units, the value of the mass refers to the mass of each individual unit. However, if one or more units are intended to be attached to ~~or~~ and supported by another unit, these units are treated as a single unit.

Conformity is checked as specified in 7.2 to 7.7.

7.2 Sharp edges

All easily-touched parts of the equipment shall be smooth and rounded so as not to cause injury during NORMAL USE of the equipment.

Unless the fault presents an obvious HAZARD, easily-touched parts of the equipment shall not cause an injury in SINGLE FAULT CONDITION.

Conformity is checked by inspection and, if necessary, by application of an object that represents a finger in size, shape and hardness, to check for abrasions or cuts.

NOTE An acceptable procedure is outlined in UL 1439.

7.3 Moving parts

7.3.1 General

HAZARDS from moving parts shall not exceed a tolerable level except as specified in 7.3.2. The conditions specified in 7.3.4 and 7.3.5 are considered to represent a tolerable level. If these conditions are not met, a RISK assessment shall be carried out according to 7.3.3 or Clause 17.

NOTE In this context moving parts mean parts that are driven by an energy source other than directly applied human or animal effort.

Conformity is checked as specified in 7.3.2, 7.3.3, 7.3.4, 7.3.5 and Clause 17 as applicable.

7.3.2 Exceptions

If it is not feasible for operating reasons to prevent certain moving parts from causing a potential HAZARD, access is permitted in the following circumstances.

a) Equipment with easily-touched moving parts which are obviously intended to operate on parts or materials external to the equipment, for example drilling and mixing equipment, shall be designed to minimize inadvertent touching of these moving parts (for example, by guards or handles).

b) If, during routine maintenance outside NORMAL USE, it is unavoidable for technical reasons for an OPERATOR to perform a function which requires access to moving parts that could cause a HAZARD, access is permitted if all of the following precautions have been taken:

   1) access is not possible without the use of a TOOL;

   2) the instructions for the RESPONSIBLE BODY include a statement that OPERATORS must be trained before being allowed to perform the hazardous operation;

   3) there are warning markings on covers or parts which have to be removed to obtain access, prohibiting access by untrained OPERATORS. As an alternative, symbol 14 of Table 1 shall be placed on the covers or parts, with the warnings included in the documentation.

Conformity is checked by inspection.

7.3.3 RISK assessment for mechanical HAZARDS to body parts

RISKS shall be reduced to a tolerable level by at least the applicable minimum protective measure of Table 12, taking into account the SEVERITY, probability of exposure and possibility of avoiding the HAZARD.

Conformity is checked by evaluation of the RISK assessment documentation to ensure that the RISKS have been eliminated or that only TOLERABLE RISKS remain.

Table 12 – Protective measures against mechanical HAZARDS to body parts

Mechanical HAZARD conditions			Minimum protective measures [d]
Severity [a]	Probability of exposure [b]	Possibility of avoiding the HAZARD [c]	
S	E_2	P_2	C
S	E_2	P_1	C
S	E_1	P_2	C
S	E_1	P_1	B
M	E_2	P_2	B
M	E_2	P_1	A
M	E_1	P_2	A
M	E_1	P_1	No action

[a] **Severity:**

M = Moderate HAZARDS, sufficient to bruise or scratch a body part.

S = Serious HAZARDS, sufficient to break bones or dismember a body part.

[b] **Probability of exposure:**

E_1 = Exposure is not intended during NORMAL USE

E_2 = Exposure is intended during NORMAL USE

[c] **Possibility of avoiding the HAZARD:**

P_1 = Possibility of avoidance:

– The motion is visible and velocity is low enough for body parts to be removed without being trapped, or

– an audible or visible alarm is activated before body parts can be trapped.

P_2 = No possibility of avoidance:

Conditions other than P1.

[d] **Minimum protective measures:**

A = Low level measures; warning markings, audible or visual signals or instructions for use.

B = Moderate measures; emergency switches, PROTECTIVE BARRIERS or covers removable only with a TOOL, distances (see ISO ~~13852~~ 13857 ~~or EN 294~~), or separations (see ISO 13854 or EN 349).

C = Stringent measures; interlocks, PROTECTIVE BARRIERS or covers removable only with a TOOL and with instructions to disconnect from the power source.

7.3.4 Limitation of force and pressure

The physical levels specified below are not considered to be hazardous. They are based on a combination of contact force, duration and contact area. The levels below shall be met in NORMAL CONDITION and SINGLE-FAULT CONDITION.

The maximum tolerable continuous contact pressure is 50 N/cm^2, with a maximum force of 150 N.

The maximum tolerable temporary force for body contact areas of at least 3 cm^2 is 250 N for a maximum duration of 0,75 s. ~~The measurement of this force is made with a force gauge which has a spring ratio of at least 25 N/mm.~~

Conformity is checked by inspection and, in case of doubt, by measurement. For the purposes of this subclause, the width of a finger is considered to be 1,2 cm and the width of any other body part is considered to be 5,0 cm. The contact area will be determined to be the width of the body part multiplied by the width of the moving part, or the cross-sectional contact area of the moving part, if smaller.

EXAMPLE In a particular case, a finger might be able to touch a moving part that is 0,9 mm wide. If the part can exert a continuous force of 40 N, then the contact pressure would be calculated as:

Area = 1,2 cm × 0,09 cm = 0,108 cm²

Pressure = 40 N / 0,108 cm² = 370 N/cm²

In this case, the pressure exceeds the permissible limit even though the force is less than the permissible limit. In this case, the moving part would be considered to be hazardous.

7.3.5 Gap limitations between moving parts

7.3.5.1 Gap limitations between moving parts – Access normally allowed

If the force and pressure of the moving parts exceed the limits of 7.3.4 and if a body part could be inserted between moving parts, the width of the gap shall not decrease from a value larger than the minimum gap of Table 13 for that body part to a value smaller than the minimum gap in NORMAL CONDITION and SINGLE-FAULT CONDITION.

Conformity is checked by inspection and, in case of doubt, by measurement.

7.3.5.2 Gap limitations between moving parts – Access normally prevented

While parts are moving, gaps between moving parts into which body parts could be inserted shall not increase to more than the acceptable gap of Table 14, in NORMAL CONDITION and SINGLE-FAULT CONDITION.

Conformity is checked by inspection and, in case of doubt, by measurement.

Table 13 – Minimum maintained gaps to prevent crushing for different body parts

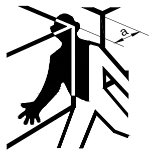
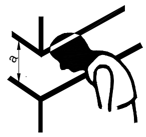
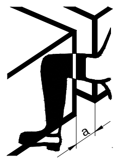
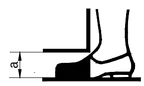
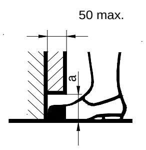
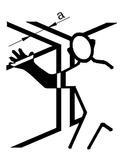
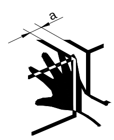
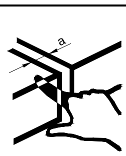
Part of body	Minimum gap (a) to avoid crushing mm	Illustration
Torso	500	
Head	300	
Leg	180	
Foot	120	
Toes	50	
Arm	120	
Hand, wrist, fist	100	
Finger	25	
The values in this table are for adults. For equipment that may be operated by children or youths, consideration should be given to smaller dimensions.		

Table 14 – Maximum gaps to prevent access for different body parts

Part of body	Maximum Gap (a) [a] to prevent access mm
Head	120
Foot	35
Finger	4
The values in this table are for adults. For equipment that may be operated by children or youths, consideration should be given to smaller dimensions.	
[a] See Table 13 for examples of gap (a).	

7.4 Stability

Equipment and assemblies of equipment not secured to the building structure before operation shall be physically stable.

If means are provided to ensure that stability is maintained after the opening of drawers, etc. by an OPERATOR, either these means shall be automatic or there shall be a warning marking to apply the means.

Each castor and support foot shall be RATED to support a load ~~of at least 4 times~~ not less than its normal load, or the castors and support feet shall be tested according to d) ~~and~~ or e), below.

Conformity is checked by inspection and by carrying out each of the following tests, if applicable, to ensure that the equipment will not overbalance. Containers contain the RATED amount of substance which provides the least favourable conditions of NORMAL USE. Castors are in their least favourable position of NORMAL USE. Doors, drawers, etc. are closed unless otherwise specified below.

a) *Equipment other than HAND-HELD EQUIPMENT is tilted in each direction to an angle of 10° from its normal position.*

b) *Equipment which has both a height of 1 m or more and a mass of 25 kg or more, and all floor-standing equipment, has a force applied at its top, or at a height of 2 m if the equipment has a height of more than 2 m. The force is 250 N, or 20 % of the weight of the equipment, whichever is less, and is applied to all surfaces in directions which could cause the equipment to topple. Stabilizers used in NORMAL USE, and doors, drawers, etc., intended to be opened by an OPERATOR, are in their least favourable positions.*

c) *Floor-standing equipment has a force of 800 N applied downwards at the point of maximum moment to:*

   1) *all horizontal working surfaces;*

   2) *other surfaces providing an obvious ledge and which are not more than 1 m above floor level.*

   Doors, drawers, etc. are closed, except that those intended to be opened by an OPERATOR are in their least favourable positions.

d) *The castor or support foot that supports the greatest load (M) is loaded with 4 times that load (4M).*

e) *The castor or support foot that supports the greatest load is removed from the equipment and the equipment is placed on a flat surface.*

NOTE ~~1~~ During this test, the unit should be secured so that complete overturning is not possible if this could present a HAZARD to those conducting the test. However, this restraint must not interfere with the determination of whether the unit would overbalance.

~~*NOTE 2 The supporting block should be removed from a distance so that the unit can not cause a HAZARD during the test.*~~

7.5 Provisions for lifting and carrying

7.5.1 General

Equipment or parts having a mass of 18 kg or more shall be provided with a means for lifting and carrying, or directions shall be given in the documentation.

Conformity is checked as specified in 7.5.2 and 7.5.3.

7.5.2 Handles and grips

If carrying handles or grips are fitted to the equipment, or supplied with it, they shall be capable of withstanding a force of four times the weight of the equipment.

Conformity is checked by inspection and by the following test.

A single handle or grip is subjected to a force corresponding to four times the weight of the equipment. Unless the handle mounting screws (if any) are secured against loosening, one screw is removed before performing these tests. The force is applied uniformly over a 70 mm width at the centre of the handle or grip, without clamping. The force is steadily increased so that the test value is attained after 10 s and maintained for a period of 1 min.

If more than one handle or grip is fitted, the force is distributed between the handles or grips in the same proportion as in NORMAL USE. If the equipment is fitted with more than one handle or grip but is so designed that it may readily be carried by only one handle or grip, the total force is applied to each handle or grip.

After the tests the handles or grips shall not have broken loose from the equipment and there shall not be any permanent distortion, cracking or other evidence of failure which could cause a HAZARD.

7.5.3 Lifting devices and supporting parts

Parts of lifting devices and parts that support heavy loads shall be RATED for the maximum load or shall be tested to withstand four times the maximum static load.

Conformity is checked by inspection of the RATINGS of the parts, or by the following test:

A total load equal to four times the maximum load is placed at the least favourable position of a RATED load in NORMAL USE.

During the test, no part of a lifting device or a load support shall break or deform to an extent that could cause a HAZARD.

7.6 Wall mounting

Mounting brackets on equipment intended to be mounted on a wall or ceiling shall withstand a force of four times the weight of the equipment.

Conformity is checked after mounting the equipment in accordance with the manufacturer's instructions, using the fasteners and wall construction specified. Adjustable brackets are adjusted to the position that will give the maximum projection from the wall.

If no wall construction is specified, a 12 mm ± 2 mm thick plasterboard (drywall) on nominal 50 mm × 100 mm ± 10 mm studs at 400 mm ± 10 mm centres is used as the support surface. Fasteners are applied as specified in the installation documentation or, if not specified, are positioned in the plasterboard between the studs.

The mounting brackets are then subjected to a weight equal to four times the weight of the equipment, acting vertically through the centre of gravity. The test weight is applied gradually and is increased from zero to full load in 5 s to 10 s, then maintained for 1 min.

If more than one fastener is specified for mounting a bracket, then one fastener is removed and the test is repeated with a weight equal to two times the weight of the equipment.

After the tests, there shall be no damage to the bracket or the mounting surface which could cause a HAZARD.

7.7 Expelled parts

Equipment shall contain or limit the energy of parts which could cause a HAZARD if expelled in the event of a fault.

The means of protection against expelled parts shall not be removable without the aid of a TOOL.

NOTE Clause 8 does not address HAZARDS from parts that could be expelled from inside the equipment.

Conformity is checked by inspection after application of the relevant fault conditions of 4.4.

8 Resistance to mechanical stresses

8.1 General

Equipment shall not cause a HAZARD when subjected to mechanical stresses likely to occur in NORMAL USE.

The normal energy protection level required is 5 J. Levels below 5 J but not less than 1 J are permitted provided that all the following criteria are met:

a) the lower level is justified by a RISK assessment carried out by the manufacturer (see Clause 17);
b) when the equipment is installed in its intended application it cannot easily be touched by unauthorized persons or the general public;
c) in NORMAL USE, the equipment is only accessed for occasional operations such as adjustment, programming or maintenance;
d) the equipment is marked with an IK code in accordance with IEC 62262 or with symbol 14 of Table 1, and the RATED energy level and test method are stated in the accompanying documentation. For non-metallic ENCLOSURES with a minimum RATED ambient temperature below 2 °C, the stated value shall be that applicable to the lowest RATED ambient

temperature. If impact energies used are between IK values of IEC 62262, any IK marking shall be for the nearest lower value.

Conformity is checked by inspection and by performing each of the following tests on the ENCLOSURE as applicable:

1) *the static test of 8.2.1;*
2) *for equipment other than HAND-HELD EQUIPMENT and DIRECT PLUG-IN EQUIPMENT, the impact test of 8.2.2 at the energy level specified above. If the specified energy level is not 5 J the test of IEC 62262 is an alternative to the impact test of 8.2.2, using test Eha (pendulum test) or test Ehc (vertical hammer) described in IEC 60068-2-75;*
3) *except for FIXED EQUIPMENT and equipment with a mass over 100 kg, the test of 8.3.1 or 8.3.2, as applicable. The equipment is not operated during the tests.*

An ENCLOSURE with an impact RATING of at least IK08 by the ENCLOSURE manufacturer, and that would clearly have met the criteria of 8.1 i) to 8.1 vii) after that test, need not be subjected to the test of 8.2.2.

Parts which do not form part of an ENCLOSURE are not subjected to the tests of 8.2.1 and 8.2.2.

After the tests, visibly damaged windows and displays shall be inspected to check that HAZARDOUS LIVE parts exceeding the values of 6.3.2 have not become ACCESSIBLE, and insulation of all other parts of the ENCLOSURE which could have been affected by the tests shall pass the voltage tests of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7). In addition the equipment is inspected to check that:

i) *there have been no leaks of corrosive or harmful substances;*
ii) *ENCLOSURES show no cracks which could cause a HAZARD;*
iii) *CLEARANCES are not less than their permitted values;*
iv) *the insulation of internal wiring remains undamaged;*
v) *PROTECTIVE BARRIERS necessary for safety have not been damaged or loosened;*
vi) *no moving parts are exposed, except as permitted by 7.3;*
vii) *there has been no damage which could cause spread of fire.*

8.2 ENCLOSURE rigidity tests

8.2.1 Static test

The equipment is held firmly against a rigid support and subjected to a force of 30 N applied by the hemispherical end of a hard rod of 12 mm diameter. The rod is applied to each part of the ENCLOSURE which could easily be touched when the equipment is ready for use, including any part of the bottom of PORTABLE EQUIPMENT, and which could cause a HAZARD if distorted.

In case of doubt whether a non-metallic ENCLOSURE will pass this test at an elevated temperature, this test is performed after the equipment is operated at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher, until a steady-state condition is reached. The equipment is disconnected from the supply source before the test is performed.

8.2.2 Impact test

Bases, covers, etc., intended to be removed and replaced by an OPERATOR have their fixing screws tightened using a torque likely to be applied in NORMAL USE. With the equipment held firmly against a rigid support, the impact is applied to any point on surfaces which are easily touched in NORMAL USE and which would be likely to cause a HAZARD if damaged.

NOTE A support is considered to be sufficiently rigid if its displacement is less than or equal to 0,1 mm under the effect of an impact directly applied and whose energy corresponds to the degree of protection.

Non-metallic ENCLOSURES of equipment with a minimum RATED ambient temperature below 2 °C are cooled to the minimum RATED ambient temperature, then tested within 10 min.

Impacts may be applied to empty ENCLOSURES if it is clear that the equipment would have passed the test if it had been tested in complete condition.

If an ENCLOSURE is damaged by an impact but meets the pass criteria, a new ENCLOSURE may be used for the next impact.

FIXED EQUIPMENT is mounted as specified in the installation instructions. Other equipment is held firmly against a rigid support and each test point is subjected to one impact by a smooth steel sphere with a mass 500 g ± 25 g and with a diameter of approximately 50 mm.

The impact test can be performed with the equipment mounted at 90° to its normal position to allow both the method of Figure 10 a) and Figure 10 b).

Figure 10 a) shows the impact applied to a horizontal surface, with the sphere allowed to fall freely from a height of X.

Figure 10 b) shows the impact applied to a vertical surface, with the sphere suspended by a cord and allowed to fall as a pendulum through a vertical distance of X.

In both cases the dimension X is determined from Table 15 according to the energy level to be applied.

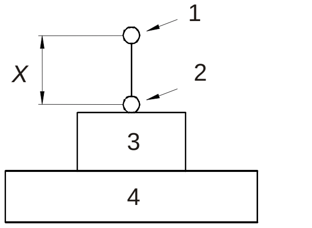


Figure 10a – Impact applied to a horizontal surface

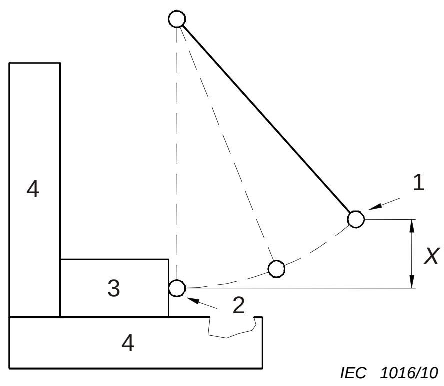


Figure 10b – Impact applied to a vertical surface

Key

1	Sphere start position	2	Sphere impact position
3	Test sample	4	Rigid supporting surface

X Vertical fall distance. See Table 15 for values of *X*

Figure 10 – Impact test using a sphere

Table 15 – Impact energy levels, test height and corresponding IK codes

	Impact energy level J and IK Code		
	1 (IK06)	**2 (IK07)**	**5 (IK08)**
Vertical fall distance (X) mm	200	400	1 000

8.3 Drop test

8.3.1 Equipment other than HAND-HELD EQUIPMENT and DIRECT PLUG-IN EQUIPMENT

The equipment is placed in its position of NORMAL USE on a smooth, hard rigid surface of concrete or steel. It is then tilted about each bottom edge in turn so that the distance between the opposite edge and the test surface is 100 mm for equipment up to 20 kg, 25 mm for equipment between 20 kg and 100 kg, or so that the angle made by the bottom and test surface is 30°, whichever is less severe. It is then allowed to fall freely onto the test surface.

If the number of bottom edges exceeds four, the number of drops shall be limited to four edges.

NOTE If the equipment consists of two or more units, the value for the mass refers to the mass of each individual unit. However, if one or more units are intended to be attached to, or supported by, another unit, these units are treated as a single unit.

The method of test shall not allow the equipment to topple onto any other face instead of falling back onto the test face as intended.

8.3.2 HAND-HELD EQUIPMENT and DIRECT PLUG-IN EQUIPMENT

The equipment is dropped once through a distance of 1 m onto a 50 mm thick hardwood board having a density of more than 700 kg/m^3 lying flat on a rigid base such as concrete. The equipment is dropped so that it lands in the position expected to present the most severe condition.

Non-metallic ENCLOSURES of equipment with a minimum RATED ambient temperature below 2 °C are cooled to the minimum RATED ambient temperature, then tested within 10 min.

9 Protection against the spread of fire

9.1 General

There shall be no spread of fire outside the equipment in NORMAL CONDITION or in SINGLE FAULT CONDITION. Figure 11 is a flow chart showing methods of conformity verification.

Equipment energized from a MAINS supply shall also meet the requirements of 9.6.

Conformity is checked by at least one of the following methods.

a) *Testing in the SINGLE FAULT CONDITIONS (see 4.4) that could cause the spread of fire outside the equipment. The conformity criteria of 4.4.4.3 shall be met.*
b) *Verifying elimination or reduction of the sources of ignition within the equipment as specified in 9.2.*
c) *Verifying, as specified in 9.3, that if a fire occurs it will be contained within the equipment.*

These alternative methods can be applied throughout the equipment or individually for different sources of HAZARDS or for different areas of the equipment.

NOTE 1 Methods b) and c) are based on fulfilling specified design criteria, in contrast to method a) which relies entirely on testing in specified SINGLE FAULT CONDITIONS.

NOTE 2 See 13.2.2 concerning protection against fire caused by batteries.

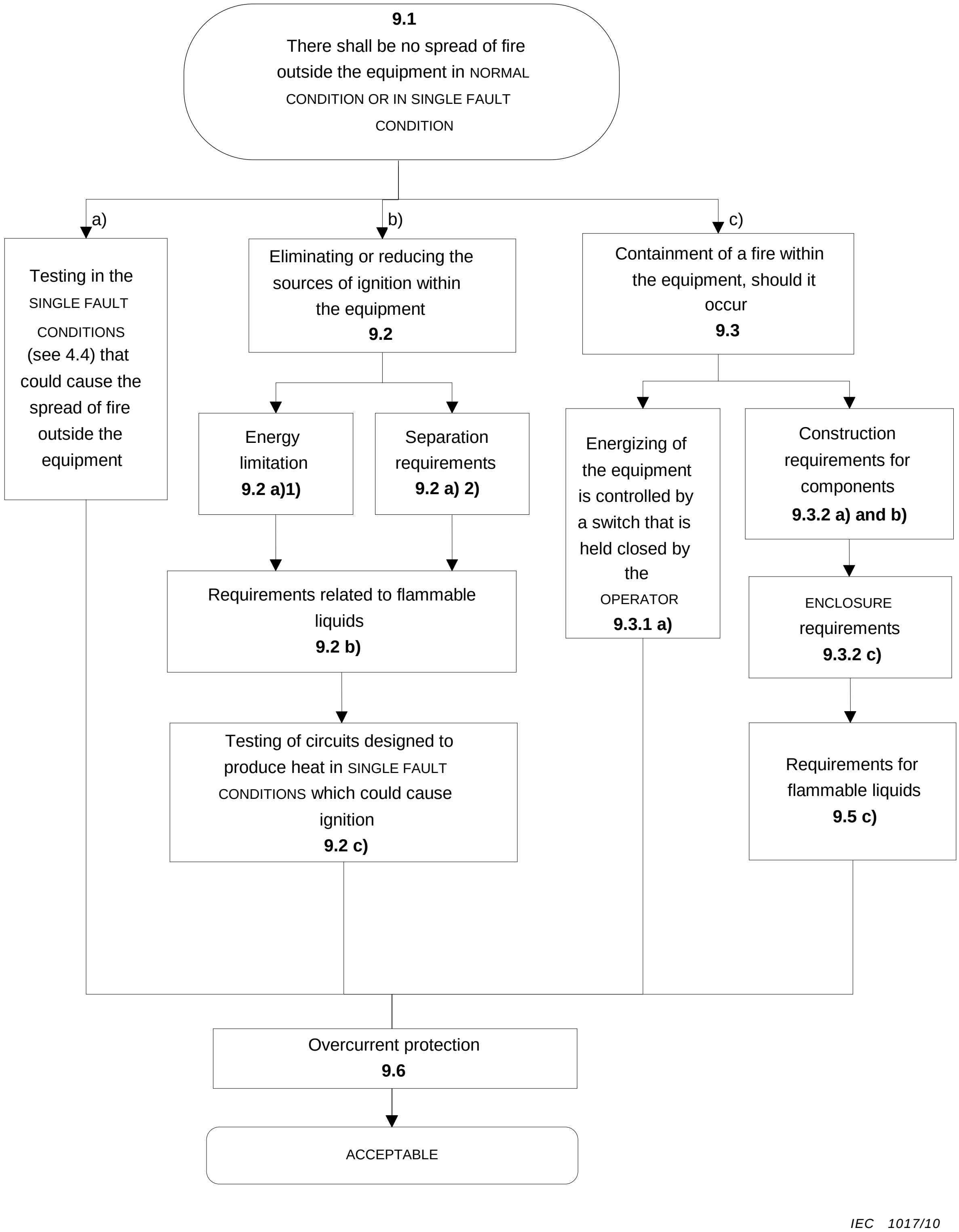


Figure 11 – Flow chart to explain the requirements for protection against the spread of fire

9.2 Eliminating or reducing the sources of ignition within the equipment

The possibility of ignition and occurrence of fire is considered to be reduced to a tolerable level if all the following requirements a), b) and c), if applicable, are met.

a) Either 1) or 2):

   1) the voltage, current and power available to the circuit or part of equipment are limited as specified in 9.4;

      Conformity is checked by measurement of limited-energy values as specified in 9.4.

   2) insulation between parts at different potentials meets the requirements for BASIC INSULATION, or it can be demonstrated that bridging the insulation will not cause ignition.

      Conformity is checked by inspection and in case of doubt by test.

b) Any ignition HAZARD related to flammable liquids is reduced to a tolerable level as specified in 9.5.

   Conformity is checked as specified in 9.5.

c) In circuits designed to produce heat, no ignition occurs when tested in SINGLE FAULT CONDITION (see 4.4).

   Conformity is checked by the relevant tests of 4.4, applying the criteria of 4.4.4.3.

9.3 Containment of fire within the equipment, should it occur

9.3.1 General

The possibility of the spread of fire outside the equipment is considered to be reduced to a tolerable level if the equipment meets one of the following constructional requirements:

a) energizing of the equipment is controlled by a switch that needs to be continuously held in the energized state by the OPERATOR;
b) the equipment and the equipment ENCLOSURE conform to the constructional requirements of 9.3.2 and the applicable requirements of 9.5 are met.

Conformity is checked by inspection and as specified in 9.3.2 and 9.5.

9.3.2 Constructional requirements

The following constructional requirements shall be met.

a) Connectors and insulating material on which components are mounted shall have a flammability classification V-2, or better, of IEC 60695-11-10. See also 14.7 for requirements for printed wiring boards.

   NOTE 1 V-0 is better than V-1, which is better than V-2.

   Conformity is checked by inspection of data on materials, and, in case of doubt, by performing the vertical burning test of IEC 60695-11-10 on samples of the material used in the relevant parts.

b) Insulated wires and cables shall retard flame propagation.

   NOTE 2 Wire with a flammability RATING of UL 2556 VW-1 or equivalent is considered to meet this requirement.

   Conformity is checked by inspection of data on materials, and, in case of doubt, by performing whichever of the following tests is applicable:

1) for wires and cables with overall cross-sectional area of the conductors exceeding 0,5 mm², the test of IEC 60332-1-2;

2) for wires and cables with overall cross-sectional area of the conductors of 0,5 mm² or less, the test of IEC 60332-2-2.

c) The ENCLOSURE shall meet the following requirements:

1) The bottom and sides of the ENCLOSURE within the 5° arc of Figure 13 of circuits that are not limited circuits according to 9.4 shall comply with one of the following requirements:

i) have no openings;

ii) be made of metal with perforations as specified in Table 16;

iii) be a metal screen with a mesh not exceeding 2 mm × 2 mm centre to centre and a wire diameter of at least 0,45 mm;

iv) have openings with baffles according to Figure 12.

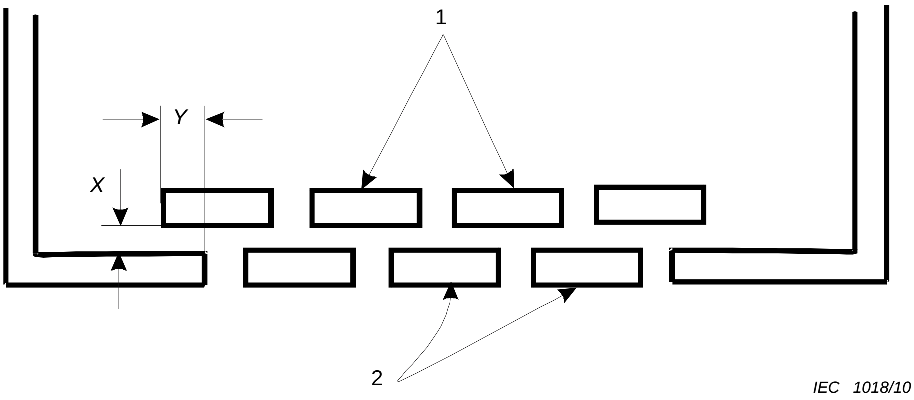
2) The ENCLOSURE, and any baffle or flame barrier, shall be made of metal (except magnesium) or of non-metallic materials having a flammability classification of V-1 or better, of IEC 60695-11-10.

3) The ENCLOSURE, and any baffle or flame barrier, shall have adequate rigidity.

Conformity is checked by inspection. In case of doubt, the flammability classification of requirement c) 2) is checked by performing the vertical burning test of IEC 60695-11-10 on samples of the material used in the relevant parts.

Table 16 – Acceptable perforation of the bottom of an ENCLOSURE

Minimum thickness mm	Maximum diameter of holes mm	Minimum spacing of holes centre to centre mm
0,66	1,14	1,70 (233 holes/645 mm²)
0,66	1,19	2,36
0,76	1.15	1,70
0,76	1,19	2,36
0,81	1,91	3,18 (72 holes/645 mm²)
0,89	1,90	3,18
0,91	1,60	2,77
0,91	1,98	3,18
1,00	1,60	2,77
1,00	2,00	3,00



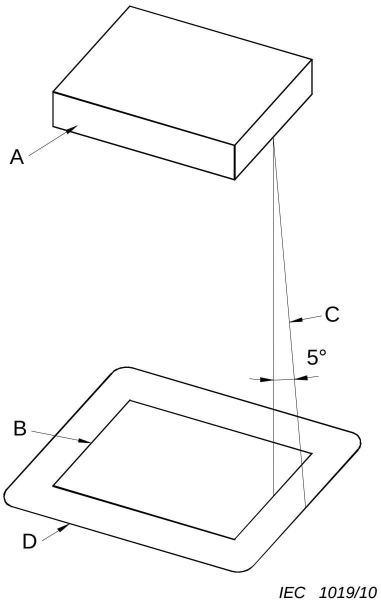
Y ≥ twice *X* but never less than 25 mm

Key

1 Baffle plates (may be below the bottom of the ENCLOSURE)

2 Bottom of ENCLOSURE

Figure 12 – Baffle



Key

A Part or component of the equipment that is considered to be a source of fire HAZARD. This consists of an entire component or part of the equipment if it is not otherwise shielded, or the unshielded portion of a component that is partially shielded by its casing.

B Projection of the outline of A on the horizontal plane.

C Inclined line that traces out the minimum area of the bottom and sides to be constructed as specified in 9.3.2 c) 1) and 9.3.2 c) 2). This line projects at a 5° angle from the vertical at every point around the perimeter of A and is oriented so as to trace out the maximum area.

D Minimum area of the bottom to be constructed as specified in 9.3.2 c) 1).

Figure 13 – Area of the bottom of an ENCLOSURE to be constructed as specified in 9.3.2 c) 1)

9.4 Limited-energy circuit

A limited-energy circuit is a circuit that meets all the following criteria.

a) The voltage appearing in the circuit is not more than 30 V r.m.s., 42,4 V peak, or 60 V d.c.

b) The current that can appear in the circuit is limited by one of the following means:

1) the maximum available current is limited inherently or by impedance so that it cannot exceed the applicable value of Table 17;

2) current is limited by an overcurrent protection device so that it cannot exceed the applicable values of Table 18;

3) a regulating network limits the maximum available current so that it cannot exceed the relevant value of Table 17 in NORMAL CONDITION or as a result of a fault in the regulating network.

c) It is separated by at least BASIC INSULATION from other circuits having energy values exceeding criteria a) ~~and~~ or b) above.

If an overcurrent protection device is used, it shall be a fuse or a non-adjustable non-self-resetting electromechanical device.

Conformity is checked by inspection and by measuring the potentials appearing in the circuit and the maximum available current, under the following conditions:

i) the potentials appearing in the circuit are measured in the load condition that maximizes the voltage;

ii) output current is measured after 60 s of operation, with the resistive load (including short circuit) which produces the highest value of current.

Table 17 – Limits of maximum available current

Open-circuit output voltage (*U or Û*) V			**Maximum available current** A
a.c. r.m.s.	**d.c.**	**Peak**[a]	**a.c. r.m.s. or d.c.**
$U \leq 2$	$U \leq 2$	$\hat{U} \leq 2,8$	50
$2 < U \leq 12,5$	$2 < U \leq 12,5$	$2,8 < \hat{U} \leq 17,6$	$100 / U$
$12,5 < U \leq 18,7$	$12,5 < U \leq 18,7$	$17,6 < \hat{U} \leq 26,4$	8
$18,7 < U \leq 30$	$18,7 < U \leq 60$	$26,4 < \hat{U} \leq 42,4$	$150 / U$

[a] The peak value ($\hat{U}$) applies to non-sinusoidal a.c. and to d.c. with ripple exceeding 10 %, and is provided for convenience. The r.m.s. value of the maximum available current shall be determined as that value is related to heating.

Table 18 – Values for overcurrent protection devices

Potential appearing in the circuit (*U or Û*) V			Current that the device breaks after not more than 120 s[b c] A
a.c. r.m.s.	**d.c.**	**Peak** [a]	**a.c. r.m.s. or d.c.**
$U \leq 2$	$U \leq 2$	$\hat{U} \leq 2{,}8$	62,5
$2 < U \leq 12{,}5$	$2 < U \leq 12{,}5$	$2{,}8 < \hat{U} \leq 17{,}6$	125 / U
$12{,}5 < U \leq 18{,}7$	$12{,}5 < U \leq 18{,}7$	$17{,}6 < \hat{U} \leq 26{,}4$	10
$18{,}7 < U \leq 30$	$18{,}7 < U \leq 60$	$26{,}4 < \hat{U} \leq 42{,}4$	200 / U

[a] The peak value (*Û)* applies to non-sinusoidal a.c. and to d.c. with ripple exceeding 10 %, and is provided for convenience. The r.m.s. value of the maximum available current shall be determined as that value is related to heating.

[b] The evaluation is based on the specified time-current breaking characteristic of the device, which is different from the RATED breaking current. (For example, an ANSI/UL 248-14 5 A fuse is specified to break 10 A at 120 s or less and an IEC 60127 T-type 4 A fuse is specified to break at 8,4 A at 120 s or less.)

[c] The breaking current of fuses is dependent on temperature, and this has to be taken into account if the temperature immediately around the fuse is significantly higher than the room temperature.

9.5 Requirements for equipment containing or using flammable liquids

Flammable liquids contained in, or specified for use with, the equipment shall not cause the spread of fire in NORMAL CONDITION or in SINGLE FAULT CONDITION.

The HAZARDS arising from flammable liquids are considered to be reduced to a tolerable level if one of the following requirements is met.

a) The temperature of the surface of the liquid and parts in contact with the surface, in NORMAL CONDITION and SINGLE FAULT CONDITION, is limited to a temperature not exceeding t – 25 °C, where t is the fire point of the liquid (see 10.3 b)).

   NOTE 1 Fire point is the temperature to which a liquid must be heated (under specified conditions) so that the vapour/air mixture at the surface will support a flame for at least 5 s when an external flame is applied and withdrawn.

b) The quantity of liquid is limited to an amount that could not cause the spread of fire.

c) If the liquid can be ignited, the flames are contained to prevent the spread of fire outside the equipment. Detailed instructions for use shall be provided to establish adequate RISK reduction procedures.

Conformity with a) and b) is checked by inspection and by temperature measurement as specified in 10.4.

Conformity with c) is checked as specified in 4.4.4.3.

NOTE 2 For liquids with toxic combustion by-products, it may be convenient to use a different liquid with similar burn characteristics for testing purposes.

9.6 Overcurrent protection

9.6.1 General

Equipment intended to be energized from a MAINS supply shall be protected by fuses, circuit-breakers, thermal cut-outs, impedance limiting circuits or similar means, to provide protection against excessive current being drawn from the MAINS in case of a fault in the equipment.

NOTE 1 Overcurrent protection devices supplied with the equipment are intended to provide protection against faults which result in increased current flow, and therefore, increased heating and the probability of the start and spread of fire. These devices are not intended to provide protection against short-circuits between MAINS conductors and protective earth conductors. The building installation contains overcurrent protection devices in each unearthed MAINS conductor which are intended to protect against short-circuits between the MAINS conductor and protective earth. The breaking capacity of the overcurrent protection device should be compatible with the current RATING of the installation.

A minimum of BASIC INSULATION is required between MAINS-connected parts of opposite polarity on the supply side of the overcurrent protection device.

Overcurrent protection devices shall not be fitted in the protective conductor. Fuses or single pole circuit-breakers shall not be fitted in the neutral conductor of multi-phase equipment.

NOTE 2 Overcurrent protection devices (for example, fuses) should preferably be fitted in all supply conductors. If fuses are used as overcurrent protection devices, the fuse holders should be mounted adjacent to each other. The fuses should be of the same RATING and characteristic. Overcurrent protection devices should preferably be located on the supply side of the MAINS CIRCUITS in the equipment, including any MAINS switch. It is recognized that, in equipment generating high frequencies, it is essential for the interference suppression components to be located between the MAINS supply and the overcurrent protection devices.

Conformity is checked by inspection and by measurement, and for solid insulation by the a.c. voltage test of 6.8.3.1 ~~with a duration of at least 1 min (without humidity preconditioning) with~~ or the d.c. voltage test of 6.8.3.2 (without humidity preconditioning) using the test voltage from Table 5 for BASIC INSULATION for the appropriate line-to-neutral voltage for 1 min. EMC capacitors meeting the requirements of ~~14.1~~ Clause 14 may be disconnected during the voltage test.

9.6.2 PERMANENTLY CONNECTED EQUIPMENT

Overcurrent protection devices are optional in PERMANENTLY CONNECTED EQUIPMENT. If none are fitted, the installation instructions shall specify the characteristics of the overcurrent protection devices required in the building installation.

Conformity is checked by inspection.

9.6.3 Other equipment

If an overcurrent protection device is provided, it shall be within the equipment.

Conformity is checked by inspection.

10 Equipment temperature limits and resistance to heat

10.1 Surface temperature limits for protection against burns

The temperature of easily touched surfaces shall not exceed the values of Table 19 in NORMAL CONDITION, and 105 °C in SINGLE FAULT CONDITION, at an ambient temperature of 40 °C.

Easily touched surfaces of equipment RATED for a maximum ambient temperature above 40 °C are permitted to exceed the values of Table 19 in NORMAL CONDITION, and to exceed 105 °C in SINGLE FAULT CONDITION, by not more than the amount by which the maximum RATED temperature exceeds 40 °C.

If easily touched heated surfaces are necessary for the processing or heating of materials, or where otherwise not avoidable, they are permitted to exceed the values of Table 19 in NORMAL CONDITION and to exceed 105 °C in SINGLE FAULT CONDITION, provided that they are recognizable as such by appearance or function or are marked with symbol 13 of Table 1. Equipment heated by its environment to temperature values exceeding the values in Table 19 in NORMAL CONDITION and 105 °C in SINGLE FAULT CONDITION need not to be marked with symbol 13.

Surfaces protected by barriers that prevent them from being touched accidentally are not considered to be easily touched surfaces, provided that the barriers cannot be removed without the use of a TOOL.

Table 19 – Surface temperature limits in NORMAL CONDITION

Part	Limit °C
1 Outer surface of ENCLOSURE (unintentional contact)	
a) metal, uncoated or anodized	65
b) metal, coated (paint, non metallic)	80
c) plastics	85
d) glass and ceramics	80
e) small areas (<2 cm^2) that are not likely to be touched in NORMAL USE	100
2 Knobs and handles (NORMAL USE contact)	
a) metal	55
b) plastics	70
c) glass and ceramics	65
d) non-metallic parts that in NORMAL USE are held only for short periods (1 s – 4 s)	70
NOTE ~~EN 563~~ ISO 13732-1 gives information about the effect of the duration of contact.	

Conformity is checked by measurement as specified in 10.4, and by inspection of barriers to check that they protect against accidentally touching surfaces that are at temperatures above the values of Table 19, and that they cannot be removed without a TOOL.

10.2 Temperatures of windings

If a HAZARD could be caused by excessive temperature, the temperature of the insulating material of windings shall not exceed the values of Table 20 in NORMAL CONDITION and SINGLE FAULT CONDITION.

Conformity is checked by measurement as specified in 10.4, in NORMAL CONDITION and in the applicable SINGLE FAULT CONDITIONS of 4.4.2.5, 4.4.2.10 and 4.4.2.11, and also in any other SINGLE FAULT CONDITIONS that could cause a HAZARD as a result of excessive temperature.

Table 20 – Maximum temperatures for insulation material of windings

Class of insulation (see IEC 60085)	NORMAL CONDITION °C	SINGLE FAULT CONDITION °C
Class A	105	150
Class B	130	175
Class E	120	165
Class F	155	190
Class H	180	210

10.3 Other temperature measurements

The following other measurements are made, if applicable, for the purposes of other sub-clauses. Tests are made in NORMAL CONDITION unless stated.

a) The temperature of a field-wiring TERMINAL box or compartment is measured if there is a possibility that it could exceed 60 °C at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher (in connection with the marking requirement of 5.1.8).

b) The temperature of the surface of flammable liquids, and parts in contact with the surface, is measured in the SINGLE FAULT CONDITIONS of 4.4.2.10 and 4.4.2.11 (in connection with 9.5 a)).

c) The temperature of non-metallic ENCLOSURES is measured during the test of 10.5.1 (to establish a base temperature for the test of 10.5.2).

d) The temperature of parts made of insulating material which are used to support parts connected to the MAINS supply (to establish a temperature for test 1) of 10.5.3).

e) The temperature of TERMINALS carrying a current exceeding 0,5 A if substantial heat could be dissipated in case of poor contact (to establish a temperature for test 1) of 10.5.3).

10.4 Conduct of temperature tests

10.4.1 General

Equipment shall be tested under reference test conditions. Unless a particular SINGLE FAULT CONDITION specifies otherwise, the manufacturer's instructions concerning ventilation, cooling liquid, limits for intermittent use, etc. are followed. Any cooling liquid shall be at the highest RATED temperature.

Maximum temperature is determined by measuring the temperature rise under reference test conditions and adding this rise to 40 °C, or to the maximum RATED ambient temperature if higher.

Alternatively, temperature measurements are made at the least favourable ambient temperature within the RATED ambient temperature range of the equipment if this represents a less favourable condition. Measures are taken to eliminate errors caused by the method of achieving the test ambient temperature (e.g. suitable baffling or enclosure if the test is conducted in an environmental chamber and the forced air movements would cool the exterior of the equipment).

The temperature of insulating material of windings is measured as the temperature of winding wire and of core lamination in contact with the insulating material. It can be determined by the resistance method or by using temperature sensors selected and positioned so that they have a negligible effect on the temperature of the winding. The latter method may be used if the windings are non-uniform or if it is difficult to measure resistance.

Temperatures are measured when steady state has been reached.

10.4.2 Temperature measurement of heating equipment

Equipment intended to produce heat for functional purposes is tested in a test corner.

The test corner consists of two walls at right angles, a floor and, if necessary, a ceiling, all of plywood approximately 20 mm thick and painted matt black. The linear dimensions of the test corner should be at least 15 % greater than those of the equipment under test. Equipment is positioned at the distances from the walls, ceiling, or floor specified by the manufacturer. If no distances are specified then:

a) equipment normally used on a floor or a table is placed as near to the walls as possible;

b) equipment normally fixed to a wall is mounted on one of the walls, as near to the other wall and to the floor or ceiling as is likely to occur in NORMAL USE;

c) equipment normally fixed to a ceiling is fixed to the ceiling as near to the walls as is likely to occur in NORMAL USE.

10.4.3 Equipment intended for installation in a cabinet or a wall

Such equipment is built in as specified in the installation instructions, using walls of plywood painted matt black, approximately 10 mm thick when representing the walls of a cabinet, approximately 20 mm thick when representing the walls of a building.

10.5 Resistance to heat

10.5.1 Integrity of CLEARANCES and CREEPAGE DISTANCES

CLEARANCES and CREEPAGE DISTANCES shall meet the requirements of 6.7 when the equipment is operated at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher.

Conformity, in cases of doubt if the equipment produces an appreciable amount of heat, is checked by operating the equipment under the reference test conditions of 4.3, except that the ambient temperature is 40 °C, or the maximum RATED ambient temperature if higher. After this test, CLEARANCES and CREEPAGE DISTANCES shall not have been reduced below the requirements of 6.7.

If the ENCLOSURE is non-metallic, the temperature of parts of the ENCLOSURE is measured during the above test for the purposes of 10.5.2.

10.5.2 Non-metallic ENCLOSURES

ENCLOSURES of non-metallic material shall be resistant to elevated temperatures.

Conformity is checked by test, after one of the following treatments.

a) *A non-operative treatment, in which the equipment, not energized, is stored for 7 h at 70 °C ± 2 °C, or at 10 °C ± 2 °C above the temperature measured during the test of 10.5.1, whichever is higher. If the equipment contains components that might be damaged by this treatment, an empty ENCLOSURE may be treated, followed by assembly of the equipment at the end of the treatment.*
b) *An operative treatment, in which the equipment is operated under the reference test conditions of 4.3, except that the ambient temperature is 20 °C ± 2 °C above 40 °C, or above the maximum RATED ambient temperature if higher than 40 °C.*

Within 10 minutes of the end of treatment the equipment shall be subjected to the suitable stresses of 8.2 and 8.3, and meet the pass criteria of 8.1.

10.5.3 Insulating material

Insulating material shall have adequate resistance to heat.

a) Parts that are made of insulating material, and which are used to support other parts that are connected to the MAINS supply, shall be made of insulating materials that will not cause a HAZARD if short circuits occur inside the equipment.
b) If in NORMAL USE, TERMINALS carry a current exceeding 0,5 A and if substantial heat could be dissipated in case of poor contact, the insulation which supports the TERMINALS shall be made of material that will not soften to an extent that could cause a HAZARD or further short circuits.

In case of doubt, conformity is checked by examination of material data. If the material data is not conclusive, one of the following tests is performed.

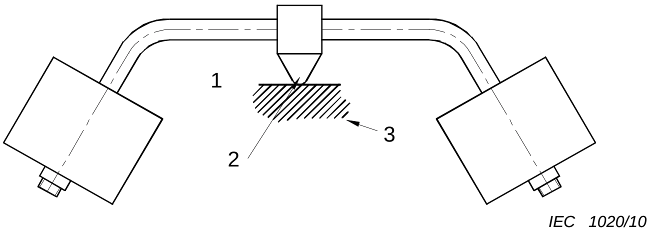
1) *A sample of the insulating material, at least 2,5 mm thick, is subjected to a ball-pressure test using the test apparatus Figure 14. The test is made in a heating cabinet at the temperature measured as specified in 10.3 d) or 10.3 e) ± 2 °C, or at 125 °C ± 2 °C, whichever is higher. The part to be tested is supported so that its upper surface is*

horizontal, and the spherical part of the apparatus is pressed against this surface with a force of 20 N. After 1 h the apparatus is removed and the sample is cooled within 10 s to approximately room temperature by immersion in cold water. The diameter of the impression caused by the ball shall not exceed 2 mm.

NOTE 1 If necessary, the required thickness may be obtained by using two or more sections of the part.

NOTE 2 For bobbins, only those parts that support or retain TERMINALS in position are subjected to the test.

NOTE 3 See IEC 60695-10-2 for more information about this test.



Key

1 Part to be tested

2 Spherical part of the apparatus (diameter 5 mm)

3 Support

Figure 14 – Ball-pressure test apparatus

2) *The Vicat softening test of ISO 306, method A120. The Vicat softening temperature shall be at least 130 °C.*

11 Protection against HAZARDS from fluids and solid foreign objects

11.1 General

Equipment shall be designed to give protection to OPERATORS and the surrounding area against HAZARDS from fluids and solid foreign objects encountered in NORMAL USE.

NOTE 1 Fluids likely to be encountered fall into three categories:

a) those having continuous contact, for example, in vessels intended to contain them;

b) those having occasional contact, for example, cleaning fluids;

c) those having accidental (unexpected) contact. The manufacturer cannot safeguard against such cases.

Fluids specified by the manufacturer, including cleaning and decontaminating fluids, are considered. Other fluids are not considered.

NOTE 2 The term “fluids” includes both liquids and gases.

NOTE 3 All pressures in Clause 11 are gauge pressures.

Conformity is checked by the treatment and tests of 11.2 to ~~11.5~~ 11.7 as applicable.

11.2 Cleaning

If a cleaning or decontamination process is specified by the manufacturer, this shall not cause a direct HAZARD, nor an electrical HAZARD, nor a HAZARD resulting from corrosion or other weakening of structural parts relied upon for safety.

Conformity is checked by cleaning the equipment three times if a cleaning process is specified and decontaminating the equipment once if a decontamination process is specified, *in accordance with the manufacturer's instructions. If, immediately after this treatment, there are any signs of wetting of parts likely to cause a HAZARD, the equipment shall pass the voltage tests of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7) and ACCESSIBLE parts shall not exceed the limits of 6.3.1.*

11.3 Spillage

If, in NORMAL USE, liquid is likely to be spilt into the equipment, the equipment shall be designed so that no HAZARD will occur, for example as a result of the wetting of insulation or of internal uninsulated parts, or as a result of the contact of potentially aggressive substances (such as corrosive, toxic or flammable liquids) with parts of the equipment.

If in NORMAL USE potentially aggressive substances (such as corrosive, toxic or flammable liquids) are likely to be spilt on parts of the equipment, the wetted material should be analyzed to determine compatibility with the aggressive substance.

Conformity is checked by inspection. In case of doubt, 0,2 l of water is poured steadily from a height of 0,1 m over a period of 15 s onto each point in turn where liquid might gain access to electrical parts. Immediately after this treatment, the CLEARANCES and solid insulation shall pass the voltage tests of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7) and ACCESSIBLE parts shall not exceed the limits of 6.3.1.

11.4 Overflow

Liquid overflowing from any container in the equipment which can be overfilled shall not cause a HAZARD during NORMAL USE, for example as a result of the wetting of insulation or of internal uninsulated parts that are HAZARDOUS LIVE.

Equipment likely to be moved while a container is full of liquid shall be protected against liquid surging out of the container.

Conformity is checked by the following treatment and tests. The liquid container is completely filled. A further quantity of liquid equal to 15 % of the capacity of the container or 0,25 l, whichever is the greater, is then poured in steadily over a period of 60 s. If equipment is likely to be moved while a container is full of liquid, it is then tilted 15° in the least favourable direction from the position of NORMAL USE. Immediately after this treatment, the CLEARANCES and solid insulation shall pass the voltage tests of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7) and ACCESSIBLE parts shall not exceed the limits 6.3.1.

11.5 Battery electrolyte

Batteries shall be so mounted that safety cannot be impaired by leakage of their electrolyte.

NOTE Also see 13.2.2.

Conformity is checked by inspection.

11.6 ~~Specially protected~~ Equipment RATED with a degree of ingress protection (IP code)

~~If the equipment is RATED and marked by the manufacturer as conforming to one of the stated degrees of protection of IEC 60529, it shall resist the entry of water to the extent specified.~~

~~Conformity is checked by inspection and by subjecting the equipment to the appropriate treatment of IEC 60529, after which the CLEARANCES and solid insulation shall pass the voltage tests of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7) and ACCESSIBLE parts shall not exceed the limits of 6.3.1.~~

11.6.1 General

Equipment RATED by the manufacturer as conforming to one of the degrees of protection as defined in IEC 60529 shall adequately resist the ingress of solid foreign objects and water which could lead to a HAZARD.

Equipment may have different degrees of protection depending on the mounting arrangements, or the assembly or operating conditions. The degrees of protection shall be specified in the documentation for each mounting arrangement. If the degree of protection depends on particular positions, covers, seals, or operating conditions, these conditions shall be specified in the documentation.

If the RATING is marked on the equipment, it shall be marked on the equipment in a manner to avoid misunderstanding and misuse. The designations of IEC 60529 shall be used (IP code). The IP code and related operating or non-operating conditions shall be explained in the documentation together with other warnings.

For IPx8 testing, the water level above the equipment and the test duration shall be applied as specified in the documentation. The aforementioned conditions shall be more severe than those for IPx7 according to IEC 60529.

Conformity is checked by inspection and as specified in 11.6.2 to 11.6.4 as applicable.

11.6.2 Conditions for testing

The equipment shall be in a clean and new condition with all parts in place and mounted in the manner defined by the manufacturer. If it is impracticable to test the complete equipment, representative parts or smaller equipment having the same full-scale design details shall be tested.

HAND-HELD EQUIPMENT is placed in the least favourable position. Portable equipment is placed in the least favourable position of normal use. Other equipment is positioned or installed as specified in the installation instructions.

TERMINALS are considered to be part of the equipment. However, TERMINALS provided with a protective cap or cover necessary to maintain the rated degree of protection are installed as specified by the manufacturer.

The equipment is operating (energized) during the treatment except

a) if the manufacturer specifies degrees of protection for non-operating (de-energized) equipment, or
b) if, whether the equipment is operating or not operating during the treatment does not affect the test results.

EXAMPLE 1 A field housing contains electronics. Generally in this case it has no influence on the test results whether the electronics inside is operated or not. So the testing of the equipment can also be conducted without the electronics built in.

EXAMPLE 2 An equipment enclosure has a rotating shaft protruding from it using an appropriate seal for the relevant ingress protection rating. In this case the rotation of the shaft is considered as affecting the test results.

11.6.3 Protection against solid foreign objects (including dust)

The applicable test of IEC 60529 for protection against solid foreign objects is performed.

After the test, conformity is checked by inspection of the sample according to the acceptance criteria of IEC 60529.

Additionally, the equipment is inspected for ingress of foreign objects. In particular, they shall not:

a) deposit on insulation parts where it could lead to a HAZARD;

b) create accumulations that have the potential to cause the spread of fire.

NOTE A HAZARD could be caused by the bridging of conductive parts by conductive dust, or by non-conductive dust made wet by humidity.

11.6.4 Protection against water

The applicable test of IEC 60529 for protection against water is performed.

The equipment is inspected for ingress of water. If any water has entered, it shall not impair safety. In particular, it shall not:

a) deposit on insulation parts where it could lead to a hazard;

b) reach hazardous live parts or windings not designed to operate when wet;

c) accumulate near the end of a cable or enter the cable where it could cause a hazard;

d) accumulate where it could lead to a HAZARD taking in consideration movement of the equipment.

11.7 Fluid pressure and leakage

11.7.1 Maximum pressure

The maximum pressure to which a part of the equipment can be subjected in NORMAL USE or SINGLE FAULT CONDITION shall not exceed the RATED maximum working pressure for the part.

The maximum pressure shall be considered to be the highest of the following:

a) the RATED maximum supply pressure specified for an external source;

b) the pressure setting of an overpressure safety device provided as part of the assembly;

c) the maximum pressure that can be developed by a pressure generating device that is part of the assembly, unless the pressure is limited by an overpressure safety device.

Conformity is checked by inspection of the RATINGS of the parts and, if necessary, by measuring pressures.

NOTE Equipment meeting the requirements of 11.7 may not be accepted as conforming to national requirements relating to high pressures. Annex G describes requirements and tests which are accepted as evidence of conformity with national regulations in the USA, in Canada, and in some other countries.

11.7.2 Leakage and rupture at high pressure

Fluid-containing parts which in NORMAL USE have both of the following characteristics shall not cause a HAZARD through rupture or leakage:

a) a product of pressure and volume greater than 200 kPa·l;

b) a pressure greater than 50 kPa.

~~*NOTE*~~ National authorities may allow safety to be established by calculation, for example according to the Pressure Equipment Directive (~~97/23/EC~~ 2014/68/EU).

Conformity is checked by inspection and, if a HAZARD could arise, by the following hydraulic test.

The test pressure (P_{test}) is the maximum pressure (P_{max}) multiplied by ~~a factor of 1,5 for testing against leakage and by factor 2,0 for testing against burst~~ the applicable factor of

Figure 16. Any overpressure safety device which could limit the test pressure is deactivated during the test.

The test pressure is raised gradually to ~~the specified test value~~ P_{test} and is held at that value for 1 min. The sample shall not burst, suffer from permanent (plastic) deformation ~~(factor 2,0)~~, or leak ~~(factor 1,5)~~. Provided that the test pressure is maintained, leakage at a gasket during these tests is not considered a failure unless it occurs at a pressure of below ~~1,5 times the maximum working pressure~~ 75 % of P_{test}, or below P_{max}, whichever is greater.

No leakage is allowed from fluid-containing parts intended for toxic, flammable, or otherwise hazardous substances if it could be a HAZARD.

If ~~unmarked~~ fluid-containing parts ~~and pipes~~ cannot be hydraulically tested, integrity ~~is to~~ may be verified by other suitable tests, for example, pneumatic tests using suitable media, at the same test pressure as for the hydraulic test.

As an exception to the above requirements, fluid-containing parts of refrigeration systems shall meet the relevant pressure-related requirements of ~~IEC 60335-2-24~~ EN 378-2 or IEC 60335-2-89 as applicable.

Conformity is checked as specified in ~~IEC 60335-2-24~~ EN 378-2 or IEC 60335-2-89 as applicable.

Pneumatic overpressure tests should only be conducted if no other option is available. This test can be extremely hazardous. The sudden release of stored energy due to a rupture of the test specimen can lead to severe injury or death. The stored energy in the pressurized system should be understood and appropriate safeguards put in place. These tests should only be conducted behind an explosion shield or within a suitable enclosure to protect laboratory personnel from flying debris, audible hazards, and in extreme cases the blast wave.

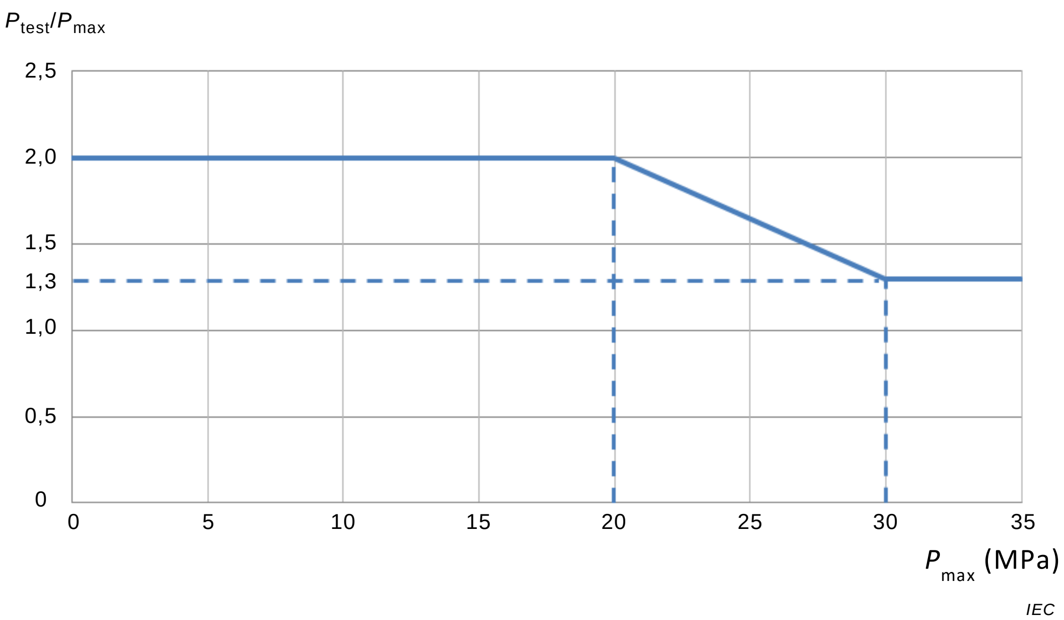


Figure 16 – Ratio between test pressure and maximum working pressure

11.7.3 Leakage from low-pressure parts

Leakage from fluid-containing parts at pressures lower than the levels of 11.7.2 shall not cause a HAZARD.

Conformity is checked by inspection of the RATINGS of parts and, if necessary, by subjecting the parts to a fluid pressure of twice the maximum pressure in NORMAL USE. No leakage shall occur which could cause a HAZARD.

11.7.4 Overpressure safety device

An overpressure safety device shall not operate in NORMAL USE. It shall conform to the following requirements.

a) It shall be connected as close as possible to the fluid-containing parts of the system that it is intended to protect.
b) It shall be installed so as to provide easy access for inspection, maintenance and repair.
c) It shall not be capable of being adjusted without the use of a TOOL.
d) It shall have its discharge opening so located and directed that the released material is not directed towards any person.
e) It shall have its discharge opening so located and directed that operation of the device will not deposit material on parts if that could cause a HAZARD.
f) It shall have adequate discharge capacity to ensure that the pressure cannot exceed the RATED maximum working pressure of the system.

There shall be no shut-off valve between an overpressure safety device and the parts that it is intended to protect.

Conformity is checked by inspection and test.

12 Protection against radiation, including laser sources, and against sonic and ultrasonic pressure

12.1 General

The equipment shall provide protection against the effects of internally generated ultraviolet, ionizing and microwave radiation; laser sources, and sonic and ultrasonic pressure.

Conformity tests are carried out if the equipment is likely to cause such HAZARDS.

12.2 Equipment producing ionizing radiation

12.2.1 Ionizing radiation

12.2.1.1 General

Equipment containing or generating ionizing radiation (from either radioactive sources or X-radiation) shall meet the following requirements.

a) If it is intended to emit radiation, it shall meet the requirements of 12.2.1.2. Alternatively, if it is within the scope of IEC ~~60405~~ 62598, it shall be tested, classified, and marked according to IEC ~~60405~~ 62598.
b) If it uses or generates radiation but only emits stray radiation, it shall meet the requirements of 12.2.1.3.

NOTE 1 See IEC ~~60405~~ 62598, for further information on the requirements for equipment which utilizes ionizing radiation.

~~NOTE 2 For X-ray and gamma radiation: 1 μSv/h = 0,1 mR/h and 5 μSv/h = 0,5 mR/h.~~

NOTE ~~3~~ 2 Equipment that emits ionizing radiation is regulated by health authorities in most countries. These regulations often address both the emissions of radiation from the equipment and the cumulative dose of radiation received by the workers and others in the vicinity of the equipment. See the Ionizing Radiation Directive (96/29/EURATOM) or USA 29 CFR 1910.1096 as examples of these regulations.

Conformity is checked by inspection of the IEC ~~60405~~ 62598 compliance documentation or as specified in 12.2.1.2 or 12.2.1.3, as applicable.

12.2.1.2 Equipment intended to emit radiation

Equipment which contains radioactive substances or that generates x-rays, and is intended to emit ionizing radiation outside the equipment, shall be tested and marked as follows:

The effective dose rate of radiation shall be measured at a constant distance of 50 mm to 1 m from all surfaces of the equipment. The measuring distance shall be between 50 mm and 1 m. If measurements are performed at any distance other than 50 mm, the equivalent effective dose rate at a distance of 50 mm shall be calculated. If the effective dose rate at any easily reached point 50 mm from the outer surface exceeds 5 µSv/h, the equipment shall be marked with all the following markings, if applicable:

a) with symbol 17 of Table 1;

b) for equipment containing one or more radioactive substances, with the abbreviations of the radionuclides;

c) either with the maximum dose rate value at 1 m, or with a dose rate value between 1 µSv/h and 5 µSv/h at the appropriate distance in m.

NOTE Examples of suitable markings are: “2,5 µSv/h at 1 m”; "3 µSv/h at 0,3 m".

Conformity is checked by measuring the amount of radiation in the conditions that will produce maximum radiation. The method of determining the amount of radiation shall be effective over the range of possible radiation energies. Equipment containing X-ray sources is set to produce the maximum possible level of radiation.

12.2.1.3 Equipment not intended to emit radiation

The effective dose rate of unintended stray radiation at any easily reached point 100 mm from the outer surface of the equipment shall not exceed 1 µSv/h.

NOTE Such equipment includes radioactive substances, cathode-ray tubes, X-ray sources, or electron accelerators with voltages exceeding 5 kV.

Conformity is checked by measuring the amount of radiation in the conditions that will produce maximum radiation. The method of determining the amount of radiation shall be effective over the range of possible radiation energies. Equipment containing cathode-ray tubes is tested while displaying a pattern from each beam not exceeding 30 mm × 30 mm or the smallest possible display, whichever is larger. Equipment containing X-ray sources is set to produce the maximum possible level of radiation. Displays are positioned so as to produce maximum radiation.

12.2.2 Accelerated electrons

The equipment shall be so constructed that compartments in which electrons are accelerated by voltages exceeding 5 kV cannot be opened without the use of a TOOL.

Conformity is checked by inspection.

12.3 ~~Ultraviolet (UV)~~ Optical radiation

Equipment ~~containing a UV source not designed to provide external UV illumination~~ with lamps and lamp systems emitting ultraviolet, visible, or infrared radiation, including light emitting diodes, shall not permit unintentional escape of ~~UV~~ radiation that could cause a HAZARD.

The radiation sources shall be assessed in accordance with IEC 62471 except for sources considered to be safe (Table 22) or conditionally safe (Table 23). Lamp and lamp systems assessed to be in Risk Groups 1, 2 or 3 of IEC 62471 shall be labelled in accordance with IEC TR 62471-2. If the size or design of the lamp or lamp systems makes labelling impractical, symbol 14 shall be marked on the equipment and the label shall be included in the documentation.

Information on protective measures, restrictions on use, and operating instructions that may be necessary shall be provided, including the applicable conditions of use of Table 23.

~~NOTE 1 Effects of UV-radiation include biological damage and degradation of materials such as plastic ENCLOSURES and insulation.~~

NOTE ~~2~~ Attention is drawn to the possible existence of additional guidelines or requirements which may be specified by national authorities ~~responsible for the health and safety of labour forces~~.

Conformity is checked by inspection and if necessary, by ~~evaluation of the RISK assessment documentation~~ measurement of the optical radiation to determine no hazard exists.

Table 22 – Lamp or lamp systems considered photobiologically safe

Lamp or lamp system
Indicator LEDs
Personal digital device screens
LCD screens
Computer displays
Photographic flash lamps
Interactive whiteboard presentation equipment
Task lighting with tungsten filament lamps, LED lamps, compact fluorescent tubes, or fluorescent tubes with diffusers
Any 'Exempt Group' (according to IEC 62471)

Table 23 – Lamp or lamp systems considered photobiologically safe under certain conditions

Lamp or lamp system	Conditions of use
Fluorescent lighting without diffusers over the lamps	Safe at normal illumination levels (~600 lux)
Metal halide/high-pressure mercury flood lights	Safe if the front cover glass is intact and if the lamp is not in line of sight
Desktop projectors	Safe if the beam is not looked into
Low-pressure UVA black-lights	Safe if not in line of sight and hands are not irradiated while holding the black-light

12.4 Microwave radiation

In NORMAL CONDITION and in SINGLE FAULT CONDITION, at any point 50 mm from the equipment, the power density of spurious microwave radiation at frequencies between 1 GHz and 100 GHz shall not exceed 10 W/m^2. This requirement does not apply to parts of the equipment where microwave radiation is propagated intentionally, for example, at waveguide output ports.

Conformity is checked by test under reference test conditions.

12.5 Sonic and ultrasonic pressure

12.5.1 Sound level

If equipment produces noise at a level which could cause a HAZARD, the manufacturer shall measure the maximum sound pressure level which the equipment can produce (except for sound from alarms and sound from parts remote from the equipment) and shall calculate the maximum sound power level as specified in ISO 3746 or ISO 9614-1.

Installation instructions shall specify how the RESPONSIBLE BODY can ensure that the sound pressure level from equipment, at its point of use after installation, will not reach a value which could cause a HAZARD. These instructions shall identify readily available and practicable protective materials or measures which may be used, including the fitting of noise-reducing baffles or hoods.

NOTE 1 A sound pressure level of 80 dBA above a reference sound pressure of 20 μPa is at present regarded by many authorities as the threshold at which a HAZARD may be caused. Special means, such as the use of protective earpieces, can make a higher level non-hazardous to an OPERATOR.

NOTE 2 The instructions for use should recommend that the sound pressure level be measured or calculated by the RESPONSIBLE BODY both at the OPERATOR'S position in NORMAL USE and at whatever point 1 m from the ENCLOSURE of the equipment has the highest sound pressure level.

Conformity is checked by measuring the maximum A-weighted sound pressure level at the OPERATOR'S position and at bystander positions, and if necessary, calculating the maximum A-weighted sound power level produced by the equipment, as specified in either ISO 3746 or ISO 9614-1. The following conditions apply.

a) *During measurement, any part necessary for the correct operation of the equipment and supplied by the manufacturer as an integral part of such equipment, for example, a pump, is fitted and operated as in NORMAL USE.*
b) *Sound level meters used in the measurement conform either to type 1 of IEC 61672-1 or, if an integrating sound level meter, to type 1 of IEC 61672-2.*
c) *The test room is semi-reverberant, with a hard reflecting floor. The distance between any wall or any other object and the surface of the equipment is not less than 3 m.*
d) *The equipment is tested with the combination of load and other operating conditions (for example, pressure, flow, temperature) which creates the maximum sound pressure level.*

12.5.2 Ultrasonic pressure

If equipment not intended to emit ultrasound produces ultrasound at a level which could cause a HAZARD, the manufacturer shall measure the maximum ultrasonic pressure level which the equipment can produce. When measured both at the OPERATOR's normal position and at 1 m from the position on the equipment with the highest pressure level, the ultrasonic pressure shall not exceed 110 dB above the reference pressure value of 20 μPa, for frequencies between 20 kHz and 100 kHz.

Conformity is checked by measuring the pressure under reference test conditions.

If equipment intended to emit ultrasound produces ultrasonic pressure at a level which could cause a HAZARD, the manufacturer shall measure the maximum ultrasonic pressure level which the equipment can produce.

The sound pressure shall be measured at the OPERATOR'S normal position and at 1 m from the position on the equipment with the highest pressure level both outside and inside the useful beam.

Outside the useful beam the ultrasonic pressure shall not exceed 110 dB above the reference pressure value of 20 μPa, for frequencies between 20 kHz and 100 kHz.

If inside the useful beam the ultrasonic pressure exceeds 110 dB for frequencies between 20 kHz and 100 kHz, the equipment shall be marked with symbol 14 of Table 1 and the following information shall be in the documentation:

a) the dimensions of the useful beam;

b) the area of the useful beam in which the ultrasonic pressure exceeds 110 dB;

c) the maximum sound pressure value inside the beam area.

Conformity is checked by inspection and measurement of the pressure under reference test conditions.

12.6 Laser sources

Equipment employing laser sources shall meet the requirements of IEC 60825-1.

Conformity is checked as specified in IEC 60825-1.

13 Protection against liberated gases and substances, explosion and implosion

13.1 Poisonous and injurious gases and substances

Equipment shall not liberate dangerous amounts of ~~poisonous or injurious gases or~~ hazardous substances in NORMAL CONDITION and in SINGLE FAULT CONDITION.

~~The manufacturer's documentation shall state which potentially poisonous or injurious gases or substances can be liberated, and the quantities.~~

If potentially-hazardous substances are liberated, the OPERATOR shall not be directly exposed to a quantity of the substance that could cause harm.

If NORMAL operation of the equipment requires the discharge of hazardous substances, and if that discharge is intended to be managed by the RESPONSIBLE BODY in accordance with the manufacturer's instructions, then such discharge is not considered to be liberation of hazardous substances.

NOTE Chemical exposure limits and handling and disposal regulations can be found in Occupational Safety and Health (OSHA) publications or national regulatory documentation. Local, national or regional regulations may apply.

Conformity is checked by inspection of the manufacturer's documentation. The wide variety of gases and substances makes it impossible to specify conformity tests based on limit values, so reference should be made to tables of occupational threshold limit values.

13.2 Explosion and implosion

13.2.1 Components

If components liable to explode if overheated or overcharged are not provided with a pressure release device, protection for OPERATORS shall be incorporated in the equipment (see 7.7 concerning expelled parts).

Pressure release devices shall be located so that a discharge will not cause danger to OPERATORS. The construction shall be such that no pressure release device is obstructed.

Conformity is checked by inspection.

13.2.2 Batteries and battery charging

Batteries shall not cause explosion or produce a fire HAZARD as a result of excessive charge or discharge, or if a battery is installed with incorrect polarity. If necessary, protection shall be incorporated in the equipment, unless the manufacturer's instructions specify that it is for use only with batteries which have built-in protection.

If an explosion or fire HAZARD could occur through fitting a battery of the wrong type (for example, if a battery with built-in protection is specified) there shall be a warning marking on or near the battery compartment or mounting, and a warning in the manufacturer's instructions. An acceptable marking is symbol 14 of Table 1.

If equipment has means for charging rechargeable batteries, and if non-rechargeable cells could be fitted and connected in the battery compartment, there shall be a warning marking in or near the compartment. The marking shall warn against the charging of non-rechargeable batteries and indicate the type of rechargeable battery that can be used with the recharging circuit. An acceptable marking is symbol 14 of Table 1.

The battery compartment shall be designed so that there is no possibility of explosion or fire caused by build-up of flammable gases.

NOTE Also see 11.5.

Conformity is checked by inspection, including inspection of battery data, to establish that failure of a single component cannot lead to an explosion or fire HAZARD. If necessary, a short circuit and an open circuit is made on any single component (except the battery itself) whose failure could lead to such a HAZARD.

For batteries intended to be replaced by an OPERATOR, an attempt is made to install a battery with its polarity reversed. No HAZARD shall arise.

13.2.3 Implosion of cathode ray tubes

Cathode-ray tubes with a maximum face dimension exceeding 160 mm shall be intrinsically protected against the effects of implosion and against mechanical impact, unless an ENCLOSURE provides adequate protection.

A non-intrinsically protected tube shall be provided with an effective protective screen which cannot be removed without the use of a TOOL. If a separate screen of glass is used, it shall not be in contact with the surface of the tube.

A cathode-ray tube is considered to be intrinsically protected with respect to the effects of implosion if no additional protection is necessary when it is correctly mounted.

Conformity for cathode-ray tubes is checked as specified in IEC 60065.

14 Components and subassemblies

14.1 General

If safety is involved, components and subassemblies, such as power supplies and built-in information technology equipment, shall be used in accordance with their specified RATINGS unless a specific exception is made. They shall conform to one of the following:

a) applicable safety requirements of a relevant IEC standard. Conformity with other requirements of the component standard is not required. If necessary for the application, components shall be subjected to the tests of this standard, except that it is not necessary to carry out identical or equivalent tests already performed to check conformity with the component standard;

NOTE 1 For example if components meet the safety requirements of IEC 60950-1 but are RATED for a less severe environment than the applicable environment of 1.4, they also need to meet relevant additional requirements of this standard.

b) the requirements of this standard and, where necessary for the application, any additional applicable safety requirements of the relevant IEC component standard, except that there are no additional requirements for motors and transformers which have passed the applicable tests of 4.4.2.5, 4.4.2.7, 14.2 and 14.6;

c) if there is no relevant IEC standard, the requirements of this standard;

d) applicable safety requirements of a non-IEC standard which are at least as high as those of the relevant IEC standard, provided that the component has been approved to the non-IEC standard by a recognized testing authority.

NOTE 2 Tests performed by a recognized testing authority which confirm conformity with applicable safety requirements need not be repeated, even if the tests were performed using a non-IEC standard.

Figure 15 is a flow chart showing methods of conformity verification.

Conformity is checked by inspection and, if necessary, by test.

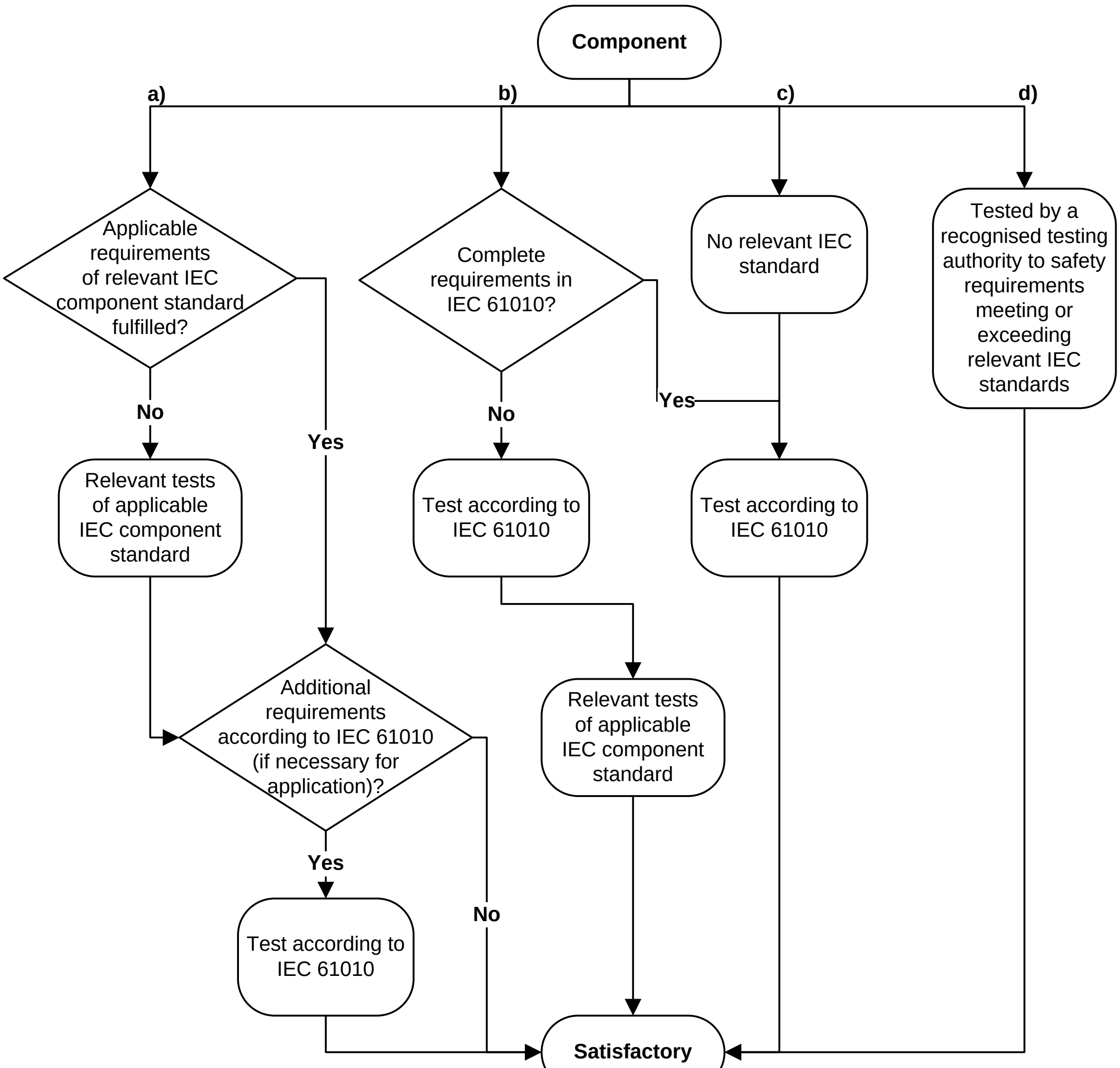


Figure 15 – Flow chart for conformity options 14.1 a), b), c) and d)

14.2 Motors

14.2.1 Motor temperatures

Motors which, when stopped or prevented from starting (see 4.4.2.5), would present an electric shock HAZARD, a temperature HAZARD, or a fire HAZARD shall be protected by an overtemperature or thermal protection device meeting the requirements of 14.3.

Conformity is checked by measurement of the temperature in the SINGLE FAULT CONDITION of 4.4.2.5.

14.2.2 Series excitation motors

If an overspeeding series excitation motor could cause a HAZARD, it shall be connected directly to the devices driven by it.

Conformity is checked by inspection.

14.3 Overtemperature protection devices

Overtemperature protection devices are devices operating in SINGLE FAULT CONDITION. They shall meet all of the following requirements:

a) be constructed so that reliable function is ensured;

b) be RATED to interrupt the maximum voltage and current of the circuit in which they are employed;

c) not operate in NORMAL USE.

If a self-resetting overtemperature protection device is used to prevent a HAZARD in case of failure of a temperature control system (for example a thermostat), the protected part of the equipment shall require intervention before becoming operational again.

Conformity is checked by inspection of the circuit diagram, the data sheet for the overtemperature protection device, and the method in which it is installed in the equipment, and by the following tests, with the equipment operated in SINGLE FAULT CONDITION (see 4.4). The number of operations is as follows:

1) self-resetting overtemperature protection devices are caused to operate 200 times;

2) non-self-resetting overtemperature protection devices, except thermal fuses, are reset after each operation and thus caused to operate 10 times;

3) non-resetting overtemperature protection devices are caused to operate once.

NOTE Forced cooling and resting periods may be introduced to prevent damage to the equipment.

During the test, resetting overtemperature protection devices shall operate each time the SINGLE FAULT CONDITION is applied and non-resetting overtemperature protection devices shall operate once. After the test, resetting overtemperature protection devices shall show no sign of damage which could prevent their operation in a further SINGLE FAULT CONDITION.

14.4 Fuse holders

If a fuse is intended to be replaced by an OPERATOR the fuse holder shall not permit HAZARDOUS LIVE parts to be ACCESSIBLE during fuse replacement.

Conformity is checked by testing with the jointed test finger (see Figure B.2) applied without force.

14.5 MAINS voltage selection devices

Devices shall be constructed so that a change from one voltage or one type of supply to another cannot occur accidentally. See 5.1.3 d) for marking requirements.

Conformity is checked by inspection and manual test.

14.6 MAINS transformers tested outside equipment

If environmental conditions could affect the test results, MAINS transformers tested outside the equipment (see 4.4.2.7) shall be tested in the same conditions as exist inside the equipment.

Conformity is checked by the short-circuit and overload tests specified in 4.4.2.7, followed by the test of 4.4.4.1 b) and c). If there is any doubt whether a transformer would pass the other tests specified in 4.4.4 and 10.2 when installed in the equipment, the tests are repeated with the transformer installed in the equipment.

14.7 Printed wiring boards

Printed wiring boards shall be made of material with a flammability classification of V-1 or better of IEC 60695-11-10.

This requirement does not apply to printed wiring boards which contain only limited-energy circuits meeting the requirements of 9.4.

Conformity of the flammability RATING is checked by inspection of data on the materials. Alternatively, conformity is checked by performing the vertical burn tests of IEC 60695-11-10 on three samples of the relevant parts. The samples may be complete boards, sections of the boards or specimens as specified in IEC 60695-11-10.

14.8 Circuits ~~or components~~ used ~~as~~ to limit TRANSIENT OVERVOLTAGES ~~limiting devices~~

~~TRANSIENT OVERVOLTAGES in a circuit may be limited by circuits or components. Components suitable for this purpose include varistors, spark gaps on printed wiring boards, and ceramic capacitors, in some cases combined with impedances or gas-filled surge arresters.~~

Any overvoltage limiting ~~component or~~ circuit that forms part of the equipment shall have adequate strength to limit likely TRANSIENT OVERVOLTAGES.

Table 21 – Impulse ~~withstand~~ voltages for OVERVOLTAGECATEGORY II

Line-to-neutral MAINS voltage V r.m.s. or d.c.	Impulse ~~withstand~~ voltage V
≤50	500
>50 ≤ 100	800
>100 ≤ 150	1 500
>150 ≤ 300	2 500
>300 ≤ 600	4 000
>600 ≤ 1 000	6 000

Conformity is checked by ~~applying~~ the following test: 5 positive and 5 negative impulses are applied with the applicable impulse ~~withstand~~ voltage of Table 21, spaced up to 1 min apart, from a hybrid impulse generator (see IEC 61180-1). The generator ~~shall~~ produces an open-circuit voltage waveform of 1,2/50 μs, a short-circuit current waveform of 8/20 μs, with an *output impedance (peak open-circuit voltage divided by peak short-circuit current) of 12 Ω (resistance may be added in series if needed to raise the impedance). The ~~test~~ impulse ~~shall be~~ is applied while the circuit is ~~working~~ operating under conditions ~~during~~ of NORMAL USE, in combination with the MAINS supply. The MAINS voltage is the maximum RATED ~~line-to-neutral~~ MAINS voltage.*

The test voltage is applied between each pair of MAINS supply TERMINALS of the equipment where overvoltage limiting ~~devices~~ circuits are present.

~~No HAZARD shall arise in the event that the component ruptures or overheats during the test. If a rupture occurs, no part of the component shall bridge safety-relevant insulation. If the component overheats, it shall not heat other materials to their self-ignition points. Tripping the circuit breaker of the MAINS supply is an indication of failure.~~

The overvoltage limiting circuit components shall not ignite or heat other materials to their self-ignition points. The overvoltage limiting circuit shall safely suppress the impulse and continue to function properly after the test.

NOTE *The ~~test~~ impulse voltage and generator output impedance specified above apply to equipment with a RATING for OVERVOLTAGE CATEGORY II. Conformity for equipment with a rating for OVERVOLTAGE CATEGORIES III and IV is specified in Clause K.4.*

15 Protection by interlocks

15.1 General

Interlocks used to protect OPERATORS from HAZARDS shall prevent an OPERATOR from being exposed to the HAZARD before the HAZARD is removed and shall meet the requirements of 15.2 and 15.3.

Conformity is checked by inspection and by performing all relevant tests of this standard.

15.2 Prevention of reactivating

Until the action which caused the interlock to operate has been reversed or cancelled, an interlock for the protection of an OPERATOR shall prevent the HAZARD being re-established by reactivating without the use of a TOOL.

Conformity is checked by inspection and, if necessary, by attempting to operate by hand any interlock part which can be touched by the jointed test finger (see Figure B.2).

15.3 Reliability

An interlock system for the protection of OPERATORS shall ensure that a single fault in the interlock system is either unlikely to occur during the expected life of the equipment, or cannot cause a HAZARD.

Conformity is checked by assessment of the interlock system. In case of doubt, the interlock system or relevant parts of the system are cycled to switch the least favourable load in NORMAL USE. The number of cycles is twice the maximum number likely to occur during the expected life of the equipment or 10 000 cycles of operation whichever is higher. After the test the protection shall not be impaired.

16 HAZARDS resulting from application

16.1 REASONABLY FORESEEABLE MISUSE

No HAZARDS shall arise if adjustments, knobs, or other software-based or hardware-based controls are set in a way not intended, and not described in the instructions. Other possible cases of REASONABLY FORESEEABLE MISUSE that are not addressed by specific requirements in this standard shall be addressed by RISK assessment (see Clause 17).

Conformity is checked by inspection and by evaluation of the RISK assessment documentation.

16.2 Ergonomic aspects

If the following factors could give rise to a HAZARD, a RISK assessment shall be documented, taking into account at least the following aspects:

a) limitation of body dimensions;

b) displays and indicators;

c) accessibility and conventions of controls;

d) arrangements of TERMINALS.

Conformity is checked by inspection and by evaluation of the RISK assessment documentation.

NOTE RISK assessment procedures for ergonomics may be found in EN 894-2, EN 894-3, ISO 9241, SEMI S8, and other documents. Not all of the requirements in these documents will be applicable to equipment within the scope of this standard.

17 RISK assessment

If examination of the equipment shows that HAZARDS not fully addressed in Clauses 6 to 16 (see 1.2.1) might arise, then RISK assessment is required. It shall be carried out and documented to achieve at least a TOLERABLE RISK by an iterative process covering the following.

a) RISK analysis

   RISK analysis is the process to identify HAZARDS and to estimate the RISKS based on the use of available information.

b) RISK evaluation

   Each RISK analysis requires a plan to evaluate the estimated severity and likelihood of a RISK, and to judge the acceptability of the resulting RISK level.

c) RISK reduction

   If the initial RISK level is not acceptable, steps shall be taken to reduce the RISK. The process of RISK analysis and RISK evaluation shall then be repeated, including checking that no new RISKS have been introduced.

RISKS remaining after a RISK assessment shall be identified in the instructions for the RESPONSIBLE BODY. Adequate information about how to mitigate these RISKS shall be given (see 5.4.1 e)).

In selecting the most appropriate methods of RISK reduction, the manufacturer shall apply the following principles, in the order given:

1) eliminate or reduce RISKS as far as possible (an inherently safe design and construction);

2) take the necessary protective measures in relation to RISKS that cannot be eliminated;

3) inform users of the residual RISKS due to any shortcomings of the protective measures adopted, indicate whether any particular training is required, and specify any need to provide personal protective equipment.

NOTE One RISK assessment procedure is outlined in Annex J. Other RISK assessment procedures are contained in ISO 14971, SEMI S10-1296, IEC 61508, ISO 14121-1, and ANSI B11.TR3. Other established procedures which implement similar steps can also be used.

Conformity is checked by evaluation of the RISK assessment documentation to ensure that the RISKS have been eliminated or that only TOLERABLE RISKS remain.

Annex A
(normative)

Measuring circuits for touch current
(see 6.3)

NOTE This annex is based on IEC 60990, which specifies procedures for measuring touch-current, and also specifies the characteristics for test voltmeters.

A.1 Measuring circuit for a.c. with frequencies up to 1 MHz and for d.c.

The current is measured using the circuit of Figure A.1. The current is calculated from:

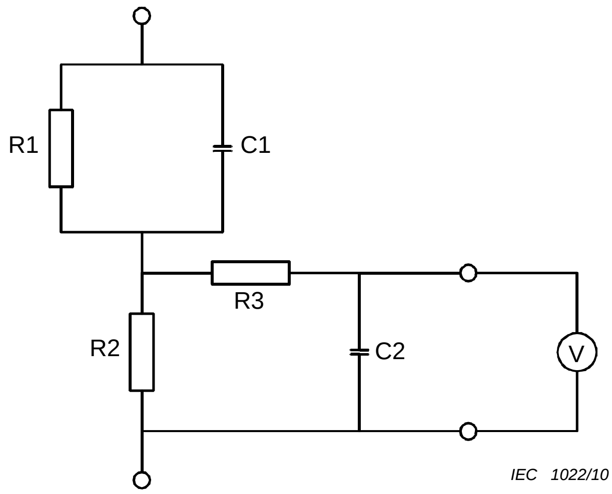
$$I = \frac{U}{500}$$

where

I is the current, in amperes;

U is the voltage, in volts, indicated by the voltmeter.

This circuit represents the impedance of the body and compensates for the change of physiological response of the body with frequency.



R1 = 1 500 Ω with a relative tolerance of ±5 %

R2 = 500 Ω with a relative tolerance of ±5 %

R3 = 10 kΩ with a relative tolerance of ±5 %

C1 = 0,22 µF with a relative tolerance of ±10 %

C2 = 0,022 µF with a relative tolerance of ±10 %

Figure A.1 – Measuring circuit for a.c. with frequencies up to 1 MHz and for d.c.

A.2 Measuring circuits for sinusoidal a.c. with frequencies up to 100 Hz and for d.c.

If the frequency does not exceed 100 Hz, the current may be measured using either of the circuits of Figure A.2. When using the voltmeter, the current is calculated from:

$$I = \frac{U}{2\ 000}$$

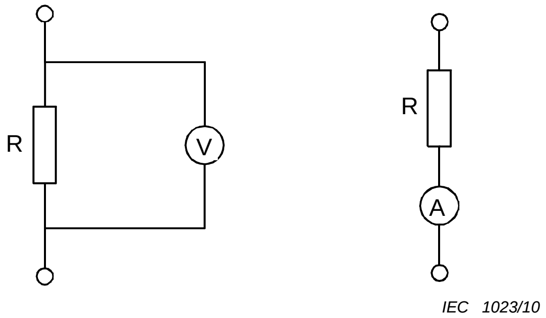
where

I is the current in amperes;

U is the voltage, in volts, indicated by the voltmeter.

The circuit represents the impedance of the body for frequencies not exceeding 100 Hz.

NOTE The value 2 000 Ω includes the impedance of the measuring instrument.



R = 2 000 Ω with a relative tolerance of ±5 %

Figure A.2 – Measuring circuits for sinusoidal a.c. with frequencies up to 100 Hz and for d.c.

A.3 Current measuring circuit for electrical burns at high frequencies

The current is measured using the circuit of Figure A.3. The current is calculated from:

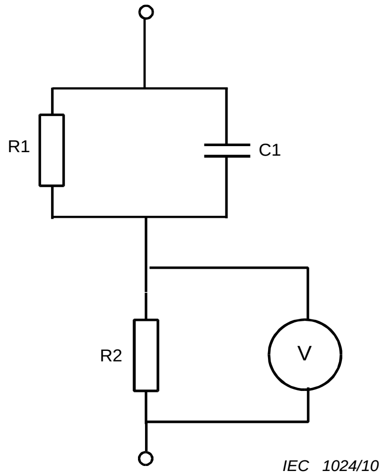
$$I = \frac{U}{500}$$

where

I is the current in amperes;

U is the voltage, in volts, indicated by the voltmeter.

This circuit compensates for the effects of high frequency on the physiological response of the body.



R1 = 1 500 Ω with a relative tolerance of ±5 %

R2 = 500 Ω with a relative tolerance of ±5 %

C1 = 0,22 μF with a relative tolerance of ±10 %

Figure A.3 – Current measuring circuit for electrical burns

A.4 Current measuring circuit for WET LOCATION

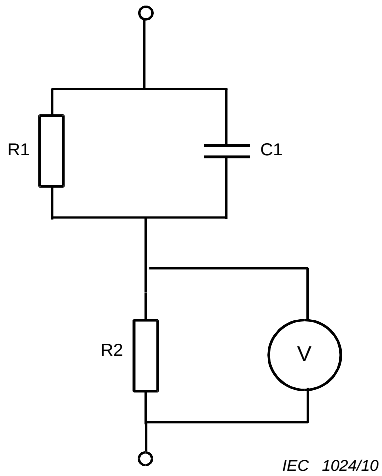
For WET LOCATION the current is measured using the circuit of Figure A.4. The current is calculated from:

$$I = \frac{U}{500}$$

where

I is the current in amperes;

U is the voltage, in volts, indicated by the voltmeter.



R1 = 375 Ω with a relative tolerance of ±5 %

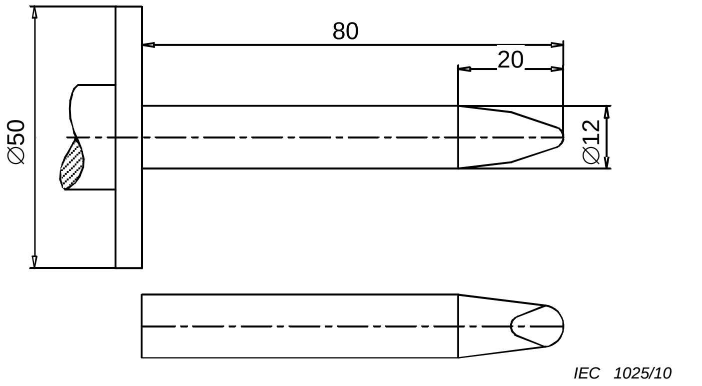
R2 = 500 Ω with a relative tolerance of ±5 %

C1 = 0,22 μF with a relative tolerance of ±10 %

Figure A.4 – Current measuring circuit for wet contact

Annex B
(normative)

Standard test fingers
(see 6.2)

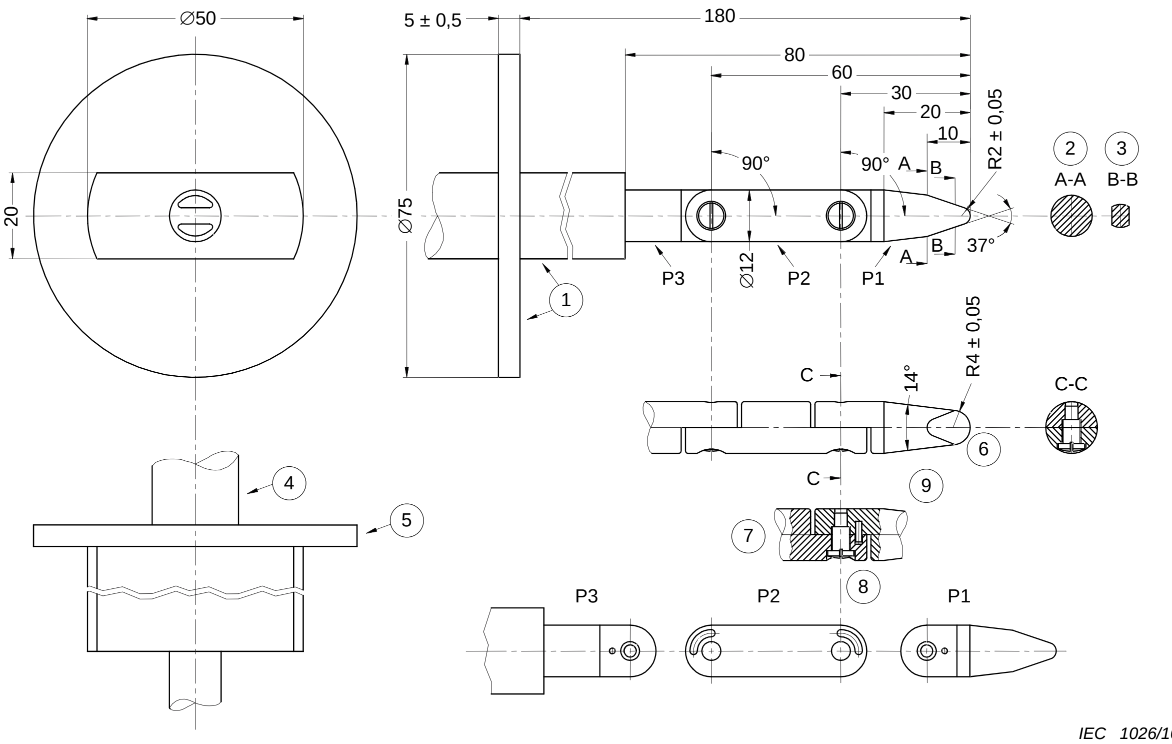


For tolerances and dimensions of the fingertip, see Figure B.2.

Dimensions in millimetres

NOTE This test finger is the same as test probe 11 of IEC 61032, Figure 7

Figure B.1 – Rigid test finger



IEC 1026/10

Key

1	insulating material		
2	section AA	6	spherical
3	section BB	7	detail x (example)
4	handle	8	side view
5	stop plate	9	chamfer all edges

Dimensions in millimetres

Tolerances on dimensions without specific tolerance:

– on angles: $^{0}_{-10'}$

– on linear dimensions:

up to 25 mm: $^{0}_{-0,05}$ mm

over 25 mm: ±0,2 mm

Material of finger: heat-treated steel, etc.

Both joints of this finger may be bent through an angle of $(90\,^{+10}_{0})°$, but in one plane only.

Using the pin and groove solution is only one of the possible approaches in order to limit the bending angle to 90°. For this reason, dimensions and tolerances of these details are not given in the drawing. The actual design shall ensure a $(90\,^{+10}_{0})°$ bending angle.

NOTE This test finger is the same as test probe B of IEC 61032, Figure 2

Figure B.2 – Jointed test finger

Annex C
(normative)

Measurement of CLEARANCES and CREEPAGE DISTANCES

The methods of measuring CLEARANCES and CREEPAGE DISTANCES are indicated in the following examples 1 to 11 (see Figure C.1). These cases do not differentiate between gaps and grooves or between types of insulation.

The following assumptions are made:

a) where the distance across a groove is equal to or larger than *X* (see Table C.1), the CREEPAGE DISTANCE is measured along the contours of the groove (see example 2);

b) any recess is assumed to be bridged with an insulating link having a length equal to *X* and being placed in the least favourable position (see example 3);

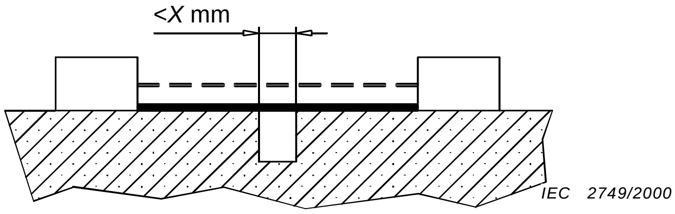
c) CLEARANCES and CREEPAGE DISTANCES measured between parts which can assume different positions in relation to each other are measured when these parts are in their least favourable position.

In the following examples dimension *X* has the value given in Table C.1 depending on the POLLUTION DEGREE.

Table C.1 – Dimensions of X

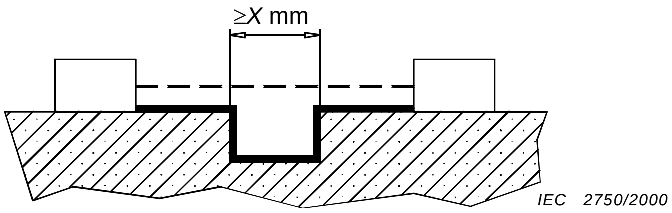
POLLUTION DEGREE	Dimension *X* mm
1	0,25
2	1,0
3	1,5

If the associated CLEARANCE is less than 3 mm, the dimension *X* in Table C.1 may be reduced to one-third of this CLEARANCE.



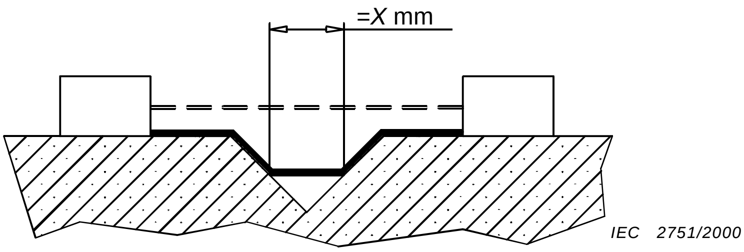
EXAMPLE 1 The path includes a parallel- or converging-sided groove of any depth with a width less than *X*.

The CLEARANCE and the CREEPAGE DISTANCE are measured directly across the groove as shown.



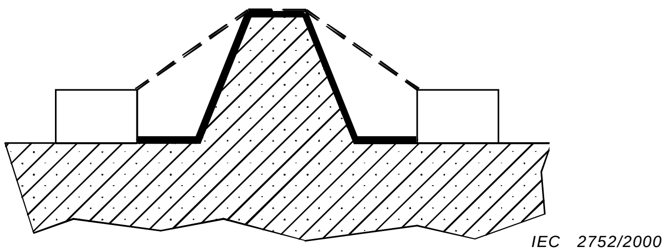
EXAMPLE 2 The path includes a parallel-sided groove of any depth and equal to or more than *X*.

The CLEARANCE is the “line-of-sight” distance. The CREEPAGE DISTANCE follows the contour of the groove.



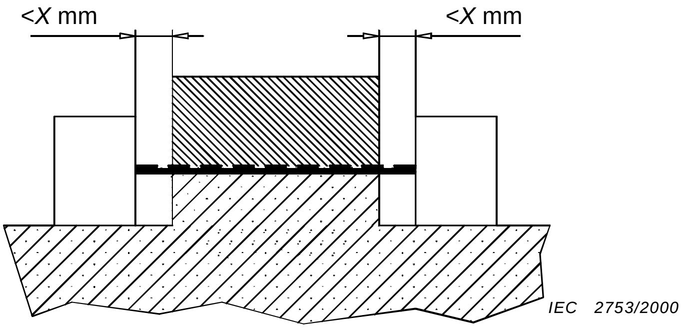
EXAMPLE 3 The path includes a V-shaped groove with a width greater than *X*.

The CLEARANCE is the “line-of-sight” distance. The CREEPAGE DISTANCE follows the contour of the groove but “short-circuits” the bottom of the groove by *X* link.



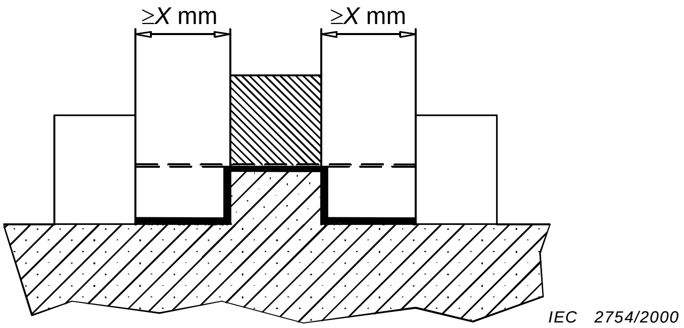
EXAMPLE 4 The path includes a rib.

The CLEARANCE is the shortest direct air path over the top of the rib. The CREEPAGE DISTANCE follows the contour of the rib.



EXAMPLE 5 The path includes an uncemented joint with grooves less than *X* wide on each side.

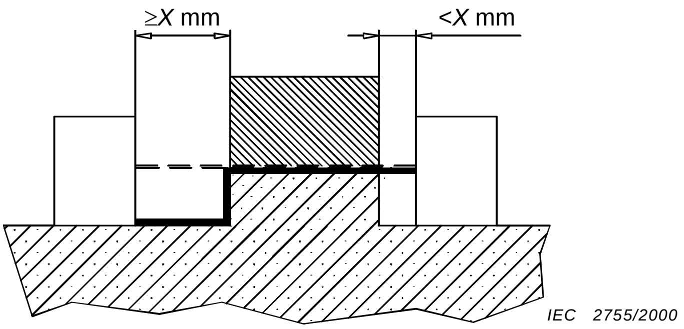
The CLEARANCE and the CREEPAGE DISTANCE path is the "line-of-sight" distance shown.



EXAMPLE 6 The path includes an uncemented joint with grooves equal to, or more than, *X*.

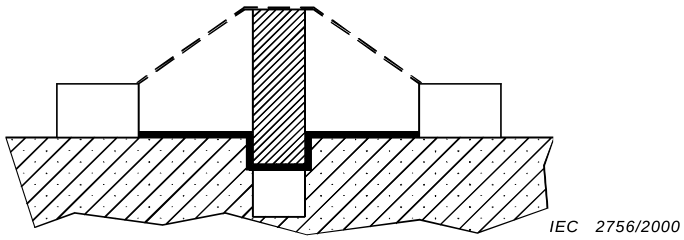
The CLEARANCE is the "line-of-sight" distance.

The CREEPAGE DISTANCE follows the contour of the grooves.



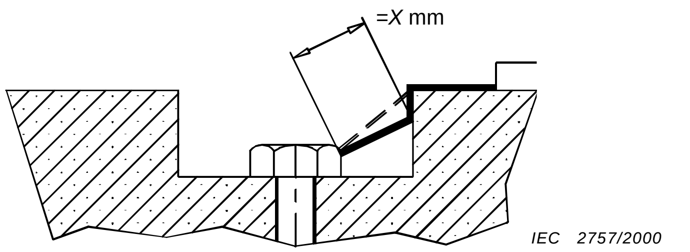
EXAMPLE 7 The path includes an uncemented joint with a groove on one side less than *X* wide and the groove on the other side equal to, or more than, *X* wide.

The CLEARANCE and the CREEPAGE DISTANCE are as shown.

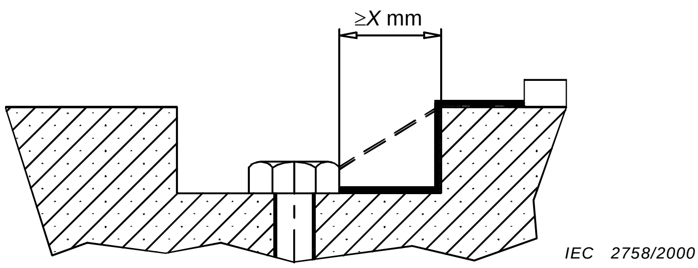


EXAMPLE 8 The CREEPAGE DISTANCE through the uncemented joint is less than the CREEPAGE DISTANCE over the barrier.

The CLEARANCE is the shortest direct air path over the top of the barrier.

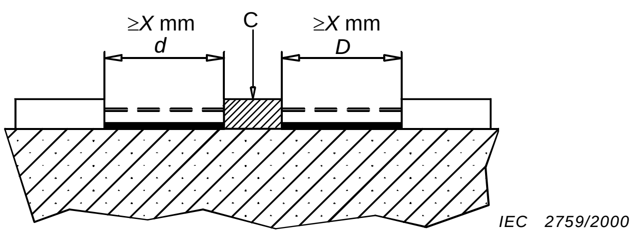


EXAMPLE 9 The gap between the head of the screw and the wall of the recess too narrow to be taken into account.



EXAMPLE 10 The gap between the head of the screw and the wall of the recess wide enough to be taken into account.

Measurement of the CREEPAGE DISTANCE is from screw to wall when the distance is equal to *X*.



EXAMPLE 11 C = floating part

The CLEARANCE is the distance $d + D$. The CREEPAGE DISTANCE is also $d + D$.

——— CREEPAGE DISTANCE

– – – CLEARANCE

Figure C.1 – Examples of methods of measuring CLEARANCES and CREEPAGE DISTANCES

Annex D
(normative)

Parts between which insulation requirements are specified
(see 6.4 and 6.5.3)

The following symbols are used in Figures D.1 to D.3 to indicate:

a) Requirements:

B BASIC INSULATION is required

D DOUBLE INSULATION or REINFORCED INSULATION is required

b) Circuits and parts:

A ACCESSIBLE part, not bonded to the PROTECTIVE CONDUCTOR TERMINAL

H circuit that is HAZARDOUS LIVE in NORMAL CONDITION

R ~~high impedance which, in combination with BASIC INSULATION, forms a PROTECTIVE IMPEDANCE (see 6.5.4)~~ impedance meeting the requirements of 6.4.4

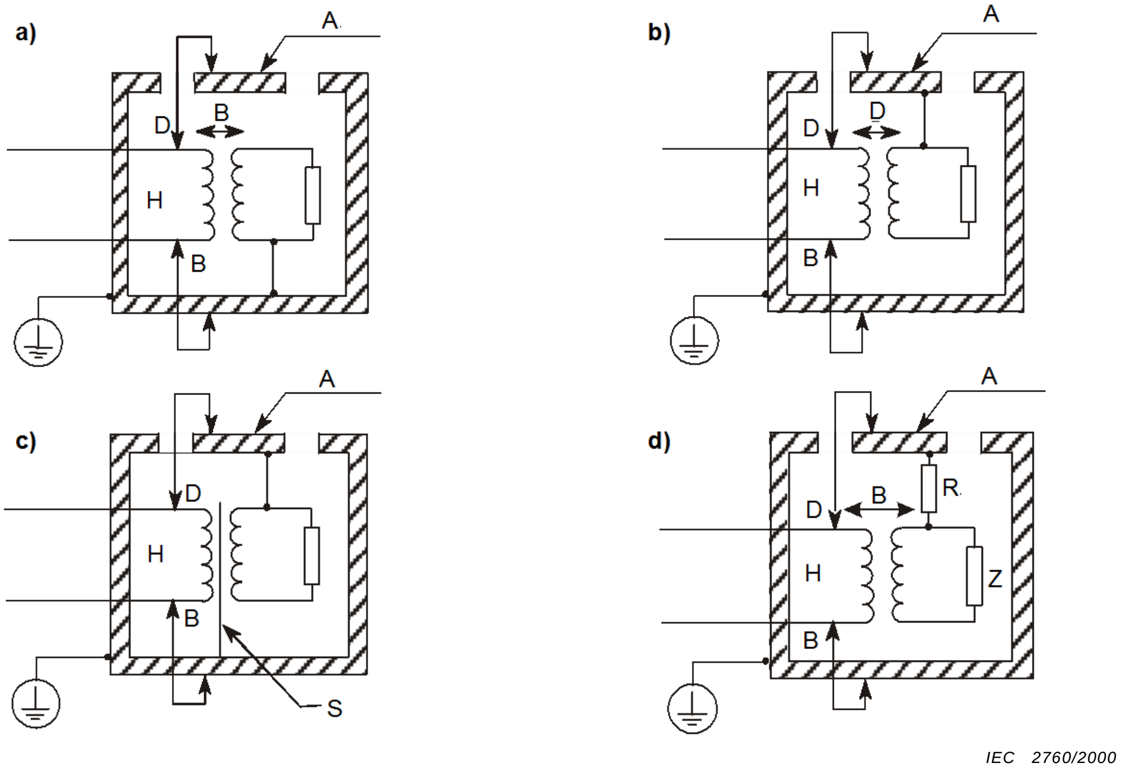
S protective screen

T_A ACCESSIBLE external TERMINAL (not exceeding the values of 6.3.1 in NORMAL CONDITION)

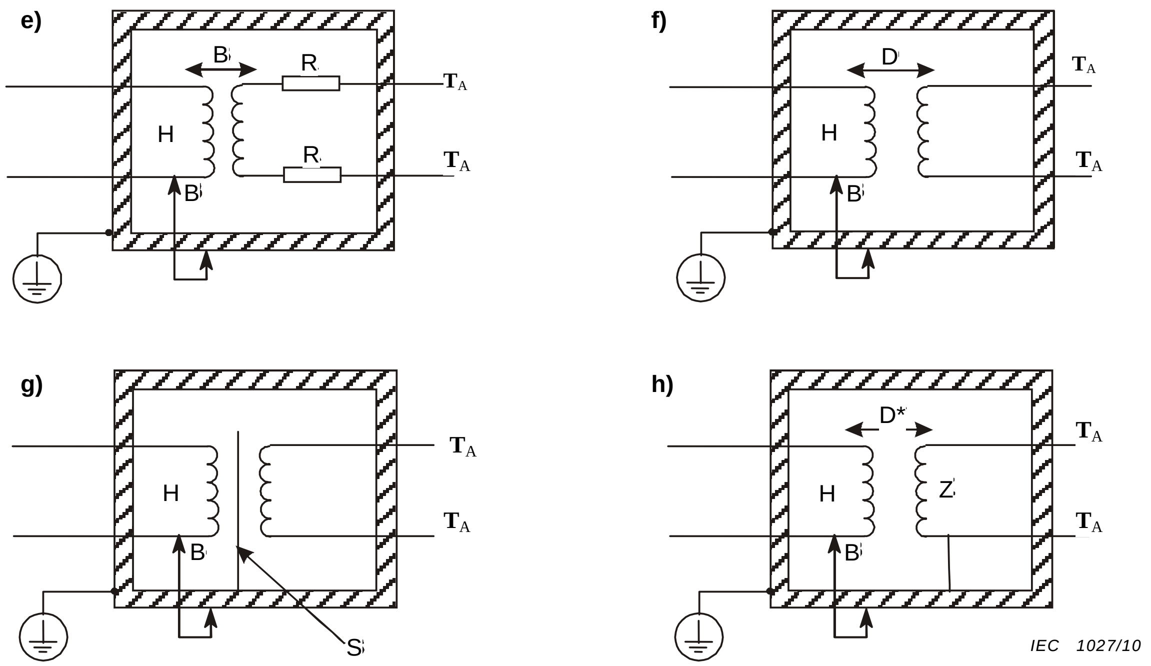
T_N TERMINAL (which may exceed the values of 6.3.1 in NORMAL CONDITION, and therefore shall not be ACCESSIBLE)

Z impedance of secondary circuit

The secondary circuits shown may also be regarded merely as parts.

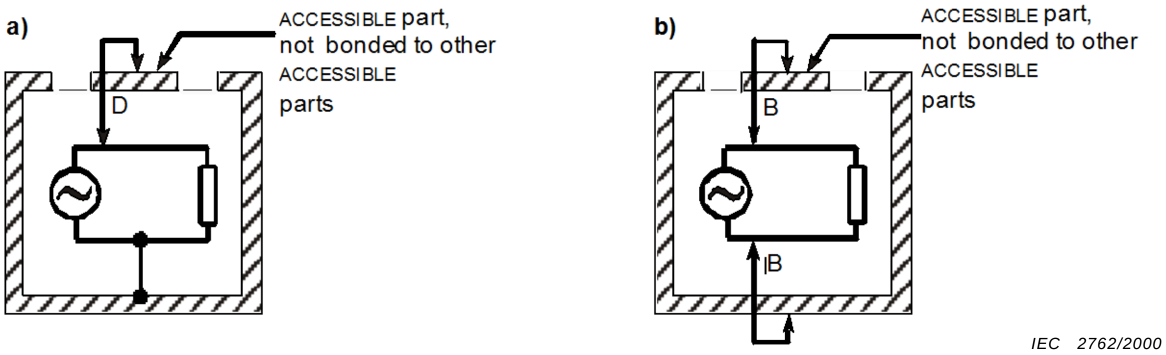


Figures D.1a) to d) – Protection between HAZARDOUS LIVE circuits and ACCESSIBLE parts

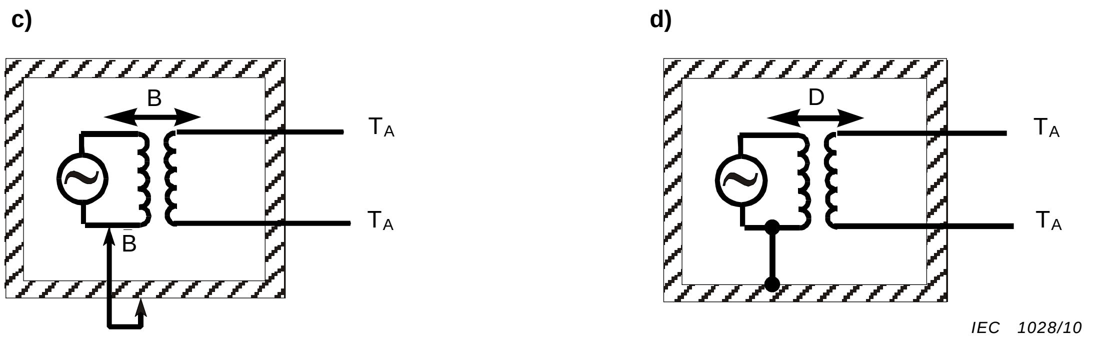


D* may be B if Z is sufficiently low ~~(see 6.6.1)~~

Figures D.1e) to h) – Protection between HAZARDOUS LIVE circuits and circuits ~~which~~ with ACCESSIBLE external TERMINALS



Figures D.2 a) and D.2 b) – Protection between a HAZARDOUS LIVE internal circuit and an ACCESSIBLE part which is not bonded to other ACCESSIBLE parts



Figures D.2 c) and D.2 d) – Protection between a HAZARDOUS LIVE primary circuit and circuits which have ACCESSIBLE external TERMINALS

NOTE 1 Other means of protection are also possible for the circuits shown in Figures D.2 c) and D.2 d), such as protective screening, PROTECTIVE BONDING of circuits (see 6.5.2) and PROTECTIVE IMPEDANCE (see 6.5.4).

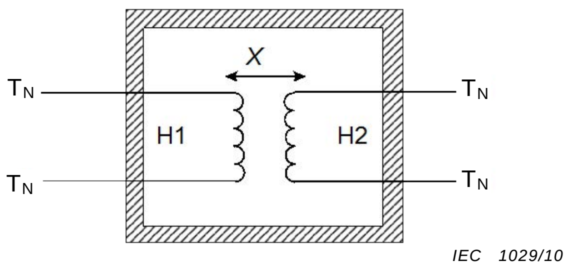


Figure D.3 – Protection of external ACCESSIBLE TERMINALS of two HAZARDOUS LIVE circuits

NOTE 2 The requirement for insulation between an ACCESSIBLE part not bonded to the PROTECTIVE CONDUCTOR TERMINAL and either of the two HAZARDOUS LIVE circuits is as shown in D.1 a) to D.1 d).

The requirement for the insulation between H1 and H2 (*X)* is the most severe of the following:

B BASIC INSULATION – if H1 and H2 are both connected, the insulation requirement is based on the highest RATED WORKING VOLTAGE that stresses the insulation between the circuits;

D DOUBLE INSULATION or REINFORCED INSULATION – if H1 is connected and the TERMINALS of H2 are ACCESSIBLE for connection purposes, the insulation requirement is based on the highest RATED WORKING VOLTAGE that stresses the insulation of H1;

D DOUBLE INSULATION or REINFORCED INSULATION – if H2 is connected and the TERMINALS of H1 are ACCESSIBLE for connection purposes, the insulation requirement is based on the highest RATED WORKING VOLTAGE that stresses the insulation of H2.

Annex E
(informative)

Guideline for reduction of POLLUTION DEGREES

The micro-environment inside equipment is determined by the environmental conditions to which the equipment is exposed during operation, installation, maintenance, and any POLLUTION generated by the equipment itself as well as by the effectiveness of applied sealing measures.

Equipment can be divided into environmental situations as depicted in Table E.1.

Table E.1 – Environmental situations

Environmental situation	Equipment operated in …	Installation or maintenance of equipment in …
A	controlled environment[a]	controlled environment
B	uncontrolled environment	controlled environment or equipment is not opened during installation or maintenance
C	uncontrolled environment	uncontrolled environment
[a] A controlled environment is an environment having the conditions of 1.4.1 c) and d).		

NOTE The environmental situation of Table E.1 provides a systematic classification of the environments to which the equipment is exposed and whether the equipment may be opened for installation and maintenance purposes.

Reduction of the POLLUTION DEGREE of the micro-environment may be achieved by the methods of Table E.2.

Table E.2 – Reduction of POLLUTION DEGREES

	POLLUTION DEGREE of micro-environment						
POLLUTION DEGREE of macro environment	2			3		4	
	Environmental situation			Environmental situation		Environmental situation	
	A	B	C	B	C	B	C
ENCLOSURE IPx5, IPx6	1	2	2	3	3	4	4
ENCLOSURE IPx7, IPx8	1	1	2	2	3	2	4
Constant heating within the equipment with an ENCLOSURE of IPx4 or higher	1	2	2	3	3	4	4
IP RATINGS are according to IEC 60529.							

Annex F
(normative)

ROUTINE TESTS

F.1 General

The manufacturer shall perform the tests of F.2 to F.4 on 100 % of equipment produced which has both HAZARDOUS LIVE parts and ACCESSIBLE conductive parts. Unless it can be clearly shown that the result of the tests cannot be invalidated by subsequent manufacturing stages, tests shall be made with equipment fully assembled. Components shall not be unwired, modified or disassembled for the test, but snap-on covers and friction-fit knobs may be removed if they would interfere with the tests. The equipment shall not be energized during the tests, but the MAINS switch shall be in the on-position.

Wrapping the equipment in foil is not required, nor is humidity preconditioning necessary.

Test site altitude correction of the test voltage is not required.

The voltage test equipment shall be able to maintain the required voltage for the specified period of time. No other requirements apply.

Conformity is checked by inspection.

F.2 Protective earth

A continuity test is made between the earth pin of the appliance inlet or the MAINS plug of plug-connected equipment, or the PROTECTIVE CONDUCTOR TERMINAL of PERMANENTLY CONNECTED EQUIPMENT on the one side, and all ACCESSIBLE conductive parts which are required by 6.5.2 to be connected to the PROTECTIVE CONDUCTOR TERMINAL on the other side.

NOTE No value is specified for the test current.

F.3 MAINS CIRCUITS

F.3.1 General

A test voltage is applied between:

a) the MAINS TERMINALS connected together, and

b) all ACCESSIBLE conductive parts including the PROTECTIVE CONDUCTOR TERMINAL, if any, connected together.

During this test, the equipment shall be electrically isolated from any external earthing. This test is not applied to small metal parts such as name plates, screws or rivets, if they are separated from parts which are HAZARDOUS LIVE by REINFORCED INSULATION or its equivalent.

NOTE For equipment which has all ACCESSIBLE conductive parts connected to the PROTECTIVE CONDUCTOR TERMINAL, the interconnection of the ACCESSIBLE conductive parts is not necessary because the correct interconnections are tested by F.2.

The test voltage may be a.c. or d.c. or impulse, and is selected from Table F.1 for the appropriate OVERVOLTAGE CATEGORY. For the a.c. and d.c. tests, the test voltage is raised to its specified value within 5 s, and maintained for at least 2 s. Impulse tests are the 1,2/50 μs *test specified in IEC 61180, conducted for a minimum of three pulses of each polarity at 1 s minimum intervals.*

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test, nor shall the test device indicate failure.

Table F.1 – Test voltages for ROUTINE TESTS of MAINS CIRCUITS

Nominal line-to-neutral voltage of MAINS supply	OVERVOLTAGE CATEGORY II			OVERVOLTAGE CATEGORY III			OVERVOLTAGE CATEGORY IV		
a.c. r.m.s. or d.c.	**a.c.**	**d.c.**	**1,2/50 μs Impulse**	**a.c.**	**d.c.**	**1,2/50 μs Impulse**	**a.c.**	**d.c.**	**1,2/50 μs Impulse**
V	V r.m.s.	V	V peak	V r.m.s.	V	V peak	V r.m.s.	V	V peak
≤150	840	1 200	1 200	1 400	2 000	2 000	2 200	3 100	3 100
>150 ≤ 300	1 400	2 000	2 000	2 200	3 100	3 100	3 300	4 700	4 700
>300 ≤ 600	2 200	3 100	3 100	3 300	4 700	4 700	4 300	6 000	6 000
>600 ≤ 1 000	3 300	4 700	4 700	4 300	6 000	6 000	5 300	7 500	7 500

F.3.2 MAINS CIRCUITS with voltage limiting devices

For MAINS CIRCUITS with voltage limiting devices that meet the requirements of 14.8, the a.c. or d.c. test of F.3.1 can be carried out using a test voltage of 0,9 times the clamping voltage of the voltage limiting device but not less than twice the WORKING VOLTAGE of the MAINS CIRCUIT.

F.4 Floating circuits

A test voltage is applied between

a) *the TERMINALS of floating input and output circuits, which can be HAZARDOUS LIVE in NORMAL USE, connected together, and*

b) *ACCESSIBLE conductive parts connected together.*

The value of the applied voltage in each case is 1,5 times the maximum RATED voltage to earth but not less than 350 V a.c. r.m.s or 500 V d.c. If voltage-limiting (clamping) devices clamp below the applied voltage, the value of the applied voltage is 0,9 times the clamping voltage, but not less than that of the maximum RATED voltage to earth.

The test voltage is raised to its specified value within 5 s and maintained for at least 2 s, with the circuit electrically isolated from any external earthing means.

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test nor shall the test device indicate failure.

Annex G
(informative)

Leakage and rupture from fluids under pressure

The requirements and tests of this annex are accepted in the USA, Canada, and in some other countries, as proof of conformity with national regulations relating to high pressures. These requirements are not adequate for equipment intended for toxic, flammable, or otherwise hazardous materials. Refer to national authorities for requirements for such equipment.

G.1 General

Fluid-containing parts of equipment under pressure shall not cause a HAZARD through rupture or leakage in NORMAL CONDITION or SINGLE FAULT CONDITION.

Conformity is checked as specified in Clause G.2 to G.4.

G.2 Pressures above 2 MPa and a product pressure and volume greater than 200 kPa·l

G.2.1 General

Fluid-containing parts of equipment which in NORMAL USE have both of the following characteristics shall not cause a HAZARD through rupture or leakage:

a) a product of pressure and volume greater than 200 kPa·l;

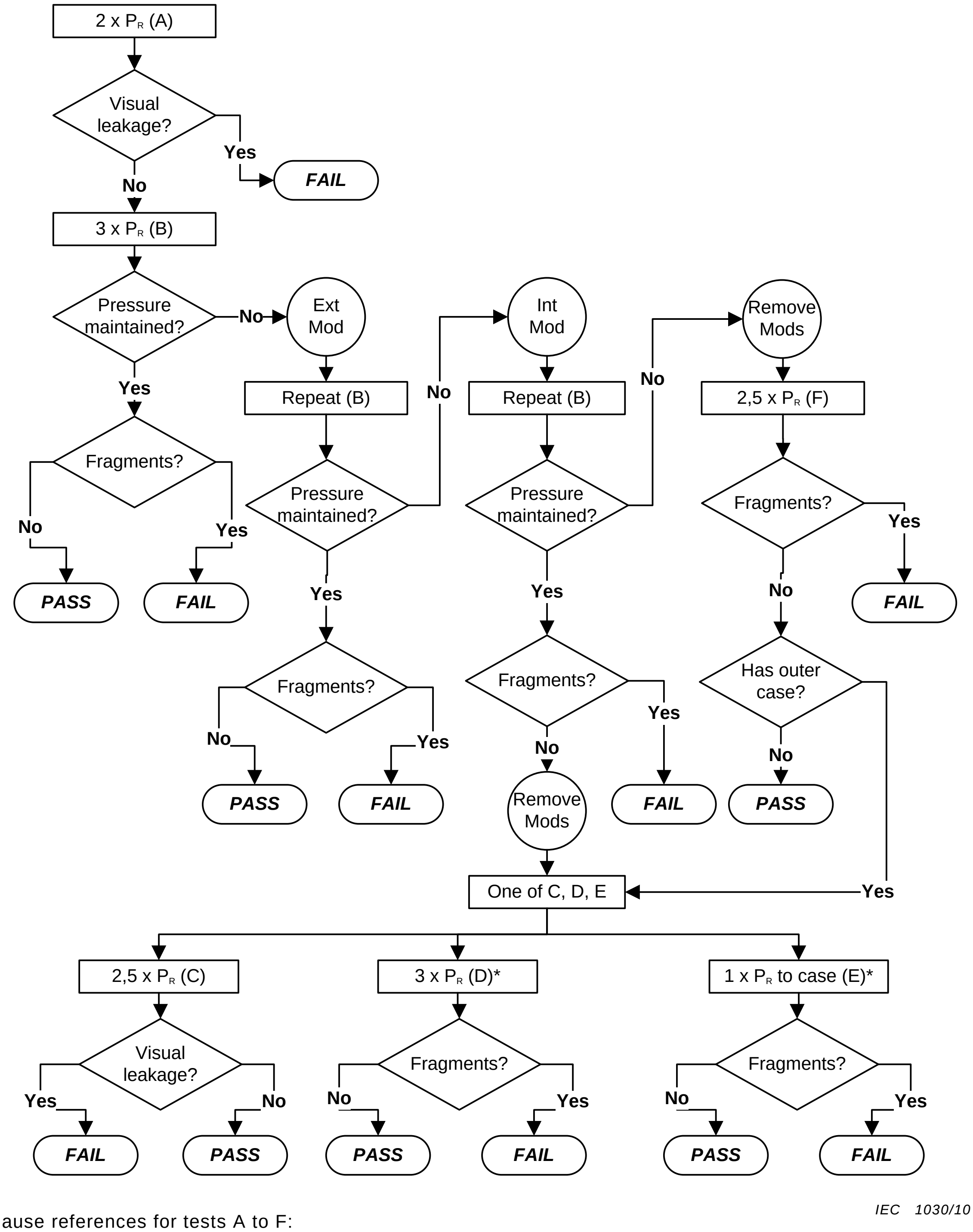
b) a pressure above 2 MPa.

NOTE Such equipment includes fluid-pressure-actuated equipment employing flexible bellows, diaphragms, Bourdon tubes, etc. and equipment such as flowmeters that are connected to process pressures RATED at or above 2 MPa.

Conformity is checked by inspection and by performing the hydrostatic tests of G.2.2 to G.2.6. Any overpressure safety device which is used to limit the maximum working pressure is inactivated during the tests.

Figure G.1 is a flow chart showing methods of conformity verification.

Throughout Clause G.2, values are based on RATED pressure P_R. This is the maximum pressure as marked on the equipment or, if no value is marked, the maximum transient overpressure (maximum pressure which may be applied without permanent change in performance). In the case of differential pressure equipment, the RATED pressure is the higher of the working pressure and the static pressure.



Subclause references for tests A to F:

A = G.2.3 a) - B = G.2.3 b) - C = G.2.5 a) - D = G.2.5 b) - E = G.2.5 c) - F = G.2.6 - P_R = RATED pressure

Figure G.1 – Conformity verification process (see G.2)

G.2.2 Conduct of hydrostatic tests for G.2.1

The part of the equipment that is normally subjected to the fluid pressure is filled with a suitable liquid, such as water, to exclude air, and is then connected to a hydraulic pump. The pressure is raised gradually to the specified test pressure.

Those portions of the equipment which normally receive indirect pressure loading, as in hydraulically coupled systems, are subjected to the test pressure at the same time, either through the original hydraulic filling fluid or, in its absence, by filling with the test liquid.

Test pressure values are based on RATED *pressure P_R, see G.2.1.*

Test pressure values specified in G.2.3 to G.2.6 apply to equipment with RATED *pressure up to 14 MPa. For higher* RATED *pressures the values of Table G.1 apply.*

~~*If it is specified that pressure is applied to "the equipment", this refers to that part of the equipment that is subjected to pressure in* NORMAL USE*. If it is specified that pressure is applied to "the outer casing" this refers to any unpressurized case, cover or housing that encloses all or part of the pressurized equipment, but that is not itself subjected to pressure in* NORMAL USE*.*~~

Where it is specified in these test procedures that pressure is to be applied to "the equipment", the pressure shall be applied to that part of the equipment that is subjected to pressure in NORMAL USE*.*

Where it is specified in these test procedures that pressure is to be applied to "the outer casing", the pressure shall be applied to any unpressurized case, cover, enclosure, or housing that encloses all or part of the pressurized equipment, but that is not itself intended to be pressurized in NORMAL USE*.*

G.2.3 Initial tests

The following tests are performed.

a) A pressure of $2 \times P_R$ is applied to the equipment for 1 min without any visible leakage.

b) A pressure of $3 \times P_R$ is applied to the equipment for 1 min without any rupture or failure which results in fragments flying outside the equipment.

During test b), leakage may occur because of splits in Bourdon tubes, diaphragms, or bellows, or because of joint or gasket failure. These are not considered to be test failures if the pressure can be maintained for 1 min. However, if leakage is at a rate which prevents pressure being maintained for 1 min, the modifications specified in G.2.4 may be made, and the test repeated.

1) If the equipment passes the test of G.2.3 b) after modification only as specified in G.2.4 a), no further tests are performed.

2) If the equipment passes the test of G.2.3 b) after modification as specified in G.2.4 b), the modifications are removed, and one of the tests of G.2.5 is performed.

3) If the equipment again fails the test of G.2.3 b), the modifications are removed and the test of G.2.6 is performed.

G.2.4 Modifications to minimize leakage

The following modifications may be made.

a) External fittings may be modified to reduce leakage.

b) A leaking gasket or a flexible seal (not part of the measuring element) which forms a structural partition between the part of the equipment that is under pressure in NORMAL USE *and the outer casing may be replaced by a stronger non-functional member to reduce leakage.*

G.2.5 Additional tests if modification succeeded in minimizing leakage

If any modification as specified in G.2.4 b) was made before successfully repeating the test of G.2.3 b), the equipment is restored to its original state, and one of tests a), b) or c) below is performed on the unmodified equipment. For equipment intended for toxic, flammable or otherwise hazardous substances, test a) is performed.

a) A pressure of $2,5 \times P_R$ is applied to the equipment for 1 min without any visible leakage.

b) *A pressure of 3 × P_R is applied to the equipment for 1 min without any rupture or failure which results in fragments flying outside the outer casing.*

NOTE 1 In this case, even if the pressure of 3 × P_{RATED} cannot be maintained within the equipment, leakage from the outer casing takes place at a rate which prevents a build-up of hazardous pressure.

c) *If the equipment has an outer casing capable of being pressurized, it is subjected to a pressure of P_R for 1 min without any rupture or failure which results in fragments flying outside the outer casing.*

NOTE 2 In this situation, rupture and flying fragments are prevented by the capability of the outer casing to resist pressure.

G.2.6 Additional test if modifications failed to reduce leakage

If the equipment failed the test of G.2.3 b) after the modifications of G.2.4, but the leakage serves as a pressure relief mechanism, the equipment conforms to the requirements of G.2.3 b) if, after removal of the modifications, it passes the test specified below and, if the equipment has an outer casing, also passes one of tests a), b), and c) of G.2.5.

A pressure of 2,5 x P_R is applied to the equipment for 1 min without any rupture or failure which results in fragments flying outside the equipment.

Table G.1 – Test pressures for equipment with pressures above 14 Mpa

P_R	Pressure for test of G.2.5 c)	Pressure for test of G.2.3 a)	Pressure for tests of G.2.5 a) and G.2.6	Pressure for tests of G.2.3 b) and G.2.5 b)
>14 ≤ 70 MPa	P_R	1,75 × P_R plus 3,5 MPa	2,0 × P_R plus 7 MPa	2,5 × P_R plus 7 MPa
>70 MPa	P_R	1,3 × P_R plus 35 MPa	1,5 × P_R plus 42 MPa	2,0 × P_R plus 42 MPa

G.3 Pressures between 50 kPa and 2 MPa, and pressure times volume above 200 kPa·l

Fluid-containing parts of equipment which in NORMAL USE have both of the following characteristics shall not cause a HAZARD through rupture or leakage:

a) a product of pressure and volume greater than 200 kPa·l;

b) a pressure between 50 kPa and 2 MPa.

Conformity is checked by a hydrostatic test conducted as specified in G.2.2. Any overpressure safety device which is used to limit the maximum working pressure is inactivated during the test.

A pressure of 3 × P_R is applied to the equipment for 1 min without leakage, permanent (plastic) deformation, or bursting. However, for equipment not intended for use with toxic, flammable, or otherwise hazardous substances, leakage at a gasket at a pressure above 1,2 × P_R is acceptable.

If a hydrostatic test cannot be performed on unmarked fluid-containing parts or pipes, their integrity is verified by suitable equivalent tests, such as pneumatic tests at 3 × P_R.

For refrigeration systems see applicable national standards for example ANSI/UL 471, CSA C22.2 No 120.

G.4 Pressures below 50 kPa, or pressure times volume below 200 kPa·l

Leakage from fluid-containing parts at lower pressures, or with a product of pressure and volume below 200 kPa·l, shall not cause a HAZARD.

Conformity is checked by inspection of the RATINGS of parts and, if necessary, by subjecting the parts to a fluid pressure of twice the maximum pressure in NORMAL USE. The pressure is applied for 1 min. No leakage is to occur which could cause a HAZARD.

G.5 Overpressure safety devices

An overpressure safety device shall not operate in NORMAL USE and shall conform to all the following requirements.

a) It shall be connected as close as possible to the fluid-containing parts of the system that it is intended to protect.
b) It shall be installed so as to provide easy access for inspection, maintenance and repair.
c) It shall not be capable of being adjusted without the use of a TOOL.
d) It shall have its discharge outlet located and directed so that the released material is not directed towards any person.
e) It shall have its discharge outlet located and directed so that operation of the device will not cause a HAZARD by depositing material that could cause deterioration of parts.
f) It shall have sufficient discharge capacity to ensure that the pressure will not exceed $1,1 \times P_R$ if there is a failure of the supply pressure control.
g) There shall be no shut-off valve between any overpressure safety device and the parts that it is intended to protect.

Also see 11.7.4.

Conformity is checked by inspection and test.

Annex H
(normative)

Qualification of conformal coatings for protection against POLLUTION

H.1 General

This annex covers requirements for conformal coatings used on printed wiring boards to reduce the POLLUTION DEGREE.

Conformal coatings shall meet the requirements of Clause H.2 and H.3.

NOTE 1 The requirements of Clause H.2 assure that the conformal coating has been suitably RATED for the purpose of coating printed wiring boards. The requirements of H.3 assure that the coating will continue to adhere to the printed wiring board after environmental and physical stresses.

Conformity is checked as specified in Clauses H.2 and H.3.

NOTE 2 Conformal coatings that meet the requirements of ANSI/UL 746E are considered to meet these requirements.

H.2 Technical properties

The technical properties of conformal coatings shall be suitable for the intended application. In particular:

a) the manufacturer of the coating material shall state that it is a coating for printed wiring boards;
b) the RATED operating temperature range shall include the temperature range of the intended application;
c) the comparative tracking index (CTI), the insulation resistance and the dielectric strength shall be suitable for the intended application;
d) if the printed wiring board coating is to be exposed to sunlight, the coating shall have adequate UV resistance;
e) the flammability RATING of the coating shall be at least the required flammability RATING of the printed wiring board to which it is applied.

Conformity is checked by inspection of the manufacturer's data.

H.3 Qualification of coatings

The coating shall meet the conformity requirements of Figure H.1 after the tests of Table H.1.

Conformity is checked as specified in Table H.1 and Figure H.1, on 6 specimens of the coated printed wiring board.

Table H.1 – Test parameters, test conditions and test procedures

Item	Test, conditioning	Test parameter, conditions	Test procedure
~~1~~	~~Scratch resistance~~	~~Temperature: 15 °C.... 35 °C~~ ~~Humidity: 45 %.... 75 % R.H.~~ ~~Any combination of temperature and humidity within these ranges is acceptable.~~	~~The scratch test is conducted according to 5.5 of IEC 60664-3.~~
~~2~~ 1	Cold conditioning	Conditioning temperature: T_{min}. T_{min} is the minimum RATED ambient temperature or the minimum RATED storage temperature, whichever is lower, of the specimen. Any humidity is acceptable. Conditioning time: 24 h	The specimens are placed in a temperature chamber and held at T_{min} for the specified conditioning time.
~~3~~ 2	Dry heat	Conditioning temperature: T_{max}. T_{max} is the maximum RATED surface temperature, maximum RATED ambient temperature, or maximum RATED storage temperature, whichever is higher, of the specimen. Any humidity is acceptable. Conditioning time: 48 h	The specimen is placed in a temperature chamber and held at T_{max} for the specified conditioning time.
~~4~~ 3	Rapid change of temperature	Maximum temperature: T_{max} T_{max} is the maximum RATED surface temperature, maximum RATED ambient temperature, or maximum RATED storage temperature, whichever is highest, of the specimen. Minimum temperature: T_{min}. T_{min} is the minimum RATED ambient temperature or the minimum RATED storage temperature, whichever is lower, of the specimen. Rate of change of temperature: within 30 s Cycle time (duration of one cycle): T_{max} and T_{min} are each held until steady state conditions of the specimens are achieved and then maintained for 10 min. The cycle starts when the specimen has reached the target within 2° C. Number of cycles: 50 cycles	The conditioning procedure follows test Na of IEC 60068-2-14.
~~5~~ 4	Damp heat	Temperature: 40 °C ± 2 °C Humidity: 90 %...95 % R.H. Conditioning time: 24 h	The specimens are placed in the humidity chamber and held at the specified temperature and humidity for the specified conditioning time.
~~6~~ 5	Adhesion of coating	Temperature: 15 °C.... 35 °C Humidity: 45 %.... 75 % R.H. Pull force: 5 N	The test procedure follows the test described in 5.8.2 of IEC 60664-3 using the specified pull force.
~~7~~ 6	Humidity conditioning	Temperature: 40 °C ± 2 °C Humidity: 90 %...95 % R.H. Conditioning time: 48 h	The specimens are placed in the humidity chamber and held at the specified temperature and humidity for the specified conditioning time.
~~8~~ 7	Insulation resistance of conductors	Temperature : 40 ± 2 °C Humidity: 90 %...95 % R.H. Insulation resistance: ≥100 MΩ	Insulation resistance is measured between the two outer conductors with the smallest CREEPAGE DISTANCE for at least 1 min. The test voltage shall be as close to the WORKING VOLTAGE as possible.

Figure H.1 (below) describes the test sequence and conformity.

Preparation and scratch resistance	
Preparation of the test specimens	Each specimen is to be assembled in the normal manner, using the normal soldering procedure, including any cleaning and protection steps that are normally applied.
~~Table H.1, item 1~~	~~Scratch resistance test~~
Visual inspection	*Conformity is checked by inspection.* The specimens shall show no: ▪ separation from base material, ▪ cracks, ▪ voids, ▪ areas with adjacent unprotected conductive parts where the CREEPAGE DISTANCE between the parts is less than the required CREEPAGE DISTANCE for uncoated printed wiring boards. *NOTE Areas of the specimens where scratch resistance test is applied need not be involved in the subsequent testing and inspection.*
Conditioning of the test specimens	
Table H.1, item ~~2~~ 1	Cold conditioning
Table H.1, item ~~3~~ 2	Dry heat
Table H.1, item ~~4~~ 3	Rapid change of temperature
Table H.1, item ~~5~~ 4	Damp heat test
Mechanical and electrical tests after conditioning	
Table H.1, item ~~6~~ 5	Adhesion of coating (tape test)
Visual inspection	*Conformity is checked by inspection.* On all specimens, the coating shall not have loosened and there shall be no material transferred to the tape that is visible to the naked eye. *NOTE In order to assess whether there has been any transfer of material, the tape ~~may~~ can be placed on a sheet of white paper or card. If a white or light-coloured coating is being tested, a suitably contrasting coloured paper or card is used instead.*
Table H.1, item ~~7~~ 6	Humidity conditioning
Table H.1, item ~~8~~ 7	Insulation resistance *Conformity is checked by measuring of the insulation resistance of Table H.1, item ~~8~~ 7. All specimens shall meet the required value.*
Visual inspection	*Conformity is checked by inspection.* All specimens shall show no ▪ blistering, ▪ swelling, ▪ separation from base material, ▪ cracks, ▪ voids, ▪ areas with adjacent unprotected conductive parts where the CREEPAGE DISTANCE between the parts is less than the required CREEPAGE DISTANCE for uncoated printed wiring boards.

IEC 1031/10

Figure H.1 – Test sequence and conformity

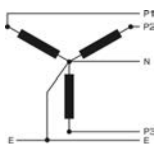
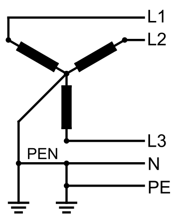
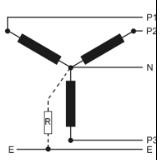
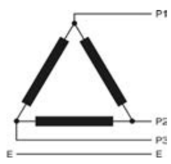
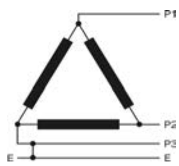
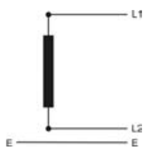
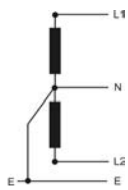
Annex I
(informative)

Line-to-neutral voltages for common MAINS supply systems

For the purposes of this standard, Table I.1 gives the line-to-neutral voltage that should be used for determining CLEARANCE, CREEPAGE DISTANCE, and solid insulation requirements of MAINS circuits.

Table I.1 is derived from Table B.1 of IEC 60664-1. It is applicable to MAINS supply systems with inherent control (see IEC 60664-1, 4.3).

Table I.1 – Line-to-neutral voltages for common MAINS supply systems

MAINS systems and nominal voltages						Line-to-neutral voltage pertinent to MAINS system type and nominal voltage
Three-phase four-wire systems [a] **with earthed neutral** **TT system**  **TN-C-S System** 	**Three-phase four-wire systems [a]** **with unearthed neutral (IT systems) [b, c]** 	**Three-phase three-wire systems** **unearthed** 	**Three-phase three-wire systems** **with earthed phase** 	**Single-phase two-wire systems** **a.c. or d.c.** 	**Single-phase (split-phase) three-wire systems [a]** **a.c. or d.c.** 	
V	V	V	V	V	V	V
				12,5 to 48	30/60	50
66/115		66		60		100
120/208 127/220	120/208	110, 115 120, 127	100 120	100 110, 115 120, 127	100/200 [d] 110/220 115/230 120/240	150
220/380 230/400 240/415 260/440 277/480	230/400 277/480	200 220, 230, 240 260, 277, 347 380, 400, 415 440, 480	200 240 347 380, 400, 415 440, 480	220 230 240	220/440 240/480	300

347/600 380/660 400/690 417/720 480/830	347/600 400/690	500 577 600	600	480	480/960	600
		660 690, 720 830, 1 000		1 000		1 000

[a] Voltages shown as two voltages separated by a "/" represent the phase-to-neutral (or line-to-neutral) voltage followed by the phase-to-phase (or line-to-line) voltage. For example, "120/208" indicates that the voltage from any phase to neutral is 120 V, and the voltage from any phase to another phase is 208 V. Likewise, "220/440" indicates that the voltage from either line-to-neutral is 220 V, and the voltage from line-to-line is 440 V.

[b] *Z* is an impedance which may connect neutral to earth (usually 1 500 Ω).

[c] When insulation is monitored, neutral of these systems is considered to be earthed.

[d] Practise in Japan.

Annex J
(informative)

RISK assessment

A RISK assessment process based on ISO/IEC Guide 51 (1999) is given below. Other RISK assessment procedures are contained in ISO 14971, SEMI S10, IEC 61508, ISO 14121-1, and ANSI TR3. Other established procedures which implement similar steps can also be used.

J.1 RISK assessment procedure

TOLERABLE RISK is achieved by the iterative process of RISK assessment (RISK analysis and RISK evaluation) and RISK reduction (see Figure J.1).

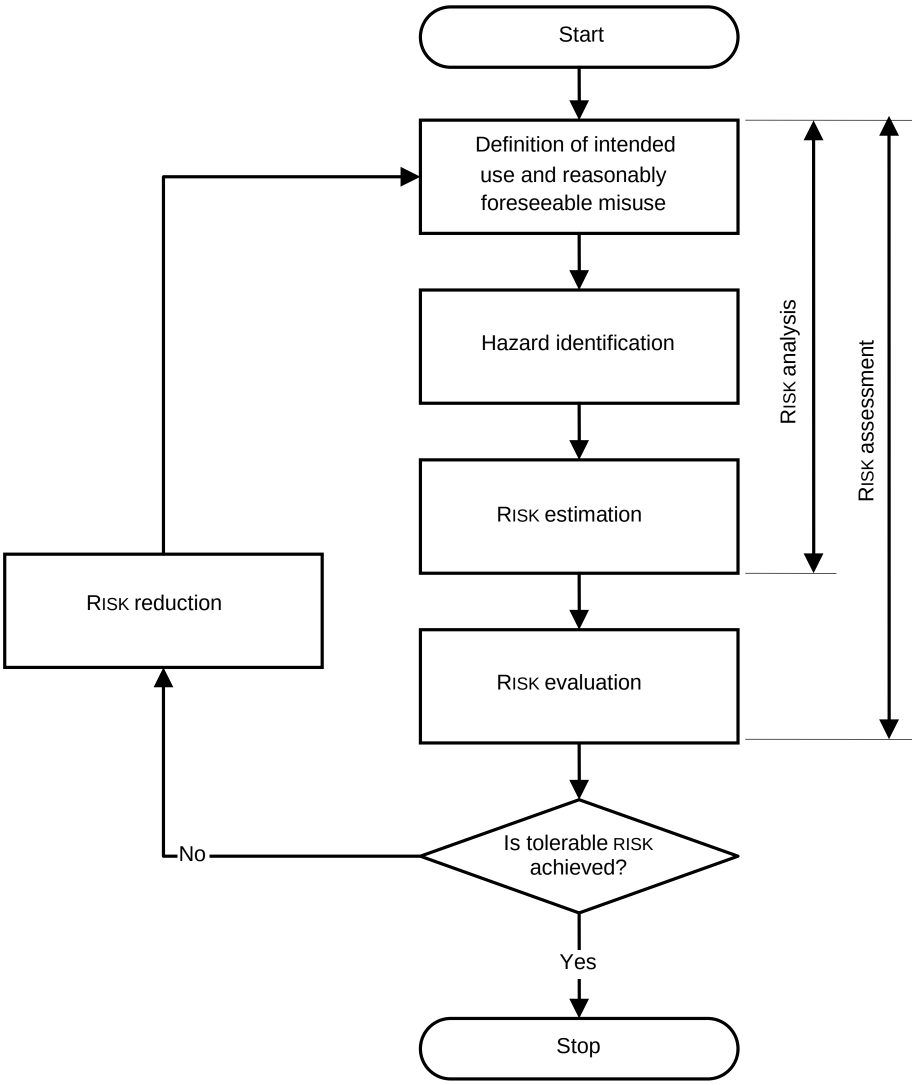


Figure J.1 – Iterative process of RISK assessment and RISK reduction

J.2 Achieving TOLERABLE RISK

The following procedure (see Figure J.1) should be used to reduce RISKS to a tolerable level:

a) identify the likely user group(s) for the product, process, or service (including those with special needs and the elderly), and any known contact group (e.g. use or contact by children);

b) identify the intended use and assess the REASONABLY FORESEEABLE MISUSE of the product, process or service;

c) identify each HAZARD (including any hazardous situation and harmful event) arising in all stages and conditions for the use of the product, process or service, including installation, maintenance, repair, and destruction or disposal;

d) estimate and evaluate the RISK (see Figure J.1) to each identified user/contact group arising from each HAZARD identified;

e) judge if the RISK is tolerable (e.g. by comparison with similar products, processes or services);

f) if the RISK is not tolerable, reduce the RISK until it becomes tolerable.

When reducing RISKS the order of priority should be as follows:

1) eliminate or reduce RISKS as far as possible (inherently safe design and construction);

2) take the necessary protection measures in relation to RISKS that cannot be eliminated (protection devices);

3) inform users of the residual RISKS due to any shortcomings of the protection measures adopted, indicate whether any particular training is required, and specify any need to provide personal protection equipment (information for safety).

This procedure is based on the assumption that the user has a role to play in the RISK reduction procedure by complying with the information provided by the manufacturer (see Figure J.2).

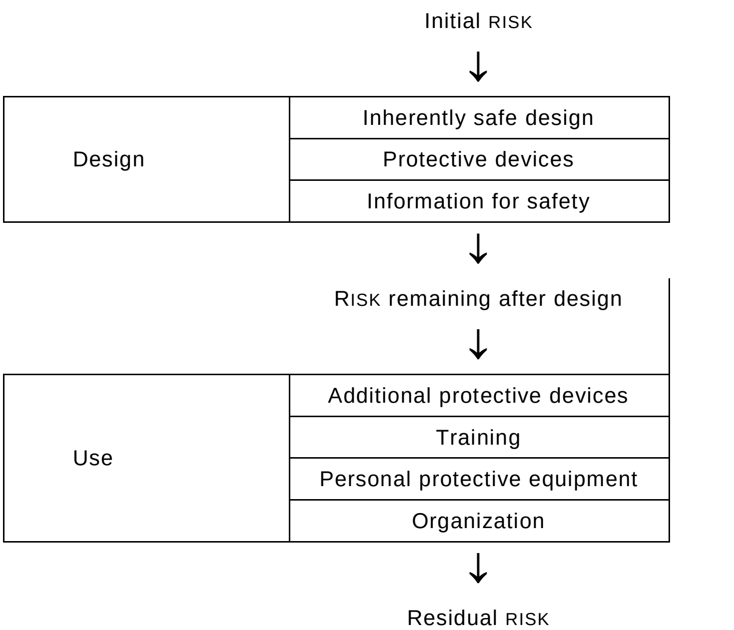


Figure J.2 – RISK reduction

The steps taken in the design procedure are shown in order of priority. The steps to be taken by the user are not in order of priority because this would depend on the application. It is emphasized that the additional protection devices, personal protection equipment and provision of information to users should not be used as substitutes for design improvements.

J.3 An application of RISK assessment procedures

For HAZARDS in the scope of this standard, examples of severity of harm are given in Table J.1. Probability of harm is given in Table J.2. The RISK category, which is selected based on severity and probability, is given in Table J.3.

Table J.1 – Severity of harm

Severity group	People	Equipment / Facility	Environment
Catastrophic	One or more fatalities	System or facility loss	Chemical release with acute or public health impact
Severe	Disabling injury/illness	Major subsystem loss or facility damage	Chemical release with temporary environmental or public health impact
Moderate	Medical treatment or restricted work activity	Minor subsystem loss or facility damage	Chemical release triggering external reporting requirements
Minor	First aid only	Non-serious equipment or facility damage	Chemical release requiring only routine cleanup without reporting

Table J.2 – Probability of harm

Likelihood	Expected rate of occurrence
Frequent	More than five times a year
Likely	More than once per year, but not more than five times a year
Possible	More than once in five years, but not more than one a year
Rare	More than once in ten years, but not more than one in five years
Unlikely	No more than once in ten years

Table J.3 – RISK category

RISK assessment / RISK category						
Severity of harm		Probability of harm				
		Frequent	Likely	Possible	Rare	Unlikely
Severity	Catastrophic	3	3	3	2	2
	Severe	3	3	2	2	1
	Moderate	3	2	1	1	1
	Minor	2	1	1	1	1

Key	Category	Description
1	Broadly acceptable	This fulfils the requirement for TOLERABLE RISK.
2	As low as reasonably practicable	This does not automatically fulfil the requirement for TOLERABLE RISK. If possible, these RISKS should be reduced further to Category 1. If not possible, then the instructions should contain a description of the RISK so that the RESPONSIBLE BODY can take appropriate steps to protect the safety of OPERATORS.
3	Intolerable	This contains RISKS that are not TOLERABLE RISKS.

Annex K
(normative)

Insulation requirements not covered by 6.7

K.1 ~~Requirements~~ Insulation for MAINS CIRCUITS

K.1.1 General

The concept of OVERVOLTAGE CATEGORIES is elaborated in IEC 60364 and in IEC 60664-1. The descriptions below are made up of edited extracts from these two standards.

An OVERVOLTAGE CATEGORY is, as the definition 3.5.17 states, a numeral defining a TRANSIENT OVERVOLTAGE condition. The OVERVOLTAGE CATEGORIES are created to achieve insulation coordination between different parts of the MAINS supply installation. IEC 60364-4-44 says that 'Impulse withstand (overvoltage) categories are to distinguish different degrees of availability of equipment with regard to required expectations on continuity of service and on an acceptable probability of failure'. This means that the decision of the appropriate RATING of the OVERVOLTAGE CATEGORY of a piece of equipment may be made on grounds of reliability as well as on grounds of safety. In this standard, requirements in Clauses 5 to 16 apply to equipment not forming part of the building installation, and the requirements for CLEARANCES and CREEPAGE DISTANCES are based on OVERVOLTAGE CATEGORY II, with MAINS voltages up to 300 V.

Equipment forming part of the building installation may include installation material, equipment intended to measure or control the MAINS supply within the building, and similar equipment. All such equipment is permanently connected to the MAINS, and is permanently installed in the building. However, equipment that utilizes the MAINS supply only for powering itself and associated equipment is not considered to be part of the building installation, even if it is permanently connected or permanently installed in the building.

If a manufacturer rates equipment for OVERVOLTAGE CATEGORY III OR OVERVOLTAGE CATEGORY IV, the relevant requirements of this annex apply.

OVERVOLTAGE CATEGORY I is used, within the context of IEC 60364-4-44, for equipment intended to be connected to a MAINS supply in which means have been taken to substantially and reliably reduce TRANSIENT OVERVOLTAGES to a level where they cannot cause a HAZARD. OVERVOLTAGE CATEGORY I is not relevant to this standard.

OVERVOLTAGE CATEGORY II is for equipment intended to be supplied from the building wiring. It applies both to plug-connected equipment and to PERMANENTLY CONNECTED EQUIPMENT. Subclause 6.7 covers only the requirements for OVERVOLTAGE CATEGORY II with a nominal supply voltage up to 300 V. The requirements for higher OVERVOLTAGE CATEGORIES and for OVERVOLTAGE CATEGORY II with a nominal supply voltage above 300 V are covered by this annex.

OVERVOLTAGE CATEGORY III is for equipment intended to form part of a building wiring installation. Such equipment includes socket outlets, fuse panels, and some MAINS installation control equipment. Manufacturers may also design equipment for OVERVOLTAGE CATEGORY III when a higher degree of reliability and availability is desired.

OVERVOLTAGE CATEGORY IV is for equipment installed at or near the origin of the electrical supply to a building, between the building entrance and the main distribution board. Such equipment may include electricity tariff meters and primary overcurrent protection devices. Manufacturers may also design equipment for OVERVOLTAGE CATEGORY IV when an even higher degree of reliability and availability is desired.

K.1.2 CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS

CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS shall meet the values of the following tables as applicable:

a) for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II, with nominal supply voltages above 300 V, Table K.2;

b) for MAINS CIRCUITS of OVERVOLTAGE CATEGORY III, Table K.3;

c) for MAINS CIRCUITS of OVERVOLTAGE CATEGORY IV, Table K.4.

NOTE 1 See Annex I for nominal voltages of MAINS supplies.

The values in the following tables are for BASIC INSULATION and SUPPLEMENTARY INSULATION. Values for REINFORCED INSULATION shall be twice the values for BASIC INSULATION.

If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCES shall be multiplied by the applicable factor of Table K.1.

NOTE 2 Material group IIIb is not recommended for application in POLLUTION DEGREE 3 above line-to-neutral voltages of 630 V.

Conformity is checked by inspection and measurement and, in case of doubt, by the impulse voltage test of 6.8.3.3 or the a.c. test of 6.8.3.1 with a duration of at least 5 s using the applicable test voltage from Table K.16 for the required CLEARANCE.

No flashover of CLEARANCES shall occur during the test.

Table K.1 – Multiplication factors for CLEARANCES for equipment RATED for operation at altitudes up to 5 000 m

RATED operating altitude m	Multiplication factor
Up to 2 000	1,00
2 001 to 3 000	1,14
3 001 to 4 000	1,29
4 001 to 5 000	1,48

Table K.2 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II above 300 V

Voltage line-to-neutral a.c. r.m.s. or d.c.	Values for CLEARANCE	Values for CREEPAGE DISTANCE								
		Printed wiring board material		Other insulating material						
		POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
		All material groups	Material groups I, II, IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
>300 ≤ 600	3,0	3,0	3,0	3,0	3,0	4,3	6,0	7,5	8,3	9,4
>600 ≤ 1 000	5,5	5,5	5,5	5,5	5,5	7,2	10,0	12,5	14,0	16,0

Table K.3 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS of OVERVOLTAGE CATEGORY III

Voltage line-to-neutral a.c. r.m.s. or d.c.	Values for CLEARANCE	Values for CREEPAGE DISTANCE								
		Printed wiring board material		Other insulating material						
		POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
		All material groups	Material groups I, II, IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
≤150	1,5	1,5	1,5	1,5	1,5	1,5	1,6	2,0	2,2	2,5
>150 ≤ 300	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,8	4,1	4,7
>300 ≤ 600	5,5	5,5	5,5	5,5	5,5	5,5	6,0	7,5	8,3	9,4
>600 ≤ 1 000	8,0	8,0	8,0	8,0	8,0	8,0	10,0	12,5	14,0	16

Table K.4 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS of OVERVOLTAGE CATEGORY IV

Voltage line-to-neutral a.c. r.m.s. or d.c.	Values for CLEARANCE	Values for CREEPAGE DISTANCE								
		Printed wiring board material		Other insulating material						
		POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
		All material groups	Material groups I, II, IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
≤150	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
>150 ≤ 300	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5
>300 ≤ 600	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,3	9,4
>600 ≤ 1 000	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	16,0

Coatings that meet the requirements of Annex H when applied to the outer surfaces of printed wiring boards reduce the POLLUTION DEGREE of the coated area to POLLUTION DEGREE 1.

Conformity of coatings is checked as specified in Annex H.

K.1.3 Solid insulation for MAINS CIRCUITS

K.1.3.1 General

Solid insulation of MAINS CIRCUITS shall withstand the electrical and mechanical stresses that may occur in NORMAL USE, in all RATED environmental conditions (see 1.4), during the intended life of the equipment.

NOTE 1 The manufacturer should take the expected life of the equipment into account when selecting insulating materials.

Conformity is checked by both of the following tests:

a) *the a.c. test of 6.8.3.1 with a duration of at least 5 s or the peak impulse test of 6.8.3.3 using the applicable voltages from Tables K.5, K.6 or K.7;*

b) *the a.c. test of 6.8.3.1 with a duration of at least 1 min, or for* MAINS CIRCUITS *stressed only by d.c. the 1 min d.c. test of 6.8.3.2 using the applicable voltages from Table K.8.*

NOTE 2 These two different voltage tests are required for these circuits for the following reasons. Test a) checks the effects of TRANSIENT OVERVOLTAGES, while test b) checks the effects of long-term stress of solid insulation.

NOTE 3 If the test from Tables K.5 to K.7 is performed for at least 1 min, there is no need to repeat the test of b) above.

Table K.5 – Test voltages for solid insulation in MAINS CIRCUITS of OVERVOLTAGE CATEGORY II above 300 V

Voltage line-to-neutral a.c. r.m.s. or d.c. V	**Test voltage**			
	5 s a.c. test V a.c. r.m.s.		**Impulse test** V peak	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	**REINFORCED INSULATION**	**BASIC INSULATION and SUPPLEMENTARY INSULATION**	**REINFORCED INSULATION**
>300 ≤ 600	2 210	3 510	4 000	6 400
>600 ≤ 1 000	3 310	5 400	6 000	9 600

Table K.6 – Test voltages for solid insulation in MAINS CIRCUITS of OVERVOLTAGE CATEGORY III

Voltage line-to-neutral a.c. r.m.s. or d.c. V	**Test voltage**			
	5 s a.c. test V r.m.s.		**Impulse test** V peak	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	**REINFORCED INSULATION**	**BASIC INSULATION and SUPPLEMENTARY INSULATION**	**REINFORCED INSULATION**
≤150	1 390	2 210	2 500	4 000
>150 ≤ 300	2 210	3 510	4 000	6 400
>300 ≤ 600	3 310	5 400	6 000	9 600
>600 ≤ 1 000	4 260	7 400	8 000	12 800

Table K.7 – Test voltages for solid insulation in MAINS CIRCUITS of OVERVOLTAGE CATEGORY IV

Voltage line-to-neutral a.c. r.m.s. or d.c. V	**Test voltage**			
	5 s a.c. test V r.m.s.		**Impulse test** V peak	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	**REINFORCED INSULATION**	**BASIC INSULATION and SUPPLEMENTARY INSULATION**	**REINFORCED INSULATION**
≤150	2 210	3 510	4 000	6 400
>150 ≤ 300	3 310	5 400	6 000	9 600
>300 ≤ 600	4 260	7 400	8 000	12 800
>600 ≤ 1 000	6 600	11 940	12 000	19 200

Table K.8 – Test voltages for testing long-term stress of solid insulation in MAINS CIRCUITS

Voltage line-to-neutral a.c. r.m.s. or d.c. V	Test voltage			
	1 min a.c. test V r.m.s.		1 min d.c. test voltage V d.c.	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION
≤150	1 350	2 700	1 900	3 800
> 150 ≤ 300	1 500	3 000	2 100	4 200
> 300 ≤ 600	1 800	3 600	2 550	5 100
> 600 ≤ 1 000	2 200	4 400	3 100	6 200

Solid insulation shall also meet the following requirements, as applicable:

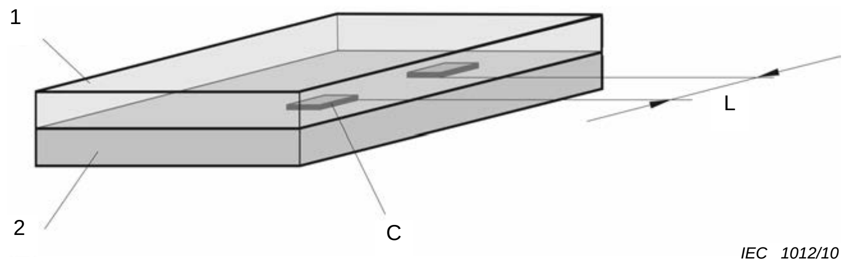
1) for solid insulation used as an ENCLOSURE or BARRIER, the requirements of Clause 8;
2) for moulded and potted parts, the requirements of K.1.3.2;
3) for inner layers of printed wiring boards, the requirements of K.1.3.3;
4) for thin-film insulation, the requirements of K.1.3.4;

Conformity is checked as specified in K.1.3.2 to K.1.3.4, and in Clause 8, as applicable.

K.1.3.2 Moulded and potted parts

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers moulded together (see Figure K.1, item L) shall be separated by at least the applicable minimum distance of Table K.9 after the moulding is completed.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications*.*



Key

1 Layer 1

2 Layer 2

C Conductor

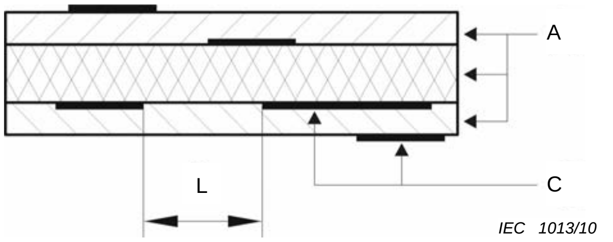
L Distance between conductors

Figure K.1 – Distance between conductors on an interface between two layers

K.1.3.3 Inner insulating layers of printed wiring boards

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers (see Figure K.2, item L) shall be separated by at least the applicable minimum distance of Table K.9.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key:

L Distance between adjacent conductors

A Layers

C Conductors

Figure K.2 – Distance between adjacent conductors along an interface of an inner layer

Table K.9 – Minimum values for distance or thickness of solid insulation

Line-to-neutral voltage V r.m.s. or d.c.	**Minimum thickness** [a] mm	**Minimum distance L (see Figure K.2)** [a, b] mm
≤ 300	0,4	0,4
> 300 ≤ 600	0,6	0,6
> 600 ≤ 1 000	1,0	1,0

[a] These values are independent of the OVERVOLTAGE CATEGORY.

[b] These values apply for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION.

REINFORCED INSULATION of inner insulating layers of printed wiring boards shall also have adequate electric strength through the respective layers. One of the following methods shall be used:

a) the thickness through the insulation is at least the value of Table K.9.

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation is assembled from at least two separate layers of printed wiring board materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of the applicable Table K.5, Table K.6 or Table K.7 for BASIC INSULATION.

   Conformity is checked by inspection of the manufacturer's specifications.

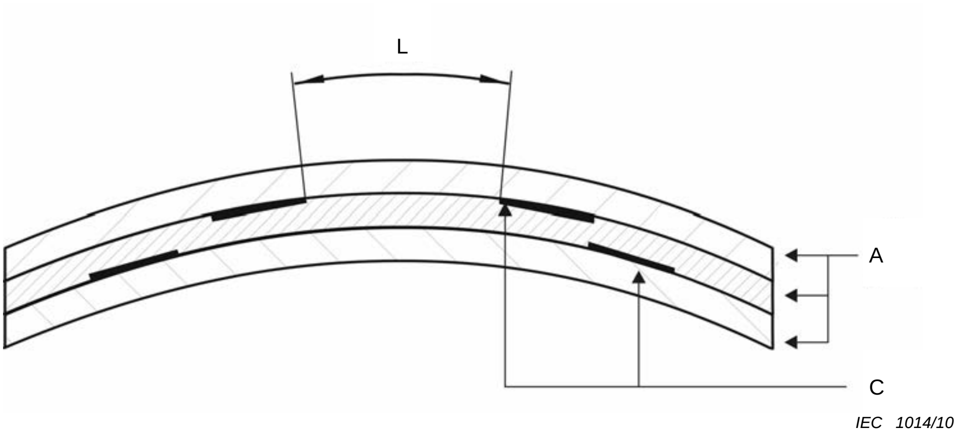
c) the insulation is assembled from at least two separate layers of printed wiring board materials, and the combination of layers is RATED by the manufacturer of the material for an electric strength of at least the value of the applicable Table K.5, Table K.6 or Table K.7 for REINFORCED INSULATION.

Conformity is checked by inspection of the manufacturer's specifications.

K.1.3.4 Thin-film insulation

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers (see Figure K.3, item L) shall be separated by at least the applicable CLEARANCE and CREEPAGE DISTANCE of K.1.2.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key:

L Distance between adjacent conductors

A Layers of thin-film material such as tape and polyester film

C Conductors

NOTE There may be air present between the layers

Figure K.3 – Distance between adjacent conductors located between the same two layers

REINFORCED INSULATION through the layers of thin-film insulation shall also have adequate electric strength. One of the following methods shall be used.

a) The thickness through the insulation is at least the value of Table K.9.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) The insulation consists of at least two separate layers of thin-film materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltages from Table K.5, Table K.6 or Table K.7 as applicable for BASIC INSULATION.

Conformity is checked by inspection of the manufacturer's specifications.

c) The insulation consists of at least three separate layers of thin-film materials, any two of which have been tested to exhibit adequate electric strength.

Conformity is checked by the a.c. test of 6.8.3.1 with a duration of at least 1 min or for MAINS CIRCUITS *stressed only by d.c. the 1 min d.c. test of 6.8.3.2 applied to two of the three layers using the applicable voltage for* REINFORCED INSULATION *of Table K.5, Table K.6 or Table K.7.*

NOTE For the purposes of this test a special sample may be assembled with only two layers of the material.

K.2 Insulation in secondary circuits

K.2.1 General

In this standard, secondary circuits are circuits where separation from MAINS CIRCUITS is achieved by a transformer in which the primary windings are separated from the secondary windings by REINFORCED INSULATION, DOUBLE INSULATION, or a screen connected to the PROTECTIVE CONDUCTOR TERMINAL.

NOTE These circuits are assumed to be subjected to lower TRANSIENT OVERVOLTAGE levels than the MAINS CIRCUIT.

K.2.2 CLEARANCES

CLEARANCES for secondary circuits shall:

a) for BASIC INSULATION or SUPPLEMENTARY INSULATION, meet the applicable values of Tables K.10, K.11 and K.12, or for REINFORCED INSULATION meet twice that value; or
b) pass the voltage test of 6.8 using the applicable value of Table K.10, Table K.11 or Table K.12.

For the application of Tables K.10 to K.12, the following applies:

1) values for test voltages for REINFORCED INSULATION are 1,6 times the values for BASIC INSULATION;
2) if the equipment is RATED to operate at an altitude greater than 2 000 m, the values for CLEARANCES are multiplied by the applicable factor of Table K.1;
3) minimum CLEARANCE is 0,2 mm for POLLUTION DEGREE 2 and 0,8 mm for POLLUTION DEGREE 3.

Conformity is checked by inspection and measurement and for b) by the a.c. test of 6.8.3.1 with a duration of at least 5 s, or by the 1 min d.c. test of 6.8.3.2, using the applicable test voltage from Tables K.10 to K.12. The value of the d.c. test voltage is $\sqrt{2}$ *times the a.c. r.m.s. test voltage.*

Table K.10 – CLEARANCES and test voltages for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY II above 300 V

Secondary WORKING VOLTAGE		MAINS VOLTAGE >300 ≤ 600 V r.m.s.		MAINS VOLTAGE >600 ≤ 1 000 V r.m.s.	
a.c. r.m.s.	**d.c. or a.c. peak**	**CLEARANCE**	**Test voltage**	**CLEARANCE**	**Test voltage**
V	V	mm	V r.m.s.	mm	V r.m.s.
16	22,6	1,5	1 390	2,9	1 590
33	46,7	1,5	1 390	3,0	2 210
50	70	1,5	1 390	3,0	2 210
100	140	1,6	1 450	3,1	2 260
150	210	1,6	1 450	3,2	2 300
300	420	1,8	1 540	3,4	2 400
600	840	2,4	1 620	3,9	2 630
1 000	1 400	3,5	2 450	5,0	3 110
1 250	1 750	4,2	2 770	5,8	3 430
1 600	2 240	5,2	3 190	6,9	3 850
2 000	2 800	6,5	3 700	8,2	4 330
2 500	3 500	8,1	4 300	9,8	4 920
3 200	4 480	10	4 950	12	5 780
4 000	5 600	12	5 780	15	7 000
5 000	7 000	16	7 400	18	8 200
6 300	8 820	20	8 980	22	9 700
8 000	11 200	26	11 200	28	11 900
10 000	14 000	33	13 800	35	14 500
12 500	17 500	42	16 900	44	17 600
16 000	22 400	55	21 200	57	21 900
20 000	28 000	71	26 300	73	27 000
25 000	35 000	91	32 600	93	33 200
32 000	44 800	120	41 600	122	42 200
40 000	56 000	154	52 200	157	53 100
50 000	70 000	199	66 100	202	67 000
63 000	88 200	261	85 300	262	85 600
Linear interpolation is allowed.					

Table K.11 – CLEARANCES and test voltages for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY III

Secondary WORKING VOLTAGE		MAINS voltage ≤150 V a.c. r.m.s.		MAINS voltage >150 ≤ 300 V a.c. r.m.s.		MAINS voltage >300 ≤ 600 V a.c. r.m.s.		MAINS voltage >600 ≤ 1 000 V a.c. r.m.s.	
a.c. r.m.s. V	**d.c. or a.c. peak** V	CLEARANCE mm	**Test voltage** V a.c. r.m.s.	CLEARANCE mm	**Test voltage** V a.c. r.m.s.	CLEARANCE mm	**Test voltage** V a.c. r.m.s.	CLEARANCE mm	**Test voltage** V a.c. r.m.s.
16	22,6	0,48	1 100	1,5	1 800	2,9	2 820	5,4	4 240
33	~~47,3~~ 46,7	0,50	1 100	1,5	1 800	3,0	2 900	5,4	4 240
50	70	0,53	1 120	1,5	1 800	3,0	2 900	5,5	4 300
100	140	0,61	1 170	1,6	1 880	3,1	2 960	5,6	4 360
150	210	0,69	1 200	1,6	1 880	3,2	3 020	5,7	4 420
300	420	0,94	1 360	1,8	2 040	3,4	3 140	6,0	4 600
600	840	1,6	1 880	2,4	2 440	3,9	3 440	6,6	4 860
1 000	1 400	2,5	2 500	3,5	3 200	5,0	4 000	7,4	5 240
1 250	1 750	3,2	3 020	4,2	3 620	5,8	4 480	8,1	5 560
1 600	2 240	4,1	3 560	5,2	4 120	6,9	5 040	9,3	6 120
2 000	2 800	5,3	4 180	6,5	4 800	8,2	5 620	11	7 000
2 500	3 500	6,9	5 040	8,1	5 560	9,8	6 320	12	7 500
3 200	4 480	9,2	6 080	10	6 400	12	7 500	15	9 100
4 000	5 600	12	7 500	12	7 500	15	9 100	17	10 100
5 000	7 000	15	9 100	16	9 600	18	10 600	20	11 600
6 300	8 820	19	11 200	20	11 600	22	12 600	25	14 100
8 000	11 200	25	14 100	26	14 600	28	15 500	31	16 900
10 000	14 000	32	17 400	33	17 800	35	18 700	38	20 000
12 500	17 500	41	21 500	42	21 900	44	22 800	47	24 200
16 000	22 400	54	27 200	55	27 600	57	28 400	60	29 700
20 000	28 000	69	33 500	71	34 300	73	35 200	76	36 400
25 000	35 000	89	41 600	91	42 400	93	43 200	96	44 400
32 000	44 800	118	53 000	120	53 700	122	54 500	125	55 600
40 000	56 000	153	66 100	154	66 500	157	67 600	160	68 700
50 000	70 000	198	82 400	199	82 700	202	83 800	205	84 900
63 000	88 200	260	104 000	261	104 400	262	104 700	265	105 700
Linear interpolation is allowed.									

Table K.12 – CLEARANCES and test voltages for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY IV

Secondary WORKING VOLTAGE		MAINS voltage ≤150 V a.c. r.m.s.		MAINS voltage >150 ≤ 300 V a.c. r.m.s.		MAINS voltage >300 ≤ 600 V a.c. r.m.s.		MAINS voltage >600 ≤ 1 000 V a.c. r.m.s.	
a.c. r.m.s. V	d.c. or a.c. peak V	CLEARANCE mm	Test voltage V a.c. r.m.s.	CLEARANCE mm	Test voltage V a.c. r.m.s.	CLEARANCE mm	Test voltage V a.c. r.m.s.	CLEARANCE mm	Test voltage V a.c. r.m.s.
16	22,6	1,5	1 800	2,9	2 820	5,4	4 240	8,3	5 680
33	46,7	1,5	1 800	3,0	2 900	5,4	4 240	8,3	5 680
50	70	1,5	1 800	3,0	2 900	5,5	4 300	8,4	5 740
100	140	1,6	1 880	3,1	2 960	5,6	4 360	8,5	5 800
150	210	1,6	1 880	3,2	3 020	5,7	4 420	8,6	5 860
300	420	1,8	2 040	3,4	3 140	6,0	4 600	8,9	5 960
600	840	2,4	2 440	3,9	3 440	6,6	4 860	9,6	6 240
1 000	1 400	3,5	3 200	5,0	4 000	7,4	5 240	10	6 400
1 250	1 750	4,2	3 620	5,8	4 480	8,1	5 560	11	7 000
1 600	2 240	5,2	4 120	6,9	5 040	9,3	6 120	12	7 500
2 000	2 800	6,5	4 800	8,2	5 620	11	7 000	13	8 100
2 500	3 500	8,1	5 560	9,8	6 320	12	7 500	15	9 100
3 200	4 480	10	6 400	12	7 500	15	9 100	17	10 100
4 000	5 600	12	7 500	15	9 100	17	10 100	19	11 200
5 000	7 000	16	9 600	18	10 600	20	11 600	23	13 100
6 300	8 820	20	11 600	22	12 600	25	14 100	27	15 100
8 000	11 200	26	14 600	28	15 500	31	16 900	33	17 800
10 000	14 000	33	17 800	35	18 700	38	20 000	40	21 000
12 500	17 500	42	21 900	44	22 800	47	24 200	50	25 500
16 000	22 400	55	27 600	57	28 400	60	29 700	63	31 000
20 000	28 000	71	34 300	73	35 200	76	36 400	79	37 600
25 000	35 000	91	42 400	93	43 200	96	44 400	99	45 400
32 000	44 800	120	53 700	122	54 500	125	55 600	129	57 100
40 000	56 000	154	66 500	157	67 600	160	68 700	164	70 100
50 000	70 000	199	82 700	202	83 800	205	84 900	209	86 300
63 000	88 200	261	104 400	262	104 700	265	105 700	268	106 800
Linear interpolation is allowed.									

K.2.3 CREEPAGE DISTANCES

CREEPAGE DISTANCES for BASIC INSULATION or SUPPLEMENTARY INSULATION for secondary circuits shall meet the applicable values of Table K.13, based on the WORKING VOLTAGE which stresses the insulation. Values for REINFORCED INSULATION are twice the values for BASIC INSULATION.

Conformity is checked by inspection and measurement.

Coatings that meet the requirements of Annex H when applied to the outer surfaces of printed wiring boards reduce the POLLUTION DEGREE of the coated area to POLLUTION DEGREE 1.

Conformity is checked by inspection and as specified in Annex H.

Table K.13 – CREEPAGE DISTANCES for secondary circuits

Secondary WORKING VOLTAGE a.c. r.m.s. or d.c.	Printed wiring board material		Other insulating material						
	POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
	All material groups	Material group I, II or IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III [b]
V	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	0,025	0,04	0,08	0,40	0,40	0,40	1,00	1,00	1,00
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05
16	0,025	0,04	0,10	0,45	0,45	0,45	1,10	1,10	1,10
20	0,025	0,04	0,11	0,48	0,48	0,48	1,20	1,20	1,20
25	0,025	0,04	0,125	0,50	0,50	0,50	1,25	1,25	1,25
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3
40	0,025	0,04	0,16	0,56	0,80	1,10	1,4	1,6	1,8
50	0,025	0,04	0,18	0,60	0,85	1,20	1,5	1,7	1,9
63	0,040	0,063	0,20	0,63	0,90	1,25	1,6	1,8	2,0
80	0,063	0,10	0,22	0,67	0,95	1,3	1,7	1,9	2,1
100	0,10	0,16	0,25	0,71	1,00	1,4	1,8	2,0	2,2
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4
160	0,25	0,40	0,32	0,80	1,1	1,6	2,0	2,2	2,5
200	0,40	0,63	0,42	1,00	1,4	2,0	2,5	2,8	3,2
250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0
320	0,75	1,6	0,75	1,60	2,2	3,2	4,0	4,5	5,0
400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0
630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0
800	2,4	4,0	2,4	4,0	5,6	8,0	10,0	11	12,5
1 000	3,2 [a]	5,0 [a]	3,2	5,0	7,1	10,0	12,5	14	16
1 250			4,2	6,3	9,0	12,5	16	18	20
1 600			5,6	8,0	11	16	20	22	25
2 000			7,5	10,0	14	20	25	28	32
2 500			10,0	12,5	18	25	32	36	40
3 200			12,5	16	22	32	40	45	50
4 000			16	20	28	40	50	56	63
5 000			20	25	36	50	63	71	80
6 300			25	32	45	63	80	90	100
8 000			32	40	56	80	100	110	125
10 000			40	50	71	100	125	140	160
12 500			50	63	90	125			
16 000			63	80	110	160			
20 000			80	100	140	200			
25 000			100	125	180	250			
32 000			125	160	220	320			
40 000			160	200	280	400			
50 000			200	250	360	500			
63 000			250	320	450	600			

[a] For voltages above 1 000 V, CREEPAGE DISTANCES on printed wiring board material are the same as for other insulators of the same material group.

[b] Material group IIIb is not recommended for application in pollution degree 3 above 630 V.

Linear interpolation is allowed.

K.2.4 Solid insulation

K.2.4.1 General

Solid insulation in secondary circuits shall withstand the electrical and mechanical stresses that may occur in NORMAL USE, in all RATED environmental conditions (see 1.4), during the intended life of the equipment.

NOTE The manufacturer should take the expected life of the equipment into account when selecting insulating materials.

Conformity is checked by both of the following tests:

a) by the voltage test of 6.8.3.1 for 5 s using the applicable test voltage of Table K.10, Table K.11 or Table K.12 for BASIC INSULATION *and* SUPPLEMENTARY INSULATION*. For* REINFORCED INSULATION*, the values are multiplied by 1,6;*

b) additionally, if the WORKING VOLTAGE *exceeds 300 V, by the voltage test of 6.8.3.1 for 1 min, with a test voltage of 1,5 times the* WORKING VOLTAGE *for* BASIC INSULATION *and* SUPPLEMENTARY INSULATION *and twice the* WORKING VOLTAGE *for* REINFORCED INSULATION*.*

Solid insulation shall also meet the following requirements, as applicable:

1) for solid insulation used as an ENCLOSURE or BARRIER, the requirements of Clause 8;
2) for moulded and potted parts, the requirements of K.2.4.2;
3) for inner insulating layers of printed wiring boards, the requirements of K.2.4.3;
4) for thin-film insulation, the requirements of K.2.4.4.

Conformity is checked as specified in K.2.4.2 to K.2.4.4 and Clause 8, as applicable.

K.2.4.2 Moulded and potted parts

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers shall be separated by the applicable minimum distance of Table K.14 (see Figure K.1, item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

Table K.14 – Minimum values for distance or thickness (see K.2.4.2 to K.2.4.4)

Peak value of the a.c. or d.c WORKING VOLTAGE or recurring peak voltage kV	Minimum value mm	Peak value of the a.c. or d.c WORKING VOLTAGE or recurring peak voltage kV	Minimum value mm
>0,046 7 ≤ 0,33	0,05	>8,0 ≤ 10	3,5
>0,33 ≤ 0,8	0,1	>10 ≤ 12	4,5
>0,8 ≤ 1,0	0,15	>12 ≤ 15	5,5
>1,0 ≤ 1,2	0,2	>15 ≤ 20	8
>1,2 ≤ 1,5	0,3	>20 ≤ 25	10
>1,5 ≤ 2,0	0,45	>25 ≤ 30	12,5
>2,0 ≤ 2,5	0,6	>30 ≤ 40	17
>2,5 ≤ 3,0	0,8	>40 ≤ 50	22
>3,0 ≤ 4,0	1,2	>50 ≤ 60	27
>4,0 ≤ 5,0	1,5	>60 ≤ 80	35
>5,0 ≤ 6,0	2	>80 ≤ 100	45
>6,0 ≤ 8,0	3		

K.2.4.3 Inner insulating layers of printed wiring boards

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION conductors located between the same two layers shall be separated by the applicable minimum distance of Table K.14 (see Figure K.2, item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

REINFORCED INSULATION of inner insulating layers of printed wiring boards shall also have adequate electric strength through the respective layers. One of the following methods shall be used:

a) the thickness of the insulation is at least the applicable minimum distance of Table K.14.

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation is assembled from at least two separate layers of printed wiring board materials, each of which is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of the applicable Table K.10 to K.12 for BASIC INSULATION.

   Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation is assembled from at least two separate layers of printed wiring board materials, and the combination of layers is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of the applicable Table K.10, Table K.11 or Table K.12 multiplied by 1,6 for REINFORCED INSULATION.

   Conformity is checked by inspection of the manufacturer's specifications.

K.2.4.4 Thin-film insulation

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION conductors located between the same two layers (see Figure K.3, item L) shall be separated by at least the applicable CLEARANCE and CREEPAGE DISTANCE of K.2.2 and K.2.3.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

REINFORCED INSULATION through the layers of thin-film insulation shall also have adequate electric strength. One of the following methods shall be used:

a) the thickness through the insulation is at least the applicable value of Table K.14;

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation consists of at least two separate layers of thin-film materials, each of which is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of the applicable Table K.10, Table K.11 or Table K.12 for BASIC INSULATION;

   Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation consists of at least three separate layers of thin-film materials, any two of which have been tested to exhibit adequate electric strength.

   Conformity is checked by the a.c. test of 6.8.3.1 with a duration of at least 1 min, or for MAINS CIRCUITS stressed only by d.c., the 1 min d.c. test of 6.8.3.2, using the applicable voltages from Table K.10, Table K.11 or Table K.12 multiplied by 1,6, applied to two of the three layers.

   NOTE For the purposes of the test for option c), a special sample may be assembled with only two layers of the material.

K.3 Insulation in circuits not addressed in 6.7, Clause K.1 or Clause K.2

K.3.1 General

These circuits have one or more of the following characteristics:

a) the maximum possible TRANSIENT OVERVOLTAGE is limited by the supply source or within the equipment (see K.4.) to a known level below the level assumed for the MAINS CIRCUIT;

b) the maximum possible TRANSIENT OVERVOLTAGE is above the level assumed for the MAINS CIRCUIT;

c) the WORKING VOLTAGE is the sum of voltages from more than one circuit, or is a mixed voltage;

d) the WORKING VOLTAGE includes a recurring peak voltage that may include a periodic non-sinusoidal waveform or a non-periodic waveform that occurs with some regularity;

e) the WORKING VOLTAGE has a frequency above 30 kHz.

In cases a) to c), CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION are determined according to K.3.2.

In cases d) and e) CLEARANCES are determined according to K.3.3.

In all cases K.3.4 addresses CREEPAGE DISTANCE and K.3.5 solid insulation

NOTE Requirements for measuring circuits are given in IEC 61010-2-030.

K.3.2 CLEARANCE calculation

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION are determined from the following formula:

$$\text{CLEARANCE} = D_1 + F \times (D_2 - D_1)$$

where

F is a factor, determined from one of the equations:

$F = (1{,}25 \times U_w/U_m) - 0{,}25$ if $U_w/U_m > 0{,}2$

$F = 0$ if $U_w/U_m \leq 0{,}2$

where

$U_m = U_w + U_t$;

U_w = the maximum peak value of the WORKING VOLTAGE;

U_t = the maximum additional TRANSIENT OVERVOLTAGE

D_1 and D_2 are values taken from Table K.15 for U_m

where

D_1 represents the CLEARANCE that would be applicable to a TRANSIENT OVERVOLTAGE with the shape of a 1,2 × 50 µs impulse.

D_2 represents the CLEARANCE that would be applicable to the peak WORKING VOLTAGE without any TRANSIENT OVERVOLTAGE;

CLEARANCES for REINFORCED INSULATION are twice the values for BASIC INSULATION.

If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCES shall be multiplied by the applicable factor of Table K.1.

Minimum CLEARANCE, for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, is 0,2 mm for POLLUTION DEGREE 2 and 0,8 mm for POLLUTION DEGREE 3.

NOTE 1 The insulation between the primary and secondary winding of a transformer connected to MAINS is stressed by the common mode voltage component transferred during a transient event from the primary side and the WORKING VOLTAGE across the insulation. This common mode voltage expressed as additional TRANSIENT OVERVOLTAGE together with the maximum peak value of WORKING VOLTAGE U_w form the maximum impulse voltage U_m.

For example for a MAINS CIRCUIT with a line-to-neutral voltage of 230 V r.m.s. and an impulse withstand voltage of 2 500 V_{PEAK} the common mode voltage (additional TRANSIENT OVERVOLTAGE) is calculated as follows:

U_w = 1,414 × 230 V r.m.s = 325 V_{PEAK}

U_t = 2 500 V_{PEAK} – 325 V_{PEAK} = 2 175 V_{PEAK}

Conformity is checked by inspection and measurement or by the a.c. test of 6.8.3.1 with a duration of at least 5 s or the impulse voltage test of 6.8.3.3, using the applicable voltage from Table K.16 for the required CLEARANCE.

Table K.15 – CLEARANCE values for the calculation of K.3.2

Maximum voltage	CLEARANCE		Maximum voltage	CLEARANCE	
U_m	D_1	D_2	U_m	D_1	D_2
V	mm	mm	V	mm	mm
14,1 to 266	0,010	0,010	4 000	2,93	6,05
283	0,010	0,013	4 530	3,53	7,29
330	0,010	0,020	5 660	4,92	10,1
354	0,013	0,025	6 000	5,37	10,8
453	0,027	0,052	7 070	6,86	13,1
500	0,036	0,071	8 000	8,25	15,2
566	0,052	0,10	8 910	9,69	17,2
707	0,081	0,20	11 300	12,9	22,8
800	0,099	0,29	14 100	16,7	29,5
891	0,12	0,41	17 700	21,8	38,5
1 130	0,19	0,83	22 600	29,0	51,2
1 410	0,38	1,27	28 300	37,8	66,7
1 500	0,45	1,40	35 400	49,1	86,7
1 770	0,75	1,79	45 300	65,5	116
2 260	1,25	2,58	56 600	85,0	150
2 500	1,45	3,00	70 700	110	195
2 830	1,74	3,61	89 100	145	255
3 540	2,44	5,04	100 000	165	290
Linear interpolation is allowed.					

Table K.16 – Test voltages based on CLEARANCES

Required CLEARANCE mm	Test voltage Impulse 1,2/50 μs V peak	a.c. r.m.s. 50/60 Hz V r.m.s.
0,010	330	230
0,025	440	310
0,040	520	370
0,063	600	420
0,1	810	500
0,2	1 150	620
0,3	1 310	710
0,5	1 550	840
1,0	1 950	1 060
1,5	2 560	1 390
2,0	3 090	1 680
2,5	3 600	1 960
3,0	4 070	2 210
4,0	4 930	2 680
4,5	5 330	2 900
5,0	5 720	3 110
6,0	6 460	3 510
8,0	7 840	4 260
10,0	9 100	4 950
12,0	10 600	5 780
15,0	12 900	7 000
20	16 400	8 980
25	19 900	10 800
30	23 300	12 700
40	29 800	16 200
50	36 000	19 600
60	42 000	22 800
80	53 700	29 200
100	65 000	35 400
Liner interpolation is allowed.		

NOTE 2 Two examples of calculations follow:

EXAMPLE 1:

CLEARANCE for REINFORCED INSULATION for a WORKING VOLTAGE with peak value of 3 500 V and an additional transient voltage of 4 500 V (this can be expected within an electronic switching-circuit):

Maximum voltage U_m $U_m = U_w + U_t$ = (3 500 + 4 500) V = 8 000 V

U_w / U_m.= 3 500 / 8 000 = 0,44 > 0,2

thus $F = (1{,}25 \times U_w / U_m) - 0{,}25$ = (1,25 x 3 500 / 8 000) – 0,25 = 0,297

Values derived from Table K.15 at 8 000 V:

D_1 = 8,25 mm, D_2 = 15,2 mm

CLEARANCE = $D_1 + F \times (D_2 - D_1)$ = 8,25 + 0,297 × (15,2 – 8,25) = 8,25 + 2,06 = 10,3 mm

For REINFORCED INSULATION the value is doubled. CLEARANCE = 20,6 mm.

EXAMPLE 2:

CLEARANCE for BASIC INSULATION for a circuit driven from a MAINS transformer connected to an outlet of the distribution system with a MAINS voltage of 230 V and OVERVOLTAGE CATEGORY II. The circuit includes transient overvoltage limiting devices (see 14.8 and K.3.4) which limit the maximum voltage (including transients) in the circuit to 1 000 V.

The peak value (U_w) of the voltage in the circuit is 150 V.

The maximum value of the voltage U_m is therefore 1 000 V.

U_m = 1 000 V

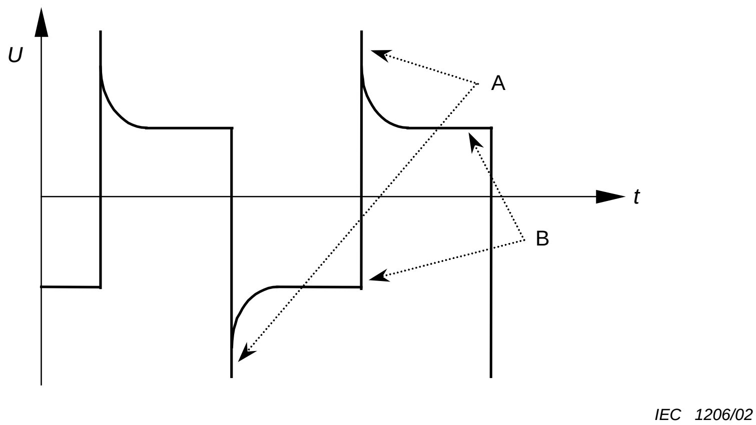
U_w / U_m = 150 / 1 000 = 0,15 < 0,2, thus F = 0

CLEARANCE D_1 = 0,15 mm interpolated from Table K.15

The CLEARANCE is then corrected for altitude and checked against POLLUTION DEGREE minimum CLEARANCES.

K.3.3 CLEARANCES in circuits having recurring peak voltages, or having WORKING VOLTAGES with frequencies above 30 kHz

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION for circuits having recurring peak voltages but not subjected to frequencies above 30 kHz shall meet the values of the second column of Table K.17, using the recurring peak voltage as the index. (See Figure K.4 for an example of a recurring peak voltage.)



Key

A Peak value of recurring voltage

B Working voltage value

Figure K.4 – Example of recurring peak voltage

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION for circuits that are subjected to frequencies above 30 kHz shall meet the values of the third column of Table K.17, using the peak value of the WORKING VOLTAGE as the index.

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION for circuits that may be subjected to both recurring peak voltages and to frequencies above 30 kHz shall meet the higher of these requirements.

CLEARANCES for REINFORCED INSULATION are twice the values for BASIC INSULATION.

If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCES are multiplied by the applicable factor of Table K.1.

The minimum CLEARANCE, for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, is 0,2 mm for POLLUTION DEGREE 2 and 0,8 mm for POLLUTION DEGREE 3.

Conformity is checked by inspection and measurement.

Table K.17 – CLEARANCES for BASIC INSULATION in circuits having recurring peak voltages or WORKING VOLTAGES with frequencies above 30 kHz

Voltage peak value	CLEARANCES	
	Frequencies up to 30 kHz	Frequencies above 30 kHz
V	mm	mm
0 to 330	0,01	0,02
400	0,02	0,04
500	0,04	0,07
600	0,06	0,11
800	0,13	0,26
1 000	0,26	0,48
1 200	0,42	0,76
1 500	0,76	1,1
2 000	1,27	1,8
2 500	1,8	2,6
3 000	2,4	3,5
4 000	3,8	5,7
5 000	5,7	8
6 000	7,9	10
8 000	11	15
10 000	15,2	20
12 000	19	25
15 000	25	32
20 000	34	44
25 000	44	58
30 000	55	72
40 000	77	100
50 000	100	
Linear interpolation is allowed.		

K.3.4 CREEPAGE DISTANCES

The requirements of K.2.3 apply.

Conformity is checked as specified in K.2.3.

K.3.5 Solid insulation

The requirements of K.2.4 apply except that in K.2.4.1 a), K.2.4.3 b) and c), and K.2.4.4 b) and c) the values of Table K.16 are used in place of the applicable values of Table K.10, Table K.11, or Table K.12.

To determine the required test voltage from Table K.16, the following procedure shall be applied:

a) Calculation of the theoretically required CLEARANCE according to K.3.2 considering the requirements of K.3.3. Minimum CLEARANCES for POLLUTION DEGREES 2 and 3 do not apply.
b) Application of the resulting theoretically required CLEARANCE value of Table K.16 to determine the required test voltage.

Conformity is checked as specified in K.2.4, using the test voltage determined above in place of the test voltage from Table K.10, Table K.11, or Table K.12.

K.4 Reduction of TRANSIENT OVERVOLTAGES by the use of overvoltage limiting devices

TRANSIENT OVERVOLTAGES in a circuit may be limited by combinations of circuits or components. Components suitable for this purpose include varistors and gas-filled surge arrestors.

If the overvoltage limiting device or circuit is intended to reduce TRANSIENT OVERVOLTAGES so that the circuit following it may have reduced CLEARANCES, a RISK assessment (see Clause 17) shall be performed, taking into account both of the following aspects:

a) the circuit shall reduce TRANSIENT OVERVOLTAGES to the lower level even under SINGLE FAULT CONDITIONS;

b) the circuit shall operate as intended even after withstanding repeated TRANSIENT OVERVOLTAGES.

Conformity is checked by evaluation of the RISK assessment documentation to ensure that the RISKS have been eliminated or that only TOLERABLE RISKS remain.

Annex L
(informative)

Index of defined terms

Bibliography

IEC 60050 (all parts), *International Electrotechnical Vocabulary*

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

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

IEC 60050-604, *International Electrotechnical Vocabulary – Chapter 604: Generation, transmission and distribution of electricity – Operation*

IEC 60050-826, *International Electrotechnical Vocabulary – Part 826: Electrical installations*

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60112:1979, *Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions*

IEC 60127 (all parts), *Miniature fuses*

IEC 60204 (all parts), *Safety of machinery – Electrical equipment of machines*

IEC 60332-1 (all parts), *Tests on electric and optical fibre cables under fire conditions*

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IEC 60439-1:1999, *Low-voltage switchgear and controlgear assemblies – Part 1: Type-tested and partially type-tested assemblies*

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IEC 60447:1993, *Man-machine-interface (MMI) – Actuating principles*

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

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IEC 61010-2-030, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 2-030: Special requirements for testing and measuring circuits*

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

IEC 61243-3, *Live working – Voltage detectors – Part 3: Two-pole low-voltage type*

IEC 61326 (all parts), *Electrical equipment for measurement, control and laboratory use – EMC requirements*

IEC 61508 (all parts), *Functional safety of electrical electronic/programmable electronic safety-related systems*

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

IEC 62366, *Medical devices – Application of usability engineering to medical devices*

ISO 9241, (all parts), *Ergonomics of human-system interaction*

ISO 13732-1, *Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 1: Hot surfaces*

~~ISO 13852, *Safety of machinery – Safety distances to prevent danger zones being reached by the upper limbs*~~

ISO 13854, ~~*Savety*~~ *Safety of machinery – Minimum gaps to avoid crushing of parts of the human body*

ISO 14121-1, *Safety of machinery – Risk assessment – Part 1: Principles*

ISO 14738, *Safety of machinery – Anthropometric requirements for the design of workstations at machinery*

ISO 14971, *Medical devices – Application of risk management to medical devices*

ISO/IEC Guide 117, *Electrotechnical equipment – Temperatures of touchable hot surfaces*

ANSI B11.TR3, *Risk Assessment and Risk Reduction – A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools*

ANSI/UL 94, *Standard for safety of flammability of plastic materials for parts in devices and appliances testing*

ANSI/UL 248-14, *Low-Voltage Fuses – Part 14: Supplemental Fuses*

ANSI/UL 471, *Standard for Commercial Refrigerators and Freezers*

ANSI/UL 746E, *Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used In Printed-Wiring Boards*

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~~EN 563, *Safety of machinery – Temperatures of touchable surfaces – Ergonomics data to establish temperature limit values for hot surfaces*~~

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SEMI S8, *Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment*

SEMI S10, *Safety guideline for risk assessment*

UL 1439, *Standard for Tests for Sharpness of Edges on Equipment*

Pressure Equipment Directive (2014/68/EU)

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5.1.5 BORNES, connexions et dispositifs de manœuvre

5.1.5.1 Généralités

Si cela est nécessaire pour la sécurité, les BORNES, fiches, dispositifs de commande et indicateurs, y compris toutes les connexions pour des fluides tels que le gaz, l'eau et l'évacuation doivent être identifiés. Lorsqu'il n'y a pas suffisamment d'espace pour de tels marquages, il est possible d'utiliser le symbole 14 du Tableau 1.

NOTE 1 Pour toute information supplémentaire, consulter l'IEC 60445 et l'IEC 60447.

NOTE 2 Les broches individuelles des fiches multipoints n'ont pas besoin d'être marquées.

Les boutons-poussoirs, les boutons d'arrêt d'urgence et les voyants utilisés uniquement pour indiquer un avertissement de DANGER ou pour une intervention urgente, doivent être de couleur rouge et codés selon les exigences de l'IEC 60073. Là où la couleur concerne la sécurité des personnes ou de l'environnement, alors des moyens supplémentaires de codage doivent être fournis (voir l'IEC 60073).

NOTE 3 Les autorités nationales peuvent exiger que l'appareil utilisé dans certains environnements réponde aux exigences d'interface homme-machine concernant cet environnement.

La conformité est vérifiée par examen.

5.1.5.2 BORNES

Les BORNES pour le branchement au RESEAU d'alimentation doivent être identifiées.

Les BORNES suivantes doivent être marquées selon ce qui suit:

a) les BORNES DE TERRE FONCTIONNELLES doivent porter le symbole 5 du Tableau 1;
b) les BORNES DE TERRE DE PROTECTION doivent porter le symbole 6 du Tableau 1, sauf si la BORNE DE TERRE DE PROTECTION fait partie d'un socle de connecteur RESEAU agréé. Le symbole doit être placé à côté de la BORNE ou sur celle-ci;
c) les BORNES des circuits ~~de commande~~ dont la connexion à des parties conductrices ACCESSIBLES est admise par le 6.6.3 doivent porter le symbole 7 du Tableau 1, sauf si le branchement est évident;

   NOTE En indiquant qu'il ne faut pas qu'une TENSION DANGEREUSE soit raccordée à la BORNE, ce symbole peut également être considéré comme un symbole d'avertissement. Il convient également d'utiliser le symbole lorsqu'il est probable qu'un OPERATEUR peut effectuer un tel branchement par inadvertance.

d) les BORNES alimentées de l'intérieur de l'appareil et qui sont sous TENSION DANGEREUSE doivent porter la valeur (ou la plage) de tension, de courant, de charge ou d'énergie, ou le symbole 14 du Tableau 1. Cette exigence ne s'applique pas aux sorties d'alimentation RESEAU lorsqu'un socle normalisé est utilisé.

La conformité est vérifiée par examen.

5.1.6 Interrupteurs et disjoncteurs

Si l'interrupteur de l'alimentation de puissance ou le disjoncteur est utilisé comme dispositif de sectionnement, la position «Arrêt» doit être clairement repérée.

NOTE Le marquage de la position «Marche» est aussi conseillé.

Les symboles 9 et 10 du Tableau 1 peuvent, dans certains cas, convenir pour identifier le dispositif (voir 6.11.3.1 c)). Un voyant lumineux seul n'est pas considéré comme un marquage satisfaisant.

Si un interrupteur à bouton-poussoir est utilisé pour la déconnexion de l'appareil, les symboles 9 et 15 du Tableau 1 peuvent être utilisés pour indiquer la position «Marche» et les symboles 10 et 16 pour indiquer la position «Arrêt», avec les symboles associés (9 et 15 ou 10 et 16) proches l'un de l'autre.

La conformité est vérifiée par examen.

5.1.7 Appareils protégés par DOUBLE ISOLATION ou par ISOLATION RENFORCEE

Les appareils qui ne sont que partiellement protégés par DOUBLE ISOLATION ou par ISOLATION RENFORCEE ne doivent pas être repérés par le symbole 11 du Tableau 1.

NOTE Les appareils protégés par une DOUBLE ISOLATION ou une ISOLATION RENFORCEE peuvent être marqués avec le symbole 11 du Tableau 1.

La conformité est vérifiée par examen.

5.1.8 Boîtes à BORNES à câbler sur place

Si la température des BORNES ou de l'ENVELOPPE d'une boîte ou d'un compartiment à BORNES à câbler sur place, dépasse 60 °C en CONDITION NORMALE, avec une température ambiante de 40 °C ou une température ambiante maximale ASSIGNEE si elle est plus élevée, un marquage doit spécifier à l'installateur de consulter les instructions d'installation avant de déterminer les CARACTERISTIQUES ASSIGNEES de température des câbles à relier aux BORNES. Le marquage doit être visible avant et durant la connexion, ou doit être à côté des BORNES. Le symbole 14 est un marquage acceptable.

La conformité, en cas de doute, est vérifiée par les mesures spécifiées en 10.3 a) et, si c'est applicable, par l'examen des marquages.

5.2 Marquage des avertissements

Le marquage des avertissements spécifiés ~~en 5.1.5.2 c), 6.1.2 b), 6.6.2, 7.3.2 b) 3), 7.4, 10.1 et 13.2.2~~ dans la présente norme doivent être conformes aux exigences suivantes.

Le marquage des avertissements doit être visible lorsque l'appareil est prêt pour UTILISATION NORMALE. Si un avertissement s'applique à une partie particulière de l'appareil, il doit être marqué sur celle-ci ou près d'elle.

Les avertissements doivent avoir les dimensions suivantes:

a) les symboles doivent avoir au moins une hauteur de 2,75 mm. Le texte doit avoir au moins une hauteur de 1,5 mm et une couleur contrastée par rapport à la couleur du fond;

b) les symboles ou les textes, moulés ou gravés dans un matériau doivent avoir au moins une hauteur de 2,0 mm. S'ils ne sont pas contrastés en couleur ils doivent avoir une gravure sur une profondeur ou une élévation de 0,5 mm.

S'il est nécessaire que l'AUTORITE RESPONSABLE ou l'OPERATEUR se reportent à la documentation pour conserver les protections offertes par l'appareil, celui-ci doit porter le symbole 14 du Tableau 1. L'utilisation du symbole 14 n'est pas obligatoire si d'autres symboles couvrant des aspects de sécurité sont utilisés et expliqués dans la documentation.

Si les instructions d'utilisation précisent qu'un OPERATEUR est autorisé à avoir accès en utilisant un OUTIL, à une partie ou à un emplacement qui peut ~~être sous TENSION DANGEREUSE~~ présenter un DANGER en UTILISATION NORMALE, un avertissement doit être marqué pour indiquer que l'appareil doit être ~~isolé ou déconnecté de la TENSION DANGEREUSE avant l'accès~~ placé dans un état sûr avant tout accès. Le symbole 14 doit être utilisé à cette fin et le texte d'avertissement doit être inclus dans la documentation. D'autres symboles peuvent être utilisés pour indiquer la nature du DANGER comme le symbole 12, 13 ou 17, selon le cas.

Les avertissements sous forme de symboles sont préférables aux avertissements sous forme de textes. Un texte complémentaire peut être inséré à côté du symbole.

La conformité est vérifiée par examen.

5.3 Durabilité du marquage

Les marquages exigés doivent rester nets et lisibles dans les conditions d'UTILISATION NORMALE et doivent résister aux effets des agents de nettoyage spécifiés par le fabricant.

La conformité est vérifiée par examen et en effectuant l'essai suivant, relatif à la durabilité des marquages sur la partie externe de l'appareil. Les marquages sont frottés à la main, sans pression excessive, pendant 30 s avec un tissu imbibé avec chacun des agents de nettoyage spécifiés (ou, si aucun agent n'est spécifié, avec de l'alcool isopropylique à 70 %).

Après le traitement ci-dessus, les marquages doivent rester clairement lisibles et les étiquettes adhésives ne doivent pas se décoller ni présenter de bords enroulés.

5.4 Documentation

5.4.1 Généralités

Pour les besoins des OPERATEURS ou de l'AUTORITE RESPONSABLE, les appareils doivent être accompagnés de la documentation suivante nécessaire à la sécurité. La documentation de sécurité pour l'entretien et la maintenance autorisés par le fabricant sera mise à la disposition de ces personnes:

a) l'utilisation prévue de l'appareil;

b) la spécification technique;

c) le nom et l'adresse du fabricant ou du fournisseur auprès duquel il est possible d'obtenir l'assistance technique nécessaire;

d) les informations spécifiées de 5.4.2 à 5.4.6;

e) les informations sur la façon d'atténuer les RISQUES restants après une appréciation du RISQUE (voir l'Article 17);

f) pour les appareils, qui pour des raisons de sécurité exigent des accessoires spécifiques (par exemple des sondes) avec des caractéristiques spécifiques, la documentation doit indiquer que seulement les accessoires conformes aux caractéristiques du fabricant doivent être utilisés;

g) si un DANGER peut être du à une lecture incorrecte lors de mesures, indications ou détections de substances dangereuses ou de grandeurs électriques sous TENSION DANGEREUSE, les instructions doivent indiquer la façon de vérifier le fonctionnement correct de l'appareil;

h) les instructions de levage et de transport (voir 7.5.1).

Les symboles et indications d'avertissement marqués sur l'appareil doivent être expliqués dans la documentation. En particulier, elle doit inclure un avis expliquant qu'elle doit être consultée chaque fois que le symbole 14 du Tableau 1 est marqué sur l'appareil, afin de connaître la nature des DANGERS potentiels et toutes actions à prendre pour les éviter.

NOTE 1 Les marquages et le texte sur l'appareil sont considérés équivalents à la documentation.

NOTE 2 Si l'UTILISATION NORMALE de l'appareil implique la manipulation de substances dangereuses, il convient de donner des instructions sur l'utilisation correcte et sur les mesures de sécurité. Si une quelconque substance dangereuse est spécifiée ou fournie par le fabricant de l'appareil, il convient également de fournir les informations nécessaires sur ses constituants et sur la manière correcte d'en disposer.

La documentation peut être fournie sur un support papier ou électronique, cependant une version papier est exigée pour toute information concernant la sécurité qui ne serait pas disponible sous format électronique au moment nécessaire. La documentation doit être livrée avec l'appareil. Une attention devra être portée sur la capacité de l'AUTORITE RESPONSABLE à lire ces supports.

La conformité est vérifiée par examen.

5.4.2 CARACTERISTIQUES ASSIGNEES des appareils

La documentation doit comporter les informations suivantes:

a) les CARACTERISTIQUES ASSIGNEES de tension d'alimentation ou plage de tensions, fréquence ou plage de fréquences et de puissance ou courant;

b) une description de tous les raccordements d'entrée et de sortie selon les exigences du 6.6.1 a);

c) les CARACTERISTIQUES ASSIGNEES de l'isolation des circuits extérieurs selon les exigences du 6.6.1 b);

d) l'indication de la plage des conditions d'environnement pour lesquelles l'appareil est conçu ~~(voir 1.4)~~ y compris:

   1) utilisation à l'intérieur ou à l'extérieur.
   2) altitude
   3) température,
   4) humidité relative,
   5) fluctuations de la tension du RESEAU d'alimentation,
   6) CATEGORIE DE SURTENSION, sauf pour les appareils connectés par cordon ou par prise,
   7) EMPLACEMENT HUMIDE, le cas échéant,
   8) DEGRE DE POLLUTION de l'environnement prévu,

e) ~~une indication sur le degré de protection procuré par les ENVELOPPES (Code IP), si cette caractéristique de l'appareil est ASSIGNEE~~ pour les appareils dont le degré de protection contre la pénétration selon l'IEC 60529 est une CARACTERISTIQUE ASSIGNEE, les informations exigées en 11.6.1;

f) pour les appareils ayant une valeur d'énergie d'impact mécanique inférieure à 5 J, les informations de 8.1 d).

La conformité est vérifiée par examen.

5.4.3 Installation des appareils

La documentation doit inclure les instructions d'installation et de mise en service spécifique et si c'est nécessaire pour la sécurité, des avertissements contre les DANGERS ~~survenant~~ qui pourraient survenir durant l'installation ou la mise en service ou en raison d'une installation ou d'une mise en service inappropriée de l'appareil. De telles informations comprennent, ~~selon le cas~~ si cela est applicable:

a) les exigences relatives à l'assemblage, à la mise en place et au montage;

b) les instructions pour mise à la terre de protection;

c) les branchements à l'alimentation;

d) pour les APPAREILS BRANCHES EN PERMANENCE,

   1) les exigences relatives au câblage d'alimentation;
   2) les exigences pour tout interrupteur ou tout disjoncteur extérieur (voir 6.11.3.1) et pour tout dispositif extérieur de protection contre les surintensités (voir 9.6.2) et une recommandation pour que l'interrupteur ou le disjoncteur soit placé à côté de l'appareil;

e) les exigences de ventilation;

f) les exigences et caractéristiques de sécurité pour les services ~~particuliers~~ externes spéciaux, par exemple: température maximale et minimale, pression ou flux d'air ou de liquide de refroidissement;

g) les instructions relatives au niveau acoustique (voir 12.5.1).

NOTE Il est recommandé d'ajouter un avis dans la documentation que, lors de l'installation, la sécurité de tout système intégrant l'appareil est de la responsabilité de l'assembleur du système.

La conformité est vérifiée par examen.

5.4.4 Fonctionnement de l'appareil

Les instructions d'emploi doivent comporter, lorsque cela s'applique:

a) l'identification et la description des dispositifs de commande et leur utilisation dans tous les modes opératoires;

b) les instructions de ne pas positionner l'appareil de manière à rendre difficile la manœuvre du dispositif de sectionnement;

c) les instructions pour l'interconnexion aux accessoires et à d'autres appareils, y compris l'indication des accessoires appropriés, pièces amovibles et tous matériaux spéciaux;

d) les spécifications des limites de fonctionnement intermittent;

e) des explications des symboles relatifs à la sécurité, utilisés sur l'appareil;

f) les instructions pour le remplacement des matières consommables;

g) les instructions relatives au nettoyage et à la décontamination;

h) un avis listant les substances potentiellement toxiques et nuisibles qui peuvent être libérées de l'appareil ainsi que les quantités probables;

i) les instructions détaillées sur les procédures de réduction des RISQUES concernant les liquides inflammables (voir 9.5 c));

j) les détails sur les méthodes de réduction des RISQUES de brûlures causées par des surfaces qui peuvent dépasser les limites de température suivant 10.1.

Lorsqu'un appareil conforme aux normes IEC 60950 est utilisé avec un appareil conforme à cette norme et qu'il existe un DANGER dû à l'humidité ou à des liquides, les instructions d'emploi doivent préciser toutes précautions supplémentaires nécessaires.

L'OPERATEUR doit être averti dans les instructions que, si l'appareil est utilisé d'une façon qui n'est pas spécifiée par le fabricant, la protection assurée par l'appareil peut être compromise.

La conformité est vérifiée par examen.

5.4.5 Entretien de l'appareil et service

Les instructions doivent être fournies à l'attention de l'AUTORITE RESPONSABLE de façon suffisamment détaillée~~s~~ pour permettre ~~un entretien préventif et des contrôles des appareils~~ l'entretien, le contrôle et l'essai de l'appareil en toute sécurité, et pour assurer ~~une~~ la sécurité permanente de l'appareil après ~~l'entretien préventif et les contrôles~~ les procédures d'entretien, de contrôle et d'essai.

Si applicable, la documentation du fabricant doit prévenir contre le remplacement des cordons d'alimentation RESEAU amovibles par des cordons aux CARACTERISTIQUES ASSIGNEES inappropriées.

Pour les appareils utilisant des piles ou des accumulateurs, le type spécifique de ces éléments doit être précisé.

Le fabricant doit spécifier toutes les parties qui ne doivent être examinées ou fournies que par le fabricant ou son représentant.

Le calibre et les CARACTERISTIQUES ASSIGNEES des fusibles utilisés doivent être également précisés.

Les instructions sur les sujets suivants doivent être fournies au personnel de maintenance selon les besoins pour permettre une maintenance sûre et une sécurité permanente de l'appareil après les opérations de maintenance si l'appareil est apte à être maintenu:

a) RISQUES spécifiques de produit qui peuvent affecter le personnel de maintenance;
b) mesures de protection pour ces RISQUES;
c) vérification que l'appareil est dans un état sûr après la réparation.

NOTE Les instructions pour le personnel de maintenance n'ont pas besoin d'être fournies à l'AUTORITE RESPONSABLE, mais il convient qu'elles soient mises à la disposition du personnel de maintenance.

La conformité est vérifiée par examen.

5.4.6 Intégration dans des systèmes ou effets résultant de conditions spéciales

Les aspects résultant de l'intégration dans des systèmes ou les effets résultant de conditions spéciales ambiantes ou liées à l'application doivent être décrites dans la documentation.

La conformité est vérifiée par inspection de la documentation.

6 Protection contre les chocs électriques

6.1 Généralités

6.1.1 Exigences

La protection contre les chocs électriques doit être maintenue en CONDITION NORMALE (voir 6.4) et en CONDITION DE PREMIER DEFAUT (voir 6.5). Les parties ACCESSIBLES (voir 6.2) ne doivent pas être sous TENSION DANGEREUSE (voir 6.3). La tension, le courant, la charge ou l'énergie entre une partie ACCESSIBLE et les parties connectées au conducteur de protection ou entre deux autres parties ACCESSIBLES situées sur le même appareil à une distance maximale de 1,8 m (sur une surface ou dans l'air), ne doivent pas dépasser les niveaux indiqués en 6.3.1 en CONDITION NORMALE, ni ceux indiqués en 6.3.2 en CONDITION DE PREMIER DEFAUT.

La conformité est vérifiée par la détermination des parties ACCESSIBLES tel que spécifié en 6.2 et par les mesures des grandeurs de 6.3 pour vérifier que les niveaux de 6.3.1 et 6.3.2 ne sont pas dépassés, suivis par les essais de 6.4 à 6.11.

6.1.2 Exceptions

S'il n'est pas possible, pour des raisons fonctionnelles, d'éviter que les parties ci-dessous soient à la fois ACCESSIBLES et sous TENSION DANGEREUSE, elles peuvent néanmoins être ACCESSIBLES à un OPERATEUR durant l'UTILISATION NORMALE tout en étant sous TENSION DANGEREUSE:

a) parties de lampes et douilles de lampes, après démontage de la lampe;
b) parties destinées à être remplacées par un OPERATEUR (par exemple, piles) et qui peuvent être sous TENSION DANGEREUSE pendant leur remplacement ou autre action de l'OPERATEUR, mais seulement si elles ne sont ACCESSIBLES qu'au moyen d'un OUTIL et portent un marquage d'avertissement (voir 5.2).

Si une des parties de a) et b) reçoit une charge en provenance d'un condensateur interne, elle ne doit pas être sous TENSION DANGEREUSE 10 s après l'interruption de l'alimentation.

Lorsqu'une charge est reçue d'un condensateur interne, la conformité est vérifiée par les mesures des grandeurs de 6.3 afin de s'assurer que les niveaux de 6.3.1 c) ne sont pas dépassés.

6.2 Détermination des parties ACCESSIBLES

6.2.1 Généralités

A moins que cela ne soit évident, la détermination d'une partie ACCESSIBLE doit être effectuée conformément aux exigences des 6.2.2 à 6.2.4 dans toutes les positions en UTILISATION NORMALE. Les doigts d'épreuve (Annexe B) et les broches d'essai doivent être appliqués sans effort, sauf si une force est spécifiée. Les parties sont considérées comme ACCESSIBLES si elles peuvent être atteintes par n'importe quelle partie d'un doigt d'épreuve ou d'une broche d'essai, ou si elles peuvent être atteintes en l'absence de tout couvercle considéré comme n'assurant pas une isolation appropriée (voir ~~6.9.1~~ 6.9.2).

Si des interventions d'un OPERATEUR prévues pendant l'UTILISATION NORMALE (avec ou sans l'aide d'un OUTIL) peuvent augmenter l'accessibilité des parties, de telles interventions doivent être entreprises avant d'effectuer les contrôles indiqués des 6.2.2 à 6.2.4.

NOTE Des exemples de telles interventions incluent ceux qui suivent:

a) le démontage des couvercles;

b) l'ouverture des portes;

c) le réglage des dispositifs de commande;

d) le remplacement de matériaux consommables;

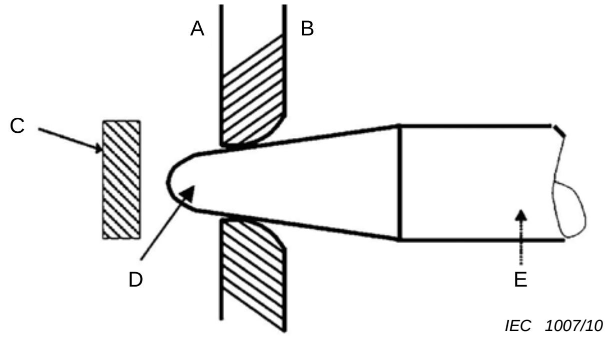
e) la dépose de parties.

Les appareils montés en baie ou en rack doivent être installés conformément aux instructions des fabricants avant d'effectuer la détermination spécifiée des 6.2.2 à 6.2.4. Pour de tels appareils, l'OPERATEUR est supposé se trouver en face du tiroir.

6.2.2 Examen

Le doigt d'épreuve articulé (voir la Figure B.2) doit être appliqué en chaque position possible. Lorsqu'une partie peut devenir ACCESSIBLE en appliquant une force, le doigt d'épreuve rigide (voir la Figure B.1) doit être appliqué avec une force de 10 N. La force doit être exercée par l'extrémité du doigt d'épreuve afin d'éviter l'action de coin et de levier. L'essai doit être appliqué à toutes les surfaces extérieures, y compris le fond. Cependant sur les appareils recevant des modules enfichables, le doigt d'épreuve articulé est inséré jusqu'à une profondeur de 180 mm à partir de l'ouverture de l'appareil.

Le doigt d'épreuve est également appliqué à toutes les ouvertures de l'ENVELOPPE, y compris les orifices et les BORNES. Dans ces cas, on considère que les parties ACCESSIBLES de l'ENVELOPPE incluent toute partie du doigt d'épreuve pouvant être insérée dans un orifice ou une BORNE (voir la Figure 1).



Légende

A intérieur de l'appareil

B extérieur de l'appareil

C partie SOUS-TENSION DANGEREUSE

D extrémité du doigt d'épreuve considérée comme ACCESSIBLE

E doigt d'épreuve

Figure 1 – Mesures à travers les ouvertures des ENVELOPPES

6.2.3 Ouvertures au-dessus de parties qui sont sous TENSION DANGEREUSE

Une broche d'essai métallique de 100 mm de long et de 4 mm de diamètre doit être insérée dans toutes les ouvertures situées au-dessus des parties qui sont sous TENSION DANGEREUSE. La broche d'essai doit être suspendue librement et peut pénétrer jusqu'à 100 mm.

Les mesures de sécurité supplémentaires de 6.5.1, concernant la protection en CONDITION DE PREMIER DEFAUT, ne sont pas exigées car ces parties ne sont ACCESSIBLES que par cet essai.

NOTE Cette exception est autorisée parce que l'insertion d'un objet semblable à cette broche d'essai est considérée comme une CONDITION DE PREMIER DEFAUT. et un seul moyen de protection est suffisant.

Cet essai n'est pas appliqué aux BORNES.

6.2.4 Ouvertures d'accès aux commandes préréglées

Une broche d'essai métallique de 3 mm de diamètre doit être insérée à travers les orifices prévus pour l'accès aux commandes préréglées qui nécessitent l'utilisation d'un tournevis ou d'un autre OUTIL. La broche d'essai doit être appliquée dans toute direction possible à travers l'orifice. La pénétration ne doit pas dépasser trois fois la distance la plus courte entre la surface de l'ENVELOPPE et l'axe de commande ou 100 mm.

6.3 Valeurs limites pour les parties ACCESSIBLES

6.3.1 Niveaux en CONDITION NORMALE

Les tensions dont les valeurs dépassent les niveaux de a) sont considérées comme TENSIONS DANGEREUSES si dans le même temps les niveaux de b) ou de c) sont aussi dépassés.

a) Les niveaux de tension alternative sont de ~~33~~ 30 V en valeur efficace et ~~46,7~~ 42,4 V en valeur de crête, et le niveau de tension continue est de ~~70~~ 60 V. Pour les appareils prévus pour un usage en EMPLACEMENT HUMIDE, les niveaux de tension alternative sont de 16 V en valeur efficace et 22,6 V en valeur de crête, et le niveau de tension continue est de 35 V.

b) Les niveaux de courant sont:

1) 0,5 mA efficace pour une forme d'onde sinusoïdale, 0,7 mA crête pour une forme d'onde non sinusoïdale ou mixte ou 2 mA continu, lorsque l'intensité est mesurée avec le circuit de la Figure A.1. Si la fréquence ne dépasse pas 100 Hz, il est également possible d'utiliser le circuit de mesure de la Figure A.2. Le circuit de mesure de la Figure A.4 est utilisé pour les appareils prévus pour un usage en EMPLACEMENT HUMIDE est une CARACTERISTIQUE ASSIGNEE.
2) 70 mA efficace, lorsque le courant est mesuré avec le circuit de mesure de la Figure A.3. Cela se rapporte aux brûlures possibles à des fréquences plus élevées.

c) Les niveaux de capacité et d'énergie sont:
1) une charge de 45 μC pour les tensions jusqu'à 15 kV crête ou continu; la courbe A de la Figure 3 indique la valeur de la capacité en fonction de la tension quand la charge vaut 45 μC;
2) une énergie accumulée de 350 mJ pour les tensions supérieures à 15 kV crête ou continu.

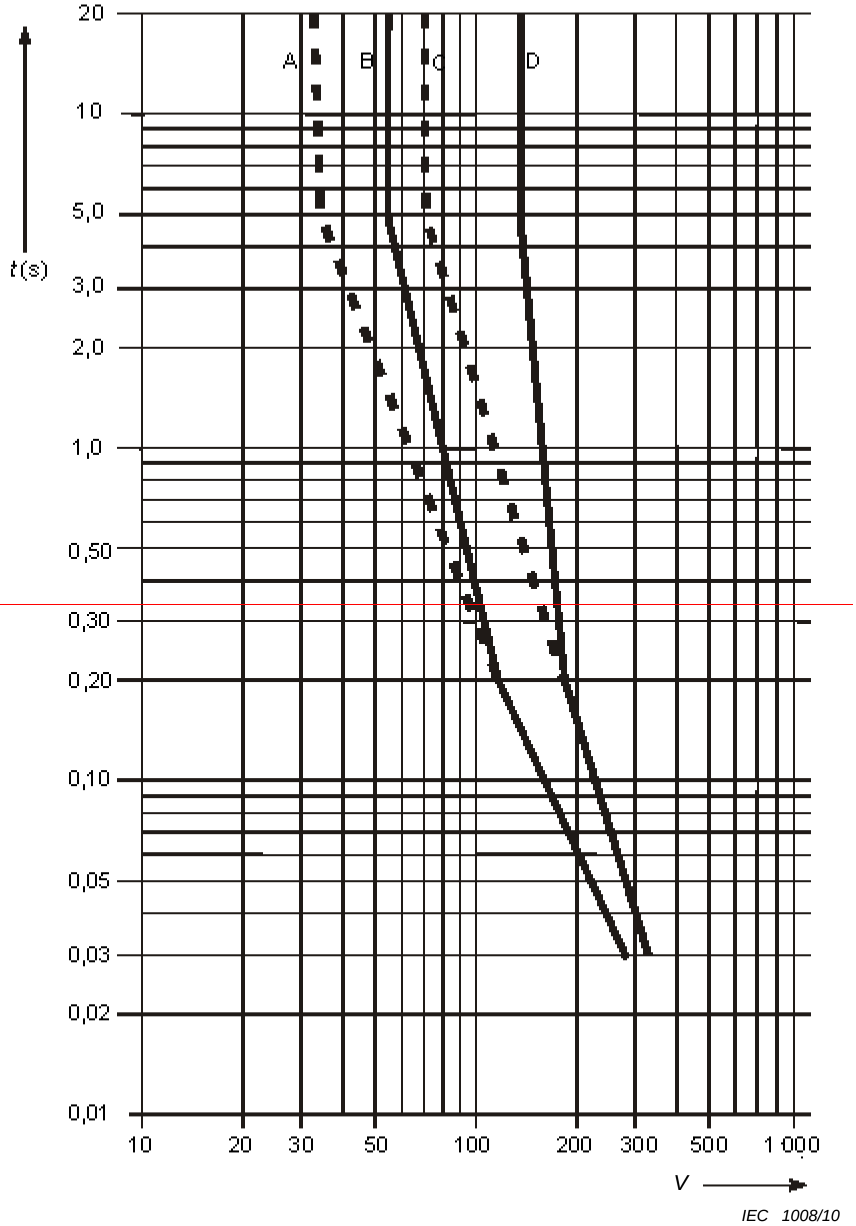
6.3.2 Niveaux en CONDITION DE PREMIER DEFAUT

Les tensions dont les valeurs dépassent les niveaux de a) sont considérées comme TENSIONS DANGEREUSES si dans le même temps les niveaux de b) ou de c) sont aussi dépassés.

a) Les niveaux de tension alternative sont de ~~55~~ 50 V en valeur efficace et ~~78~~ 70 V en valeur de crête, et le niveau de tension continue est de ~~140~~ 120 V. Pour les appareils prévus pour un usage en EMPLACEMENT HUMIDE, les niveaux de tension alternative sont de 33 V en valeur efficace et 46,7 V en valeur de crête, et le niveau de tension continue est de 70 V. Pour les tensions de courte durée, la durée par rapport aux niveaux de tension sont celles de la Fgure 2, mesurée aux bornes d'une résistance de 50 kΩ.

b) Les niveaux de courant sont:
1) 3,5 mA efficace pour une forme d'onde sinusoïdale, 5 mA crête pour une forme d'onde non sinusoïdale ou mixte, ou 15 mA continu, lorsque l'intensité est mesurée avec le circuit de la Figure A.1. Si la fréquence ne dépasse pas 100 Hz, il est également possible d'utiliser le circuit de mesure de la Figure A.2. Le circuit de mesure de la Figure A.4 est utilisé pour les appareils prévus pour un usage en EMPLACEMENT HUMIDE.
2) 500 mA efficace, lorsque le courant est mesuré avec le circuit de mesure de la Figure A.3. Cela se rapporte aux brûlures possibles à des fréquences plus élevées.

c) Le niveau de la capacité en fonction de la tension est celui de la courbe B de la Figure 3.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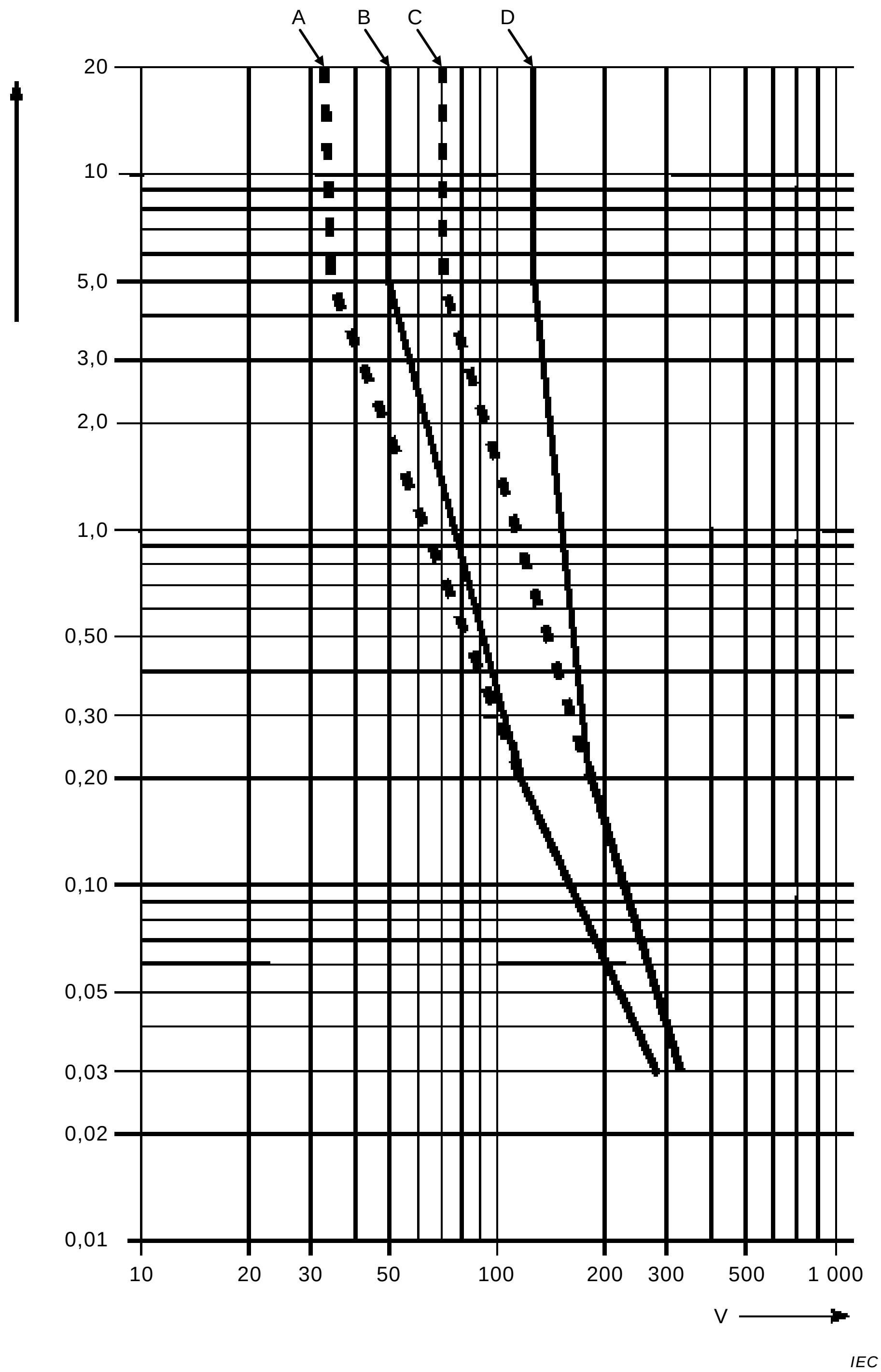


Légende

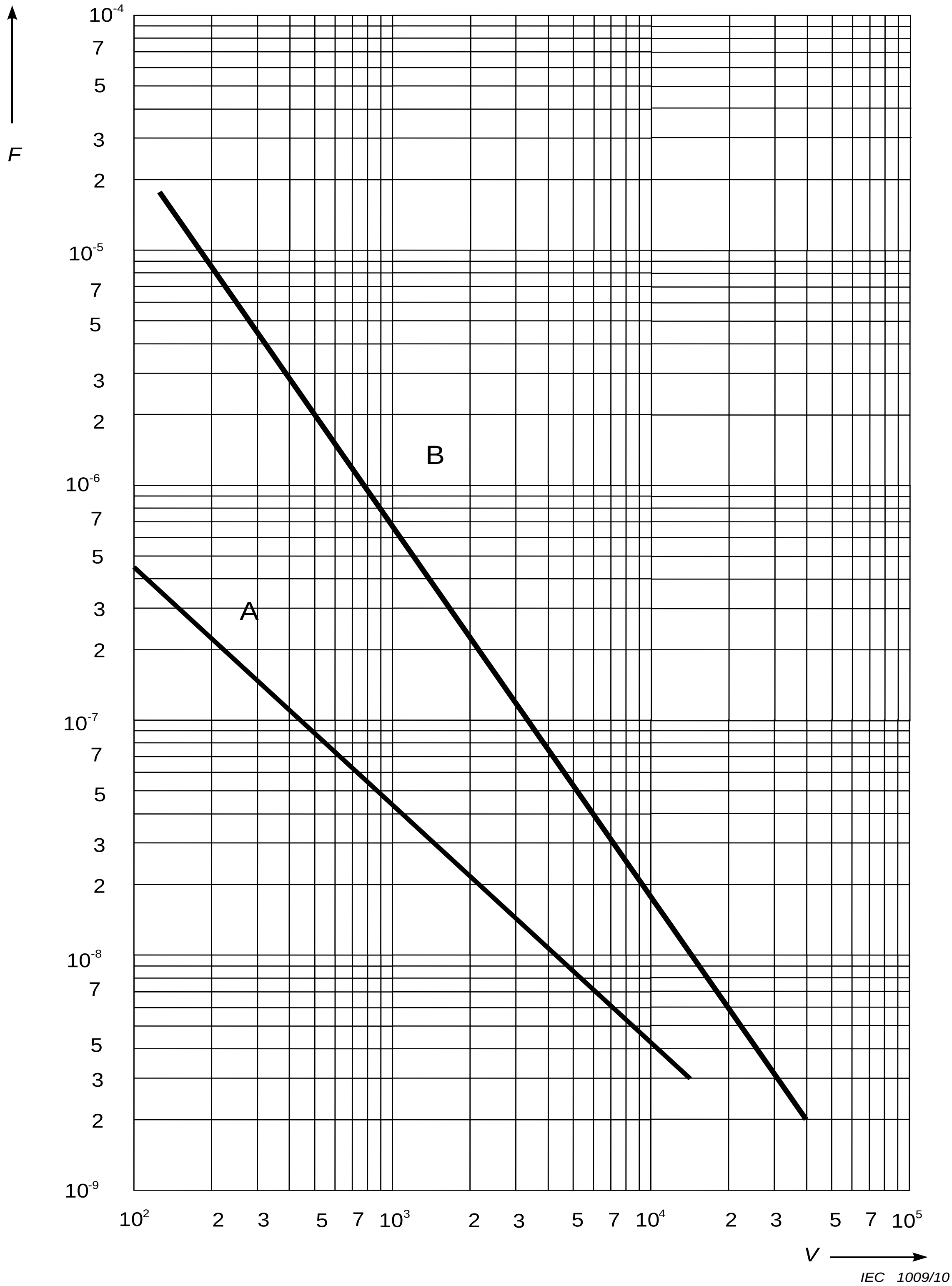
A niveau de tension alternative en EMPLACEMENT HUMIDE

B niveau de tension alternative en emplacement sec

C niveau de tension continue en EMPLACEMENT HUMIDE

D niveau de tension continue en emplacement sec

Figure 2 – Durée maximale des tensions de courte durée accessibles en CONDITION DE PREMIER DEFAUT (voir 6.3.2 a))



Légende

A CONDITION NORMALE

B CONDITION DE PREMIER DEFAUT

Figure 3 – Niveau de la capacité en fonction de la tension en CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT (voir 6.3.1 c) et 6.3.2 c))

6.4 Moyens principaux de protection

6.4.1 Généralités

Un ou plusieurs des moyens ci-dessous doivent empêcher les parties ACCESSIBLES d'être mises sous TENSION DANGEREUSE (voir Annexe D):

a) ENVELOPPES ou BARRIERES DE PROTECTION (voir 6.4.2);

b) ISOLATION PRINCIPALE (voir 6.4.3);

c) impédance (voir 6.4.4).

La conformité est vérifiée par examen et tel que spécifié de 6.4.2 à 6.4.4.

6.4.2 ENVELOPPES ou BARRIERES DE PROTECTION

Les ENVELOPPES et BARRIERES DE PROTECTION doivent satisfaire aux exigences de rigidité mécanique de 8.1.

Si des ENVELOPPES ou des BARRIERES DE PROTECTION apportent une protection par isolation, elles doivent satisfaire aux exigences de l'ISOLATION PRINCIPALE.

Si des ENVELOPPES ou BARRIERES DE PROTECTION apportent une protection en limitant l'accès, les DISTANCES D'ISOLEMENT et les LIGNES DE FUITE entre les parties ACCESSIBLES et les parties sous TENSION DANGEREUSE doivent respecter les exigences de 6.7 et celles applicables à l'ISOLATION PRINCIPALE.

La conformité est vérifiée tel que spécifié en 6.7 et en 8.1.

6.4.3 ISOLATION PRINCIPALE

Les DISTANCES D'ISOLEMENT, les LIGNES DE FUITE et l'isolation solide constituant l'ISOLATION PRINCIPALE entre les parties ACCESSIBLES et les parties sous TENSION DANGEREUSE doivent respecter les exigences de 6.7.

La conformité est vérifiée tel que spécifié en 6.7.

6.4.4 Impédance

Une impédance utilisée comme principal moyen de protection doit satisfaire aux exigences suivantes:

a) elle doit limiter la tension ou le courant à une valeur ne dépassant pas le niveau applicable de 6.3.2;

b) elle doit être caractérisée pour la TENSION DE SERVICE maximale et la quantité d'énergie qu'elle aura à dissiper;

c) la DISTANCE D'ISOLEMENT ET la LIGNE DE FUITE entre les extrémités de l'impédance doivent respecter les exigences de 6.7 pour l'ISOLATION PRINCIPALE.

La conformité est vérifiée par examen, par la mesure de la tension ou du courant pour confirmer qu'ils ne dépassent pas les niveaux de 6.3.2 et par la mesure de la DISTANCES D'ISOLEMENT et de la LIGNE DE FUITE tel que spécifié en 6.7.

6.5 Moyens additionnels de protection en cas de CONDITION DE PREMIER DEFAUT

6.5.1 Généralités

Les moyens principaux de protection (voir 6.4) doivent être complétés par un des moyens de a), b), c) ou d) pour empêcher les parties ACCESSIBLES d'être mises sou TENSION DANGEREUSE en CONDITION DE PREMIER DEFAUT. En alternative, l'un des moyens uniques de protection de e) ou f) doit être utilisé. Voir la Figure 4 et l'Annexe D.

a) LIAISON DE PROTECTION (voir 6.5.2);
b) ISOLATION SUPPLEMENTAIRE (voir 6.5.3);
c) déconnexion automatique de l'alimentation (voir 6.5.5);
d) limiteur de tension ou de courant (voir 6.5.6);
e) ISOLATION RENFORCEE (voir 6.5.3);
f) IMPEDANCE DE PROTECTION (voir 6.5.4).

La conformité est vérifiée par examen et tel que spécifié de 6.5.2 à 6.5.6.

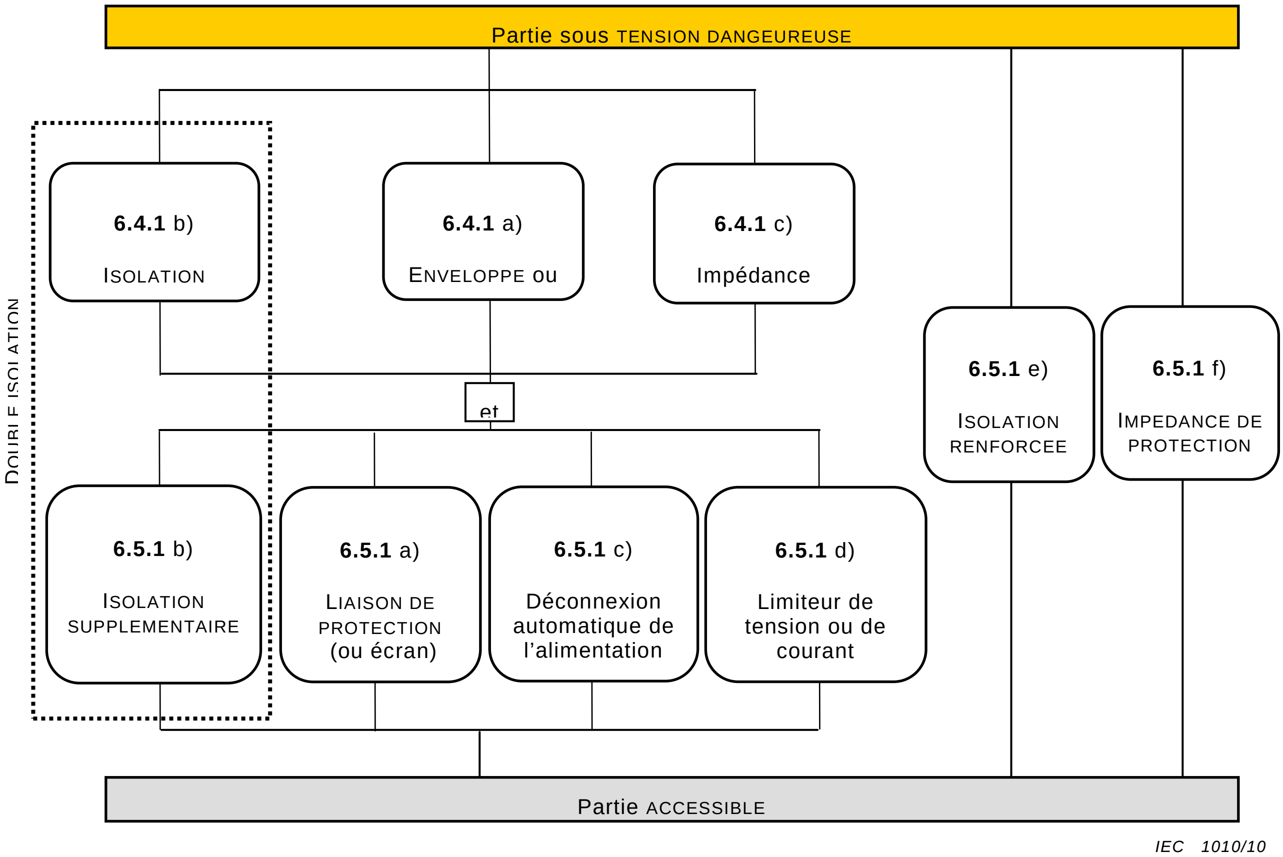


Figure 4 – Organisation acceptable des moyens de protection contre les chocs électriques

6.5.2 LIAISON DE PROTECTION

6.5.2.1 Généralités

Les parties conductrices ACCESSIBLES, pouvant être sous TENSION DANGEREUSE en cas de premier défaut des moyens principaux de protection spécifiés en 6.4, doivent être raccordées à la BORNE DE TERRE DE PROTECTION. En variante, ces parties conductrices ACCESSIBLES doivent être séparées des parties qui sont sous TENSION DANGEREUSE par un écran conducteur de protection relié à la BORNE DE TERRE DE PROTECTION.

La conformité est vérifiée tel que spécifié de 6.5.2.2 à 6.5.2.6.

6.5.2.2 Intégrité de la LIAISON DE PROTECTION

L'intégrité de la LIAISON DE PROTECTION doit être assurée comme spécifié ci-dessous.

a) La LIAISON DE PROTECTION doit se composer de parties structurelles directement branchées ou de conducteurs discrets, ou des deux à la fois. Elle doit supporter toutes les contraintes thermiques et dynamiques pouvant se produire avant qu'un des moyens de protection contre les surintensités spécifiés en 9.6 ne déconnecte l'appareil de l'alimentation.

b) Les connexions soudées soumises à une contrainte mécanique doivent avoir une fixation mécanique indépendamment de la soudure. De telles connexions ne doivent pas être utilisées à d'autres fins, telles que la fixation de parties structurelles.

c) Les connexions vissées doivent être protégées contre le desserrage.

d) Lorsqu'une partie d'un appareil est démontable par un OPERATEUR, la LIAISON DE PROTECTION pour le reste de l'appareil ne doit pas être interrompue (sauf lorsque cette partie porte également la connexion d'entrée RESEAU à l'ensemble de l'appareil).

e) A moins qu'elles ne soient spécifiquement conçues pour assurer une interconnexion électrique et qu'elles ne soient conformes aux exigences de 6.5.2.4, les connexions conductrices amovibles, telles que charnières, coulisses, etc., ne doivent pas constituer l'unique parcours de la LIAISON DE PROTECTION.

f) La tresse métallique extérieure des câbles ne doit pas être considérée comme une LIAISON DE PROTECTION, même si elle est reliée à la BORNE DE TERRE DE PROTECTION.

g) Lorsque la puissance fournie par l'alimentation RESEAU traverse l'appareil pour être utilisée par d'autres appareils, il est également nécessaire de prévoir un moyen permettant de faire passer le conducteur de protection à travers l'appareil tout en protégeant l'autre appareil. L'impédance de chemin du conducteur de protection à travers l'appareil ne doit pas dépasser la valeur spécifiée en 6.5.2.4.

h) Les conducteurs de mise à la terre de protection peuvent être nus ou isolés. L'isolation doit être verte/jaune, sauf pour les cas suivants:

   1) pour les tresses de mise à la terre, l'isolation doit être verte/jaune ou transparente;

   2) pour les conducteurs de protection interne, et pour les autres conducteurs branchés à la BORNE DE TERRE DE PROTECTION dans des ensembles tels que câbles en nappe, barres omnibus, câblages imprimés flexible etc., n'importe quelle couleur peut être utilisée, à condition que la non-identification d'un conducteur de protection ne puisse pas provoquer un DANGER.

Les appareils utilisant une LIAISON DE PROTECTION doivent être munis d'une BORNE adaptée au raccordement à un conducteur de protection et conforme aux exigences de 6.5.2.3.

La conformité est vérifiée par examen.

6.5.2.3 BORNE DE TERRE DE PROTECTION

La BORNE DE TERRE DE PROTECTION doit être conforme aux exigences suivantes.

a) Les surfaces de contact doivent être métalliques.

   NOTE 1 Il convient de choisir les matériaux entrant dans la composition de la LIAISON DE PROTECTION de manière à minimiser la probabilité de corrosion électrochimique entre la BORNE et le conducteur de protection ou entre la BORNE ou le conducteur de protection et tout autre métal en contact avec eux.

b) La connexion intégrale du conducteur de protection d'un socle de connecteur doit être considérée comme la BORNE DE TERRE DE PROTECTION.

c) Pour les appareils munis d'un cordon souple démontable et pour les APPAREILS BRANCHES EN PERMANENCE, la BORNE DE TERRE DE PROTECTION doit être placée près des BORNES d'alimentation RESEAU.

d) Si un appareil n'a pas besoin d'être raccordé à une alimentation RESEAU, mais qu'il ait un circuit ou une partie qui doit être protégé par une mise à la terre, la BORNE DE TERRE DE PROTECTION doit être placée près des BORNES du circuit pour lequel la mise à la terre de protection est nécessaire. Si ce circuit a des BORNES extérieures, la BORNE DE TERRE DE PROTECTION doit être également extérieure.

e) Les BORNES DE TERRE DE PROTECTION des CIRCUITS RESEAU doivent être au moins équivalentes, en ce qui concerne l'intensité admissible, aux BORNES d'alimentation RESEAU.

f) Les BORNES DE TERRE DE PROTECTION de type enfichable, combinées à d'autres BORNES et destinées à être reliées et déconnectées sans l'aide d'un OUTIL doivent être conçues de telle sorte que la connexion du conducteur de protection soit établie en premier et qu'elle se coupe en dernier par rapport aux autres connexions. Les fiches et connecteurs pour cordons d'alimentation RESEAU ou ensembles de connecteurs pour unités enfichables sont des exemples de BORNES DE TERRE DE PROTECTION.

g) Si la BORNE DE TERRE DE PROTECTION est aussi utilisée pour d'autres raisons de liaison, le conducteur de protection doit être mis le premier et fixé indépendamment des autres connexions. Le conducteur de protection doit être branché de telle manière qu'il soit improbable qu'il puisse être enlevé, lors d'une maintenance qui ne requiert pas le débranchement du conducteur de protection.

h) Pour les appareils dans lesquels le conducteur de protection est exigé pour la protection en CONDITION DE PREMIER DEFAUT dans un circuit de mesure, ce qui suit doit s'appliquer:

   1) la BORNE DE TERRE DE PROTECTION et le conducteur de protection doivent avoir au moins le courant ASSIGNE des BORNES de mesure;

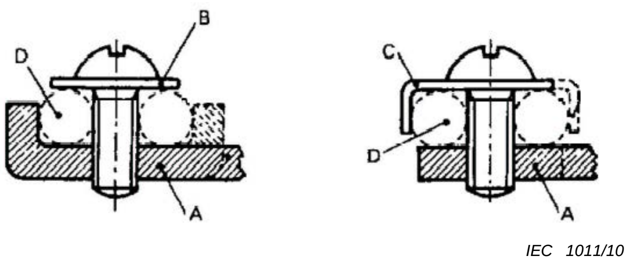
   2) la LIAISON DE PROTECTION ne doit pas être interrompue par la présence de tout interrupteur ou commutateur.

i) Les BORNES DE TERRE FONCTIONNELLE (par exemple BORNES de terre de mesure) doivent, le cas échéant, permettre une connexion indépendante de celle du conducteur de protection.

NOTE 2 L'appareil peut être muni de BORNES DE TERRE FONCTIONNELLE, quel que soit le moyen de protection utilisé.

j) Si la BORNE DE TERRE DE PROTECTION est une BORNE à visser (voir Figure 5), elle doit être d'un calibre adapté au fil à serrer, mais d'une taille pas plus petite que 4,0 mm, avec au moins trois filets de la vis engagés.

k) La pression de contact exigée pour la connexion de la liaison ne doit pas pouvoir être réduite par la déformation des matériaux formant la connexion.



Légende

A partie fixe

B tête ou rondelle de serrage

C dispositif anti-rotation

D emplacement du conducteur

Figure 5 – Exemples de montages vissés

La conformité est vérifiée par examen. La conformité de j) est également vérifiée par l'essai suivant:

Le montage vissé est serré et desserré trois fois, avec le conducteur à brider le moins favorable, en utilisant les couples de serrage indiqués au Tableau 2. Toutes les parties du montage vissé doivent résister à cet essai sans défaillance mécanique.

Tableau 2 – Couples de serrage pour les montages vissés

Taille de la vis mm	4,0	5,0	6,0	8,0	10,0
Couple de serrage N·m	1,2	2,0	3,0	6,0	10,0

6.5.2.4 Impédance de la LIAISON DE PROTECTION des appareils raccordés par une fiche

L'impédance entre la BORNE DE TERRE DE PROTECTION et chaque partie ACCESSIBLE pour laquelle une LIAISON DE PROTECTION est spécifiée ne doit pas dépasser 0,1 Ω. Si un cordon d'alimentation RESEAU est relié en permanence à l'appareil, l'impédance entre le conducteur de protection de la prise du cordon d'alimentation RESEAU et chaque partie ACCESSIBLE pour laquelle la LIAISON DE PROTECTION est spécifiée ne doit pas dépasser 0,2 Ω.

La conformité est vérifiée en appliquant un courant d'essai pendant 1 min et en calculant ensuite l'impédance. La valeur du courant d'essai est la valeur la plus élevée entre

a) *25 A alternatif efficace à la fréquence ASSIGNEE du RESEAU ou continu,*

b) *deux fois le courant ASSIGNE de l'appareil.*

Si l'appareil est muni de dispositifs de protection contre les surintensités sur toutes les phases de l'alimentation RESEAU et si le câblage entre cette alimentation et les dispositifs de protection contre les surintensités ne peut pas être raccordé à des parties conductrices ACCESSIBLES en CONDITION DE PREMIER DEFAUT, il n'est pas nécessaire que le courant de mesure dépasse le double du courant ASSIGNE des dispositifs internes de protection contre les surintensités.

6.5.2.5 Impédance de la LIAISON DE PROTECTION des APPAREILS BRANCHES EN PERMANENCE

L'impédance de la LIAISON DE PROTECTION d'un APPAREIL BRANCHE EN PERMANENCE doit être faible.

La conformité est vérifiée en appliquant un courant d'essai d'une valeur double de la valeur du courant du moyen de protection contre les surintensités spécifiée dans les instructions d'installation pour le circuit d'alimentation RESEAU du bâtiment, pendant 1 min entre la BORNE DE TERRE DE PROTECTION et chaque partie conductrice ACCESSIBLE pour laquelle une LIAISON DE PROTECTION est spécifiée. La tension entre elles ne doit pas dépasser 10 V continu ou alternatif (valeur efficace).

Si l'appareil est muni de dispositifs de protection contre les surintensités sur toutes les phases de l'alimentation RESEAU, et si le câblage entre cette alimentation et les dispositifs de protection contre les surintensités ne peut pas être raccordé à des parties conductrices ACCESSIBLES en CONDITION DE PREMIER DEFAUT, le courant pour le mesurage de l'impédance de liaison ne doit pas dépasser le double du courant ASSIGNE des dispositifs internes de protection contre les surintensités.

6.5.2.6 Ecran de LIAISON DE PROTECTION des transformateurs

Si le transformateur est équipé d'un écran de LIAISON DE PROTECTION que seule une ISOLATION PRINCIPALE sépare d'un enroulement, lui-même relié à un circuit sous TENSION DANGEREUSE, l'écran doit être conforme aux exigences de 6.5.2.2 a) et b) et avoir une faible impédance.

La conformité est vérifiée par examen et un des essais suivants:

a) *un courant d'essai d'une valeur double de la valeur du courant du moyen de protection contre les surintensités de l'enroulement est appliqué pendant 1 min entre l'écran et la*

BORNE DE TERRE DE PROTECTION. *La tension entre ces parties ne doit pas dépasser 10 V continu ou alternatif efficace ;*

b) l'essai de 6.5.2.4 en utilisant un courant d'essai de deux fois la valeur du courant des moyens de protection contre les surintensités de l'enroulement. L'impédance ne doit pas dépasser 0,1 Ω.

NOTE Si l'essai a) ou b) est effectué, un transformateur échantillon, préparé spécialement avec un fil de sortie supplémentaire partant de l'extrémité libre de l'écran, est utilisé pour s'assurer que le courant pendant l'essai traverse l'écran.

6.5.3 ISOLATION SUPPLEMENTAIRE et ISOLATION RENFORCEE

Les DISTANCES D'ISOLEMENT, les LIGNES DE FUITE et l'isolation solide d'une ISOLATION SUPPLEMENTAIRE ou d'une ISOLATION RENFORCEE doivent satisfaire aux exigences applicables de 6.7.

La conformité est vérifiée tel que spécifié en 6.7.

6.5.4 IMPEDANCE DE PROTECTION

Une IMPEDANCE DE PROTECTION doit limiter le courant ou la tension en dessous des niveaux de 6.3.1 en CONDITION NORMALE et de 6.3.2 en CONDITION DE PREMIER DEFAUT.

L'isolation entre les extrémités de l'IMPEDANCE DE PROTECTION doit respecter les exigences de 6.7 pour la DOUBLE ISOLATION ou l'ISOLATION RENFORCEE.

Une IMPEDANCE DE PROTECTION doit se composer d'un ou de plusieurs des éléments ci-après:

a) un composant individuel approprié qui doit être fabriqué, choisi et essayé de telle sorte que la sécurité et la fiabilité pour la protection contre les chocs électriques soit assurée. Ce composant doit notamment:
   1) être ASSIGNE pour le double de la TENSION DE SERVICE maximale;
   2) si c'est une résistance, être ASSIGNE pour le double de la dissipation en puissance pour la TENSION DE SERVICE maximale;
b) une combinaison de composants.

Une IMPEDANCE DE PROTECTION ne doit pas être un dispositif électronique individuel qui emploie une conduction électronique dans le vide, dans un gaz ou dans un semi-conducteur.

La conformité est vérifiée par examen, par la mesure de la tension ou du courant pour vérifier qu'ils ne dépassent pas les niveaux applicables de 6.3 et en mesurant les LIGNES DE FUITE et les DISTANCES D'ISOLEMENT comme spécifié en 6.7. La conformité d'un composant individuel est vérifiée par l'examen de ses CARACTERISTIQUES ASSIGNEES.

6.5.5 Déconnexion automatique de l'alimentation

Un dispositif de déconnexion automatique doit être conforme aux exigences suivantes.

a) Il doit avoir une valeur ASSIGNEE pour déconnecter la charge dans le temps spécifié de la Figure 2.
b) Il doit avoir une valeur ASSIGNEE pour les conditions de charge maximale ASSIGNEE de l'appareil.

La conformité est vérifiée par examen des spécifications du dispositif. En cas de doute, le dispositif est vérifié pour tester la déconnexion de l'alimentation dans le temps exigé.

6.5.6 Limiteur de tension ou de courant

Un limiteur de tension ou de courant doit satisfaire aux exigences suivantes:

a) ses caractéristiques ASSIGNEES doivent limiter le courant ou la tension à des valeurs ne dépassant pas les niveaux de 6.3.2;
b) la tension ASSIGNEE doit être la TENSION DE SERVICE maximale et, si applicable, le courant ASSIGNE doit être le courant opérationnel maximal;
c) la DISTANCE D'ISOLEMENT et la LIGNE DE FUITE entre les extrémités du limiteur de tension ou de courant doivent satisfaire aux exigences applicables de 6.7 pour l'ISOLATION SUPPLEMENTAIRE.

La conformité est vérifiée par examen, par la mesure de la tension ou du courant pour vérifier qu'ils ne dépassent pas les niveaux applicables de 6.3.2 et en mesurant la DISTANCE D'ISOLEMENT et la LIGNE DE FUITE comme spécifié en 6.7.

6.6 Connexion aux circuits externes

6.6.1 Généralités

En CONDITION NORMALE ou en CONDITION DE PREMIER DEFAUT de l'appareil, connecter l'appareil à un circuit externe ne doit pas mettre sous TENSION DANGEREUSE les parties ACCESSIBLES de l'appareil ou les parties ACCESSIBLES du circuit externe.

NOTE 1 Les circuits externes sont tous les circuits connectés aux BORNES de l'appareil.

NOTE 2 Pour les raccordements à la source d'alimentation RESEAU, voir 6.10.

La protection doit être obtenue par la séparation des circuits, à moins que le court-circuit de la séparation ne puisse pas provoquer de DANGER.

Les instructions du fabricant ou les marquages de l'appareil doivent donner les informations suivantes, si applicables, pour chaque BORNE externe:

a) les conditions ASSIGNEES pour lesquelles la BORNE a été conçue pour fonctionner tout en maintenant la sécurité (tension d'entrée/sortie maximale ASSIGNEE, type de connecteur spécifique, utilisation donnée, etc.);
b) la valeur ASSIGNEE de l'isolation exigée des circuits externes pour être conforme aux exigences de protection contre les chocs électriques, suite à la connexion de la BORNE, en CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT.

La conformité est vérifiée par:

1) examen;

2) détermination de 6.2;

3) mesures de 6.3 et 6.7;

4) l'essai de tension de 6.8 (sans le pré-conditionnement à l'humidité) applicable au type d'isolation (voir 6.7).

6.6.2 BORNES pour circuits externes

Les parties conductrices ACCESSIBLES des BORNES qui reçoivent une charge d'un condensateur interne ne doivent pas être sous TENSION DANGEREUSE 10 s après coupure de l'alimentation.

La conformité est vérifiée par examen et par la détermination des parties conductrices ACCESSIBLES tel que spécifié en 6.2 et, en cas de doute, par la mesure de la tension présente ou de la charge.

6.6.3 Circuits avec BORNES qui sont sous TENSION DANGEREUSE

Ces circuits ne doivent pas être reliés à des parties conductrices ACCESSIBLES, sauf pour les circuits qui ne sont pas des CIRCUITS RESEAU et qui sont conçus pour fonctionner avec un seul contact de BORNE au potentiel de terre. Dans de tels cas, les parties conductrices ACCESSIBLES ne doivent pas être sous TENSION DANGEREUSE.

Si un tel circuit est également conçu pour fonctionner avec un seul contact ACCESSIBLE de BORNE (signal bas) fluctuant à une tension qui n'est pas une TENSION DANGEREUSE, le contact de BORNE peut être connecté à une BORNE DE TERRE FONCTIONNELLE commune ou à un système commun (par exemple, un système de blindage coaxial). Il est également admis que cette BORNE DE TERRE FONCTIONNELLE commune ou ce système commun puisse être relié à d'autres parties conductrices ACCESSIBLES.

La conformité est vérifiée par examen.

6.6.4 BORNES pour les conducteurs souples

~~Les BORNES pour cordons souples doivent être positionnées ou protégées de manière à éviter toute possibilité de contact accidentel entre des parties sous TENSION DANGEREUSE de polarité différente ou entre de telles parties et d'autres parties ACCESSIBLES, même si un brin de conducteur sort d'une BORNE. A moins que cela ne soit évident (ce qui est préférable), les BORNES doivent porter un marquage indiquant si elles sont reliées ou non à des parties conductrices ACCESSIBLES (voir 5.1.5.2 c)).~~

Les bornes pour les conducteurs câblés destinés à être branchés durant l'installation, l'entretien ou le fonctionnement de l'appareil doivent être positionnées ou protégées de manière à éviter toute possibilité de contact accidentel entre des parties SOUS TENSION DANGEREUSE de polarité différente ou entre de telles parties et d'autres parties ACCESSIBLES, même si un brin de conducteur sort d'une BORNE. Cette exigence ne s'applique pas aux raccordements qui ne doivent être réalisés que par le site de production.

La conformité est vérifiée par examen après l'insertion complète d'un conducteur ~~souple~~ câblé

a) dont l'isolation a été dénudée sur la longueur maximale spécifiée par le fabricant de l'appareil, ou

b) dont l'isolation a été dénudée sur 8 mm ~~et dont l'un des brins est laissé libre~~ en l'absence de spécification de la part du fabricant de l'appareil.

~~Le brin~~ L'un des brins laissé libre ne doit pas toucher de parties de polarité différente ni de parties ACCESSIBLES lorsqu'il est plié dans toutes les directions possibles sans déchirer l'isolation ni faire de coudes à faible rayon de courbure.

Les BORNES de circuits conduisant une TENSION DANGEREUSE ou un courant dangereux doivent être fixées, montées ou conçues de manière à ce que les conducteurs ne prennent pas de jeu lorsqu'elles sont serrées ou desserrées, ou lorsque les connexions sont établies.

La conformité est vérifiée par essai manuel et par examen.

6.7 Exigences relatives à l'isolation

6.7.1 Type d'isolation

6.7.1.1 Généralités

L'isolation entre les circuits et les parties ACCESSIBLES (voir 6.2) ou entre des circuits séparés est constituée d'une combinaison de DISTANCES D'ISOLEMENT, de LIGNES DE FUITE et d'isolation solide. Quand elle est utilisée pour fournir une protection contre un DANGER, l'isolation doit résister aux contraintes électriques qui sont provoquées par les tensions qui peuvent apparaître sur l'alimentation RESEAU ou dans l'appareil.

Les contraintes électriques provenant du RESEAU ont pour origine:

a) la TENSION DE SERVICE à travers l'isolation. Cette TENSION DE SERVICE est normalement la tension phase-neutre de l'alimentation RESEAU (voir aussi l'Annexe I);

b) les SURTENSIONS TRANSITOIRES qui peuvent apparaître occasionnellement sur les conducteurs de ligne. L'amplitude des surtensions dépend de la CATEGORIE DE SURTENSION et de la tension phase-neutre de l'alimentation RESEAU;

c) les SURTENSIONS TEMPORAIRES de courte durée qui peuvent se produire entre les conducteurs de ligne et la terre dans les installations électriques. L'amplitude de ces SURTENSIONS TEMPORAIRES peut valoir la tension phase-neutre de l'alimentation RESEAU plus 1 200 V, et durer jusqu'à 5 s;

d) les SURTENSIONS TEMPORAIRES de longue durée qui peuvent se produire entre les conducteurs de ligne et la terre dans les installations électriques. L'amplitude de ces SURTENSIONS TEMPORAIRES peut valoir la tension phase-neutre de l'alimentation RESEAU, plus 250 V, et durer plus de 5 s.

NOTE Voir l'IEC 60364-4-44, Article 442 pour plus d'informations sur les SURTENSIONS TEMPORAIRES.

Les exigences pour l'isolation dépendent:

1) du niveau exigé de l'isolation (ISOLATION PRINCIPALE, ISOLATION RENFORCEE ou ISOLATION SUPPLEMENTAIRE);
2) de la SURTENSION TRANSITOIRE maximale qui peut apparaître sur le circuit, soit résultante d'un événement externe (tels que la foudre ou un transitoire lié à une commutation), soit résultante du fonctionnement de l'appareil;
3) de la TENSION DE SERVICE maximale (régime établi et tension de crête répétitive inclus);
4) du DEGRE DE POLLUTION du microenvironnement;
5) de la SURTENSION TEMPORAIRE maximale qui peut apparaître sur le circuit à cause d'un défaut dans le réseau de distribution.

6.7.1.2 DISTANCES D'ISOLEMENT

Les exigences pour les DISTANCES D'ISOLEMENT dépendent des contraintes de 6.7.1.1 a) à d) et aussi de la valeur de l'altitude ASSIGNEE pour le fonctionnement. Si l'altitude de fonctionnement ASSIGNEE à l'appareil est supérieure à 2 000 m, toutes les DISTANCES D'ISOLEMENT doivent être multipliées par le coefficient applicable du Tableau 3.

Tableau 3 – Coefficients multiplicateurs pour des DISTANCES D'ISOLEMENT pour les altitudes de fonctionnement ASSIGNEES jusqu'à 5 000 m d'altitude

Altitude de fonctionnement ASSIGNEE m	Coefficient multiplicateur
Jusqu'à 2 000	1,00
2 001 à 3 000	1,14
3 001 à 4 000	1,29
4 001 à 5 000	1,48

Voir l'Annexe C pour les détails sur la manière de mesurer les DISTANCES D'ISOLEMENT.

6.7.1.3 LIGNES DE FUITE

Les exigences pour les LIGNES DE FUITE dépendent des contraintes de 6.7.1.1 a) à d) et aussi de l'indice de résistance au cheminement (IRC) du matériau isolant.

Les matériaux sont séparés en quatre groupes selon leurs valeurs de l'indice de résistance au cheminement, comme suit:

Matériau du groupe I 600 ≤ IRC

Matériau du groupe II	400 ≤ IRC < 600
Matériau du groupe IIIa	175 ≤ IRC < 400
Matériau du groupe IIIb	100 ≤ IRC < 175

Ces valeurs d'IRC renvoient aux valeurs obtenues selon les spécifications de l'IEC 60112 sur des échantillons spécialement faits pour cela et testés avec la solution A. Les matériaux dont on ne connaît pas l'IRC, sont assimilés au groupe IIIb.

Il n'y a pas d'exigence pour les LIGNES DE FUITE pour le verre, les céramiques et autres matériaux isolants inorganiques qui ne cheminent pas.

Une LIGNE DE FUITE peut être divisée dans plusieurs portions de matériaux distincts et/ou avoir différents DEGRES DE POLLUTION si l'une des lignes de fuite est dimensionnée de façon à résister à la tension totale ou si la distance totale est établie en fonction du matériau présentant l'IRC le plus faible et le DEGRE DE POLLUTION le plus élevé.

Voir l'Annexe C pour les indications sur la manière de mesurer les LIGNES DE FUITE.

6.7.1.4 Isolation solide

Les exigences pour l'isolation solide dépendent des contraintes de 6.7.1.1 a) à d).

Le terme «isolation solide» est utilisé pour décrire beaucoup de différents types de constructions, y compris les blocs monolithiques de matière isolante, et les sous-ensembles d'isolation composés de multiples matières isolantes, organisées en couches ou autrement.

La tenue électrique d'une épaisseur d'isolation solide est considérablement plus importante que celle de la même épaisseur d'air. Les distances d'isolement à travers l'isolation solide sont donc en général plus petites que les distances dans l'air. En conséquence, les champs électriques dans l'isolation solide sont en général plus élevés, et sont souvent moins homogènes.

Les matières utilisées pour l'isolation solide peuvent contenir des manques ou des vides. Quand un ensemble d'isolation solide est constitué de couches de matières solides, il peut également y avoir des manques ou des vides entre les couches. Ces vides perturberont le champ électrique dont une part importante et disproportionnée se retrouvera dans le vide, pouvant potentiellement entraîner une ionisation de l'air et des décharges partielles. Un autre facteur important est la permittivité différente entre l'air et l'isolation solide. Ces décharges partielles auront un effet sur l'isolation solide adjacente et peuvent réduire sa durée de vie.

L'isolation solide n'est pas renouvelable: les dommages s'accumulent au cours de la vie de l'appareil. L'isolation solide est également sujette aux dégradations dues au vieillissement et à des essais répétés à haute tension.

6.7.1.5 Exigences pour l'isolation suivant le type de circuit

Les exigences pour l'isolation de types particuliers de circuits sont spécifiées suivant:

a) 6.7.2 pour les CIRCUITS RESEAU en CATEGORIE DE SURTENSION II avec une tension nominale d'alimentation jusqu'à 300 V;

   NOTE 1 Voir l'Annexe I pour les tensions nominales des RESEAUX de distribution.

b) 6.7.3 pour les circuits secondaires séparés des circuits du a) au moyen seulement d'un transformateur;

c) l'Article K.1 pour les CIRCUITS RESEAU en CATEGORIE DE SURTENSION III ou IV, ou en CATEGORIE DE SURTENSION II au-delà de 300 V;

d) l'Article K.2 pour les circuits secondaires séparés des circuits du c) au moyen seulement d'un transformateur;

e) l'Article K.3 pour les circuits ayant une ou plusieurs des caractéristiques suivantes:

   i) la SURTENSION TRANSITOIRE maximale possible est limitée par la source d'alimentation ou à l'intérieur de l'appareil à une valeur connue inférieure aux valeurs supposées pour les CIRCUITS RESEAU;

   ii) la SURTENSION TRANSITOIRE maximale possible est supérieure aux valeurs supposées pour les CIRCUITS RESEAU;

   iii) la TENSION DE SERVICE est la somme des tensions de plusieurs circuits, ou est une tension composée;

   iv) la TENSION DE SERVICE comporte une tension de crête répétitive pouvant être composée d'une forme d'onde périodique non sinusoïdale ou d'une forme d'onde non périodique survenant régulièrement;

   v) la fréquence de la TENSION DE SERVICE est supérieure à 30 kHz.

NOTE 2 Les exigences pour l'isolation des circuits de mesure sont spécifiées dans l'IEC 61010-2-030.

NOTE 3 Voir l'Article K.3 pour les exigences des circuits à découpage tels que les alimentations de puissance à découpage.

NOTE 4 Le niveau de SURTENSION TRANSITOIRE théorique du RESEAU est égal à la tension ASSIGNEE de tenue aux chocs exigée pour les appareils dans le Tableau 443.2 de l'IEC 60364-4-44:2007/AMD1 :2015.

6.7.2 Isolation des CIRCUITS RESEAU en CATEGORIE DE SURTENSION II avec une tension nominale d'alimentation jusqu'à 300 V

6.7.2.1 DISTANCES D'ISOLEMENT et LIGNES DE FUITE

Les valeurs des DISTANCES D'ISOLEMENT et des LIGNES DE FUITE des CIRCUITS RESEAU doivent être égales aux valeurs du Tableau 4 en tenant compte des exigences suivantes:

a) les valeurs du Tableau 4 sont données pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE. Les valeurs pour l'ISOLATION RENFORCEE doivent être doublées;

b) la valeur minimale de la DISTANCE D'ISOLEMENT pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE en DEGRE DE POLLUTION 3 est de 0,8 mm;

c) si l'altitude de fonctionnement ASSIGNEE à l'appareil est supérieure à 2 000 m, les DISTANCES D'ISOLEMENT doivent être multipliées par le coefficient applicable du Tableau 3.

La conformité est vérifiée par examen et mesure.

Tableau 4 – DISTANCES D'ISOLEMENT et LIGNES DE FUITE des CIRCUITS RESEAU en CATEGORIE DE SURTENSION II jusqu'à 300 V

Tension phase-neutre alternative efficace ou continue	Valeurs de la DISTANCE D'ISOLEMENT	Valeurs de la LIGNE DE FUITE								
		Circuits imprimés		Autres matériaux isolants						
		DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2	DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2			DEGRE DE POLLUTION 3		
		Tout groupe de matériau	Matériau des groupes I, II et IIIa	Tout groupe de matériau	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
≤150	0,5	0,5	0,5	0,5	0,8	1,1	1,6	2,0	2,2	2,5
>150 ≤ 300	1,5	1,5	1,5	1,5	1,5	2,1	3,0	3,8	4,1	4,7

L'interpolation linéaire des LIGNES DE FUITE est autorisée.

Les revêtements appliqués aux surfaces extérieures des circuits imprimés et qui satisfont aux exigences de l'Annexe H réduisent le DEGRE DE POLLUTION de la zone enrobée au DEGRE DE POLLUTION 1.

La conformité des revêtements est vérifiée comme spécifié à l'Annexe H.

6.7.2.2 Isolation solide

6.7.2.2.1 Généralités

L'isolation solide des CIRCUITS RESEAU doit résister aux contraintes électriques et mécaniques pouvant survenir en UTILISATION NORMALE, dans toutes les conditions d'environnement ASSIGNEES (voir 1.4) pendant la durée de vie prévue de l'appareil.

NOTE Lors du choix des matières isolantes, il convient que le fabricant prenne en compte la durée de vie prévue de l'appareil.

La conformité est vérifiée par examen, et par l'essai en tension alternative de 6.8.3.1~~ d'une durée d'au moins 1 min ou, pour les CIRCUITS RESEAU contraints uniquement en tension continue,~~ ou l'essai en tension continue de~~ 1 min~~ de 6.8.3.2 en utilisant la tension applicable du Tableau 5 pendant 1 min.

Tableau 5 – Tensions d'essai de l'isolation solide des CIRCUITS RESEAU en CATEGORIE DE SURTENSION II jusqu'à 300 V

Tension phase-neutre alternative efficace ou continue	Essai de 1 min en tension alternative		Essai de 1 min en tension continue	
	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE
V	V	V	V	V
≤150	1 350	2 700	1 900	3 800
>150 ≤ 300	1 500	3 000	2 100	4 200

Selon le cas, l'isolation solide doit satisfaire aux exigences suivantes:

a) pour l'isolation solide utilisée en tant qu'ENVELOPPE ou BARRIERE DE PROTECTION, les exigences de l'Article 8;

b) pour les pièces moulées ou empotées, les exigences de 6.7.2.2.2;

c) pour les couches internes des circuits imprimés, les exigences de 6.7.2.2.3;

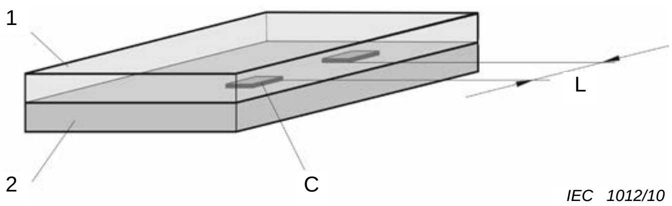
d) pour l'isolation en couche mince, les exigences de 6.7.2.2.4.

La conformité est vérifiée tel que spécifié de 6.7.2.2.2 à 6.7.2.2.4, et à l'Article 8 selon le cas.

6.7.2.2.2 Pièces moulées et empotées

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés sur l'interface entre les deux mêmes couches moulées ensemble, doivent être séparés par une distance d'au moins 0,4 mm (voir la Figure 6, point L) après l'application du moulage.

La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.



Légende

1 Couche 1

2 Couche 2

C Conducteur

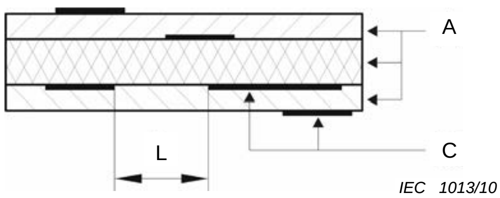
L Distance entre conducteurs

Figure 6 – Distance entre conducteurs situés sur l'interface entre deux couches

6.7.2.2.3 Couches isolantes internes des circuits imprimés

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches doivent être séparés par une distance d'au moins 0,4 mm (voir la Figure 7, point L).

La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.



Légende

L Distance entre conducteurs adjacents

A Couches

C Conducteurs

Figure 7 – Distance entre conducteurs adjacents situés sur l'interface entre deux couches internes

L'ISOLATION RENFORCEE de couches isolantes internes de circuits imprimés doit aussi avoir une rigidité électrique suffisante à travers les couches respectives. Un des moyens suivants doit être utilisé:

a) L'épaisseur de l'isolation est au moins de 0,4 mm;

   La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

b) l'isolation est constituée par au moins deux couches séparées de matière du circuit imprimé, chacune étant spécifiée par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai du Tableau 5 pour l'ISOLATION PRINCIPALE;

   La conformité est vérifiée par l'examen des spécifications du fabricant.

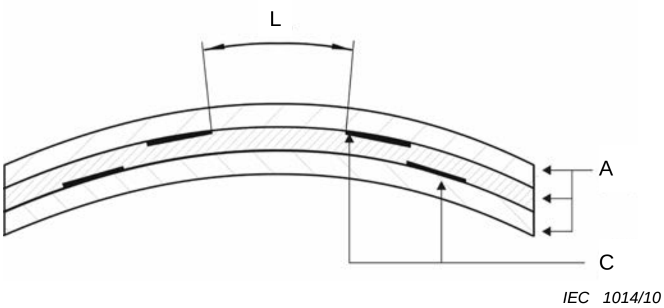
c) l'isolation est constituée par au moins deux couches séparées de matière du circuit imprimé, l'assemblage des couches étant spécifié par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai du Tableau 5 pour l'ISOLATION RENFORCEE.

La conformité est vérifiée par l'examen des spécifications du fabricant.

6.7.2.2.4 Isolation en couche mince

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches (voir la Figure 8, point L) doivent être séparés par au moins la DISTANCE D'ISOLEMENT et la LIGNE DE FUITE applicables du 6.7.2.1.

La conformité est vérifiée par examen et, soit par la mesure des distances, soit par l'examen des spécifications du fabricant.



Légende

L Distance entre conducteurs adjacents

A Couches du matériau en couche mince comme ruban ou film polyester

C Conducteurs

NOTE De l'air peut être présent entre les couches.

Figure 8 – Distance entre conducteurs adjacents situés entre les deux mêmes couches

L'ISOLATION RENFORCEE entre les couches minces doit aussi avoir une rigidité électrique suffisante. Un des moyens suivants doit être utilisé:

a) l'épaisseur de l'isolant est au moins de 0,4 mm;

La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

b) l'isolation est constituée par au moins deux couches séparées de matière, chacune étant spécifiée par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai du Tableau 5 pour l'ISOLATION PRINCIPALE;

La conformité est vérifiée par l'examen des spécifications du fabricant.

c) l'isolation est constituée par au moins trois couches séparées de matière, chaque paire de couches ayant été testée pour la rigidité électrique adéquate.

La conformité est vérifiée par l'essai en tension alternative de 6.8.3.1 ~~d'une durée d'au moins 1 min ou, pour les CIRCUITS RESEAU contraints uniquement en tension continue, par~~ ou l'essai en tension continue ~~de 1 min~~ de 6.8.3.2, effectué sur deux des trois couches en utilisant la tension applicable du Tableau 5 pendant 1 min pour l'ISOLATION RENFORCEE.

NOTE Pour les besoins de cet essai, un échantillon peut être spécialement préparé avec seulement deux couches de matière.

6.7.3 Isolation des circuits secondaires dérivés des CIRCUITS RESEAU en CATEGORIE DE SURTENSION II jusqu'à 300 V

6.7.3.1 Généralités

Dans cette norme, les circuits secondaires sont des circuits où la séparation des CIRCUITS RESEAU est réalisée par un transformateur dont les enroulements primaires sont séparés des enroulements secondaires par une ISOLATION RENFORCEE, une DOUBLE ISOLATION ou un écran connecté à la BORNE DE TERRE DE PROTECTION.

NOTE Ces circuits sont supposés être soumis à des niveaux de SURTENSIONS TRANSITOIRES inférieurs à ceux des CIRCUITS RESEAU.

6.7.3.2 DISTANCES D'ISOLEMENT

Les DISTANCES D'ISOLEMENT des circuits secondaires doivent:

a) être égales aux valeurs du Tableau 6 pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE, ou le double pour l'ISOLATION RENFORCEE; ou
b) tenir l'essai de tension du 6.8 en utilisant la tension d'essai applicable du Tableau 6.

Les exigences supplémentaires suivantes sont applicables:

1) les valeurs de la tension d'essai pour l'ISOLATION RENFORCEE sont 1,6 fois les valeurs pour l'ISOLATION PRINCIPALE:
2) si l'altitude de fonctionnement ASSIGNEE à l'appareil est supérieure à 2 000 m, les valeurs des DISTANCES D'ISOLEMENT sont multipliées par le coefficient applicable du Tableau 3;
3) la valeur minimale de la DISTANCE D'ISOLEMENT est de 0,2 mm en DEGRE DE POLLUTION 2 et de 0,8 mm en DEGRE DE POLLUTION 3.

La conformité est vérifiée par examen et mesure, et pour b) par l'essai en tension alternative de 6.8.3.1 d'une durée d'au moins 5 s ou par l'essai en tension continue de 1 min de 6.8.3.2, en utilisant la tension d'essai applicable du Tableau 6. La valeur de la tension d'essai continue est de $\sqrt{2}$ fois la tension d'essai alternative efficace.

Tableau 6 – DISTANCES D'ISOLEMENT et tensions d'essai des circuits secondaires dérivés des CIRCUITS RESEAU en CATEGORIE DE SURTENSION II jusqu'à 300 V

TENSION DE SERVICE au secondaire		Tension RESEAU, phase-neutre, CATEGORIE DE SURTENSION II			
		≤ 150 V alternatif efficace		> 150 ≤ 300 V alternatif efficace	
Alternatif efficace V	Continu ou alternatif crête V	DISTANCE D'ISOLEMENT mm	Tension d'essai V alternatif efficace	DISTANCE D'ISOLEMENT mm	Tension d'essai V alternatif efficace
16	22,6	0,10	500	~~0,50~~ 0,48	~~840~~ 830
~~33~~ 30	~~46,7~~ 42,4	0,11	510	~~0,52~~ 0,50	~~850~~ 840
50	70	0,12	520	0,53	860
100	140	0,13	540	0,61	900
150	210	0,16	580	0,69	940
300	420	0,39	770	0,94	1 040
600	840	1,01	1 070	1,61	1 450
1 000	1 400	1,92	1 630	2,52	1 970
1 250	1 750	2,50	1 960	3,16	2 280
1 600	2 240	3,39	2 390	4,11	2 730
2 000	2 800	4,49	2 890	5,30	3 230
2 500	3 500	6,02	3 520	6,91	3 850
3 200	4 480	8,37	4 390	9,16	4 660
4 000	5 600	10,9	5 320	11,6	5 610
5 000	7 000	14,0	6 590	14,9	6 960
6 300	8 820	18,2	8 270	19,1	8 620
8 000	11 200	23,9	10 400	24,7	10 700
10 000	14 000	30,7	12 900	31,6	13 300
12 500	17 500	39,6	16 100	40,5	16 400
16 000	22 400	52,5	20 400	53,5	20 700
20 000	28 000	67,9	25 300	68,9	25 600
25 000	35 000	87,9	31 600	89,0	32 000
32 000	44 800	117	40 400	118	40 700
40 000	56 000	151	50 300	153	50 800
50 000	70 000	196	62 800	198	63 400
63 000	88 200	258	79 400	260	80 000
L'interpolation linéaire est permise.					

6.7.3.3 LIGNES DE FUITE

Pour l'ISOLATION PRINCIPALE ou l'ISOLATION SUPPLEMENTAIRE, les LIGNES DE FUITE des circuits secondaires doivent avoir les valeurs spécifiées dans le Tableau 7 basées sur la valeur de la TENSION DE SERVICE qui contraint l'isolation. Les valeurs pour l'ISOLATION RENFORCEE sont le double des valeurs pour l'ISOLATION PRINCIPALE.

La conformité est vérifiée par examen et mesure.

Les revêtements appliqués aux surfaces extérieures des circuits imprimés et qui satisfont aux exigences de l'Annexe H réduisent le DEGRE DE POLLUTION de la zone enrobée au DEGRE DE POLLUTION 1.

La conformité des revêtements est vérifiée comme spécifié à l'Annexe H.

Tableau 7 – LIGNES DE FUITE des circuits secondaires

TENSION DE SERVICE secondaire alternative efficace ou continue	Circuits imprimés		Autres matériaux isolants						
	DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2	DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2			DEGRE DE POLLUTION 3		
	Tout groupe de matériau	Matériau des groupes I, II et IIIa	Tout groupe de matériau	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III [b]
V	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	0,025	0,04	0,08	0,40	0,40	0,40	1,00	1,00	1,00
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05
16	0,025	0,04	0,10	0,45	0,45	0,45	1,10	1,10	1,10
20	0,025	0,04	0,11	0,48	0,48	0,48	1,20	1,20	1,20
25	0,025	0,04	0,125	0,50	0,50	0,50	1,25	1,25	1,25
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3
40	0,025	0,04	0,16	0,56	0,80	1,10	1,4	1,6	1,8
50	0,025	0,04	0,18	0,60	0,85	1,20	1,5	1,7	1,9
63	0,040	0,063	0,20	0,63	0,90	1,25	1,6	1,8	2,0
80	0,063	0,10	0,22	0,67	0,95	1,3	1,7	1,9	2,1
100	0,10	0,16	0,25	0,71	1,00	1,4	1,8	2,0	2,2
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4
160	0,25	0,40	0,32	0,80	1,1	1,6	2,0	2,2	2,5
200	0,40	0,63	0,42	1,00	1,4	2,0	2,5	2,8	3,2
250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0
320	0,75	1,6	0,75	1,60	2,2	3,2	4,0	4,5	5,0
400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0
630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0
800	2,4	4,0	2,4	4,0	5,6	8,0	10,0	11	12,5
1 000	3,2 [a]	5,0 [a]	3,2	5,0	7,1	10,0	12,5	14	16
1 250			4,2	6,3	9,0	12,5	16	18	20
1 600			5,6	8,0	11	16	20	22	25
2 000			7,5	10,0	14	20	25	28	32
2 500			10,0	12,5	18	25	32	36	40
3 200			12,5	16	22	32	40	45	50
4 000			16	20	28	40	50	56	63
5 000			20	25	36	50	63	71	80
6 300			25	32	45	63	80	90	100
8 000			32	40	56	80	100	110	125
10 000			40	50	71	100	125	140	160
12 500			50	63	90	125			
16 000			63	80	110	160			
20 000			80	100	140	200			
25 000			100	125	180	250			
32 000			125	160	220	320			
40 000			160	200	280	400			
50 000			200	250	360	500			
63 000			250	320	450	600			

[a] Pour les tensions supérieures à 1 000 V, les LIGNES DE FUITE sur les circuits imprimés sont les mêmes que celles des autres matériaux isolants du même groupe de matériaux.

[b] Les matériaux du groupe IIIb ne sont pas recommandés pour les applications au-dessus de 630 V en DEGRE DE POLLUTION 3.

L'interpolation linéaire est permise.

6.7.3.4 Isolation solide

6.7.3.4.1 Généralités

L'isolation solide des circuits secondaires doit résister aux contraintes électriques et mécaniques pouvant survenir en UTILISATION NORMALE, dans toutes les conditions d'environnement ASSIGNEES (voir 1.4) pendant la durée de vie prévue de l'appareil.

NOTE Lors du choix des matières isolantes, il convient que le fabricant prenne en compte la durée de vie prévue de l'appareil.

La conformité est vérifiée par les deux essais suivants à la fois:

a) l'essai en tension alternative de 6.8.3.1 d'une durée d'au moins 5 s en utilisant la tension d'essai applicable du Tableau 6 pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE. La valeur de la tension d'essai est multipliée par 1,6 pour l'ISOLATION RENFORCEE;

b) en plus, si la TENSION DE SERVICE dépasse 300 V, par l'essai de tension de 6.8.3.1 pendant 1 min. La tension d'essai vaut 1,5 fois la TENSION DE SERVICE pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE et deux fois la TENSION DE SERVICE pour l'ISOLATION RENFORCEE.

Selon le cas, l'isolation solide doit satisfaire aux exigences suivantes:

1) pour l'isolation solide utilisée en tant qu'ENVELOPPE ou BARRIERE DE PROTECTION, les exigences de l'Article 8;
2) pour les pièces moulées ou empotées, les exigences de 6.7.3.4.2;
3) pour les couches internes des circuits imprimés, les exigences de 6.7.3.4.3;
4) pour l'isolation en couche mince, les exigences de 6.7.3.4.4.

La conformité est vérifiée tel que spécifié de 6.7.3.4.2 à 6.7.3.4.4, et à l'Article 8, selon le cas.

6.7.3.4.2 Parties moulées et empotées

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches moulées doivent être séparés par la distance minimale applicable du Tableau 8 (voir la Figure 6, point L).

La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

Tableau 8 – Valeurs minimales de la distance ou de l'épaisseur (voir 6.7.3.4.2 à 6.7.3.4.4)

Valeur crête de la TENSION DE SERVICE alternative ou continue ou de la tension de crête répétitive	Valeur minimale	Valeur crête de la TENSION DE SERVICE alternative ou continue ou de la tension de crête répétitive	Valeur minimale
kV	mm	kV	mm
>0,046 7 ≤ 0,33	0,05	>8,0 ≤ 10	3,5
>0,33 ≤ 0,8	0,1	>10 ≤ 12	4,5
>0,8 ≤ 1,0	0,15	>12 ≤ 15	5,5
>1,0 ≤ 1,2	0,2	>15 ≤ 20	8
>1,2 ≤ 1,5	0,3	>20 ≤ 25	10
>1,5 ≤ 2,0	0,45	>25 ≤ 30	12,5
>2,0 ≤ 2,5	0,6	>30 ≤ 40	17
>2,5 ≤ 3,0	0,8	>40 ≤ 50	22
>3,0 ≤ 4,0	1,2	>50 ≤ 60	27
>4,0 ≤ 5,0	1,5	>60 ≤ 80	35
>5,0 ≤ 6,0	2	80 ≤ 100	45
>6,0 ≤ 8,0	3		

6.7.3.4.3 Couches isolantes internes des circuits imprimés

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches doivent être séparés par la distance minimale applicable du Tableau 8 (voir la Figure 7, point L).

La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

L'ISOLATION RENFORCEE des couches isolantes internes des circuits imprimés doit aussi avoir une rigidité électrique suffisante entre les couches respectives. Un des moyens suivants doit être utilisé:

a) l'épaisseur de l'isolation est au moins la distance minimale applicable du Tableau 8;

   La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

b) l'isolation est constituée par au moins deux couches séparées de matière du circuit imprimé, chacune étant spécifiée par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai du Tableau 6 pour l'ISOLATION PRINCIPALE;

   La conformité est vérifiée par l'examen des spécifications du fabricant.

c) l'isolation est constituée par au moins deux couches séparées de matière du circuit imprimé, l'assemblage des couches étant spécifié par le fabricant de la matière pour une rigidité électrique ASSIGNEE valant au moins la tension d'essai applicable du Tableau 6 multipliée par 1,6 pour l'ISOLATION RENFORCEE..

   La conformité est vérifiée par l'examen des spécifications du fabricant.

6.7.3.4.4 Isolation en couche mince

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches (voir la Figure 8, point L) doivent être séparés par au moins la DISTANCE D'ISOLEMENT et la LIGNE DE FUITE applicables des 6.7.3.2 et 6.7.3.3.

La conformité est vérifiée par examen et, soit par la mesure des distances, soit par l'examen des spécifications du fabricant.

L'ISOLATION RENFORCEE à travers les couches minces doit aussi avoir une rigidité électrique suffisante. Un des moyens suivants doit être utilisé:

a) l'épaisseur de l'isolation est au moins la distance minimale applicable du Tableau 8;

   La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

b) l'isolation est constituée par au moins deux couches séparées de matière, chacune étant spécifiée par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai du Tableau 6 pour l'ISOLATION PRINCIPALE;

   La conformité est vérifiée par l'examen des spécifications du fabricant.

c) l'isolation est constituée par au moins trois couches séparées de matière, chaque paire de couches ayant été testée pour la rigidité électrique adéquate.

   La conformité est vérifiée par l'essai en tension alternative de 6.8.3.1 d'une durée d'au moins 1 min ou, pour les circuits contraints uniquement en tension continue, l'essai en tension continue de 1 min de 6.8.3.2 effectué sur deux des trois couches en utilisant 1,6 fois la tension applicable du Tableau 6.

   NOTE Pour les besoins de cet essai, un échantillon peut être spécialement préparé avec seulement deux couches de matière.

6.8 Procédure pour les essais de tension

6.8.1 Généralités

Les méthodes d'essai suivantes s'appliquent aux ESSAIS DE TYPE, et la détérioration du spécimen de test est possible. L'utilisation ultérieure du spécimen de test peut ne pas être appropriée.

Les équipements d'essais pour les essais de tension sont spécifiés dans les normes IEC 61180-1 et IEC 61180-2.

Les parties isolantes ACCESSIBLES de l'ENVELOPPE sont entièrement couvertes avec une feuille de métal sauf autour des BORNES. Pour les valeurs de tension d'essai allant jusqu'à 10 kV alternatifs crêtes ou continus, la distance de la feuille à la BORNE ne doit pas excéder 20 mm. Pour les valeurs supérieures,c'est la valeur minimale pour éviter l'arc. Voir le Tableau 9 pour ces distances minimales.

NOTE Les distances du Tableau 9 empêcheront l'apparition d'un arc entre la feuille et les BORNES.

Tableau 9 – Distances entre les BORNES et la feuille

Tension d'essai	Distance
kV	mm
10	20
20	45
30	70
50	130
70	195
100	290

Les parties ACCESSIBLES des organes de commandes réalisés en matériau isolant sont enveloppées dans une feuille de métal ou sont recouvertes d'un matériau conducteur souple pressé contre elles.

La feuille de métal est posée après le pré-conditionnement à l'humidité (si applicable) et connectée à la BORNE froide du générateur de tension d'essai.

Lors de la vérification d'une DISTANCE D'ISOLEMENT dans l'appareil, il est nécessaire de s'assurer que la tension spécifiée est bien appliquée à la DISTANCE D'ISOLEMENT. L'IMPEDANCE DE PROTECTION, les impédances et les limiteurs de tension en parallèle avec l'isolation à soumettre à l'essai peuvent être débranchés.

L'appareil n'est pas alimenté durant les essais.

Les tensions d'essai de 6.7 pour les DISTANCES D'ISOLEMENT sont celles applicables à un site d'essai à une altitude de 2 000 m. Pour des sites d'essai situés à d'autres altitudes, les tensions d'essai sont multipliées par le coefficient applicable du Tableau 10. Ces coefficients ne s'appliquent qu'aux tensions d'essai des DISTANCES D'ISOLEMENT et non de l'isolation solide.

NOTE 1 Les essais de tension des DISTANCES D'ISOLEMENT vont aussi contraindre l'isolation solide associée.

NOTE 2 Là où deux moyens de protection ou plus sont utilisés en association (voir 6.5.1), les tensions spécifiées pour l'ISOLATION RENFORCEE pourraient être appliquées à des parties de circuits qui n'ont pas à tenir ces tensions. Pour éviter cela, de telles parties peuvent être déconnectées pendant les essais.

Tableau 10 – Coefficients de correction des tensions d'essai des DISTANCES D'ISOLEMENT suivant l'altitude du site d'essai

	Coefficients de correction			
Tension d'essai crête	**≥327 V < 600 V**	**≥600 V < 3 500 V**	**≥3 500 V < 25 kV**	**≥25 kV**
Tension d'essai efficace	**≥231 V < 424 V**	**≥424 V < 2 475 V**	**≥2 475 V < 17,7 kV**	**≥17,7 kV**
Altitude du site d'essai m				
0	1,08	1,16	1,22	1,24
500	1,06	1,12	1,16	1,17
1 000	1,04	1,08	1,11	1,12
2 000	1,00	1,00	1,00	1,00
3 000	0,96	0,92	0,89	0,88
4 000	0,92	0,85	0,80	0,79
5 000	0,88	0,78	0,71	0,70
L'interpolation linéaire est autorisée.				

6.8.2 Pré-conditionnement à l'humidité

L'appareil est soumis à un pré-conditionnement à l'humidité avant d'effectuer les essais de tension, sauf indication contraire dans cette norme. L'appareil n'est pas alimenté pendant le pré-conditionnement.

Ce traitement ne doit pas être appliqué aux parties qui clairement ne peuvent pas être influencées par l'humidité et la température.

Les parties qui peuvent être démontées sans l'aide d'un OUTIL sont déposées et soumises au pré-conditionnement à l'humidité en même temps que la partie principale.

Le préconditionnement est effectué dans une étuve contenant de l'air ayant une humidité de 93 % HR ± 3 % HR. La température de l'air dans l'étuve doit être maintenue à 40 °C ± 2 °C.

Avant d'appliquer l'humidité, l'appareil est porté à une température de 42 °C ± 2 °C et est normalement maintenu à cette température pendant au moins 4 h avant de le soumettre au pré-conditionnement à l'humidité.

L'air de l'étuve est brassé et aucune condensation ne doit se produire sur l'appareil.

L'appareil reste dans l'étuve pendant 48 h. Au bout de cette période, on le retire et on le laisse récupérer pendant 2 h dans les conditions d'environnement de 4.3.1, les couvercles des appareils non ventilés étant retirés.

Les essais sont effectués et achevés dans l'heure qui suit la fin de la période de reprise, après le pré-conditionnement à l'humidité. Les parties qui ont été démontées, sont remontées ou non, selon ce qui est le moins favorable.

6.8.3 Conduite des essais

6.8.3.1 Essai en tension alternative

~~Le générateur doit pouvoir fournir une puissance de 500 VA au minimum.~~ Le générateur de tension doit avoir une sortie régulée capable de maintenir la tension d'essai tout au long de

l'essai. La forme d'onde de la tension d'essai~~ à fréquence industrielle~~ doit être~~ à peu près~~ *pratiquement* sinusoïdale.~~ Il faut que~~ *Cette exigence est remplie si* le rapport entre la valeur crête et la valeur efficace~~ de la tension soit~~ *est* de $\sqrt{2} \pm 3$ %.

L'essai en tension alternative est réalisé à la fréquence ASSIGNEE du RESEAU, mais pour les appareils ayant des fréquences réseau ASSIGNEES de 50 Hz et 60 Hz, un essai à 50 Hz ou à 60 Hz est suffisant.

La tension d'essai est augmentée uniformément de zéro volt à la valeur spécifiée en moins de 5 s et maintenue à cette valeur pendant le temps spécifié.

Aucun arc dans les DISTANCES D'ISOLEMENT ou claquage partiel de l'isolation solide ne doit se produire durant l'essai.

6.8.3.2 Essai en tension continue~~ de 1 min~~

La tension d'essai continue ne doit pas avoir trop d'ondulation. Il faut que le rapport de la valeur crête à la valeur moyenne de la tension soit de 1,0 $\pm$ 3 %.

La tension d'essai continue est augmentée uniformément de 0 V à la valeur spécifiée en moins de 5 s et maintenue à cette valeur pendant~~ 1 min~~ au moins le temps spécifié.

Aucun arc dans les DISTANCES D'ISOLEMENT ou claquage partiel de l'isolation solide ne doit se produire durant l'essai.

6.8.3.3 Essai de tension de choc

L'essai doit être effectué en appliquant cinq impulsions de chaque polarité espacées d'au moins 1 s. Le générateur doit produire une tension de forme d'onde 1,2/50 μs (voir la Figure 1 dans l'IEC 61180-1). La forme d'onde de chaque impulsion de choc doit être vérifiée (voir la Note 1).

Lors de la vérification des DISTANCES D'ISOLEMENT dans l'appareil par l'essai de tension de choc, il est nécessaire de s'assurer que la tension de l'onde de choc spécifiée est bien appliqué à la DISTANCE D'ISOLEMENT. L'IMPEDANCE DE PROTECTION et les limiteurs de tensions en parallèle avec l'isolation à tester doivent être débranchés.

Aucun arc dans les DISTANCES D'ISOLEMENT ou claquage partiel de l'isolation solide ne doit se produire durant l'essai, mais des décharges partielles sont admises. Un claquage partiel sera indiqué par un échelon dans la forme d'onde résultante et cet échelon apparaîtra prématurément dans les tensions de chocs successives. Un claquage sur la première impulsion peut indiquer soit une défaillance complète du système d'isolation, soit le fonctionnement de limiteurs de surtensions présents dans l'appareil.

NOTE 1 Si l'appareil comporte des limiteurs de surtensions, des précautions doivent être prises pour examiner la forme d'onde afin de s'assurer que leur fonctionnement ne conduit pas à l'interpréter comme une défaillance de l'isolation. Les distorsions de la tension de choc qui ne varient pas d'une impulsion à l'autre, peuvent être occasionnées par le fonctionnement de limiteurs de surtensions et n'indiquent pas un claquage (partiel) de l'isolation solide.

NOTE 2 Des décharges partielles au niveau des soufflures peuvent entraîner des discontinuités d'une durée extrêmement brève qui peuvent se répéter au cours d'une impulsion.

6.9 Exigences relatives à la construction pour la protection contre les chocs électriques

6.9.1 Généralités

Si une défaillance peut provoquer un DANGER:

a) la sécurité des connexions câblées soumises à des contraintes mécaniques ne doit pas dépendre uniquement de la soudure;
b) les vis qui fixent les couvercles amovibles doivent être imperdables si leur longueur détermine une LIGNE DE FUITE ou une DISTANCE D'ISOLEMENT entre parties conductrices ACCESSIBLES et parties sous TENSION DANGEREUSE;
c) un desserrage ou une libération accidentelle des câbles, vis, etc. ne doit pas rendre des parties ACCESSIBLES sous TENSION DANGEREUSE;
d) les LIGNES DE FUITE et les DISTANCES D'ISOLEMENT entre l'ENVELOPPE et des parties sous TENSION DANGEREUSE ne doivent pas être réduites en dessous des valeurs de l'ISOLATION PRINCIPALE en cas de desserrage de parties ou de câbles.

NOTE Les vis ou écrous munis de rondelles frein ne sont pas considérés comme susceptibles de se desserrer; il en est de même pour les fils qui sont fixés mécaniquement par un moyen supplémentaire à la seule soudure.

La conformité est vérifiée par examen et par la mesure des LIGNES DE FUITE et des DISTANCES D'ISOLEMENT.

6.9.2 Matériaux isolants

Les matériaux qui suivent ne doivent pas être utilises comme isolant quand la sécurité est impliquée:

a) les matériaux qui peuvent être facilement endommagés (par exemple: laque, émail, oxydes et films anodiques);
b) les matériaux hygroscopiques non imprégnés (par exemple: papier, fibres et les matériaux fibreux).

La conformité est vérifiée par examen.

6.9.3 Codage des couleurs

Les isolants de couleur verte et jaune ne doivent être utilisés que pour:

a) les conducteurs des terres de protection;
b) les conducteurs des LIAISONS PROTECTRICES;
c) les conducteurs d'équilibrage de potentiel à des fins de sécurité;
d) les conducteurs de terre fonctionnelle.

La conformité est vérifiée par examen.

6.10 Raccordement à la source d'alimentation RESEAU et connexion entre les parties de l'appareil

6.10.1 Cordons d'alimentation RESEAU

Les exigences suivantes s'appliquent à la fois aux cordons d'alimentation RESEAU à demeure et aux cordons d'alimentation RESEAU fournis avec les appareils.

Les cordons doivent être de calibre ASSIGNE pour le courant maximal prévu pour l'appareil et le câble utilisé doit être conforme à l'IEC 60227 ou IEC 60245. Les cordons certifiés et approuvés par tout laboratoire national d'essai national sont considérés comme conformes à cette exigence.

Si le cordon peut toucher une partie externe très chaude de l'appareil, il doit être réalisé avec un matériau adapté résistant à la chaleur.

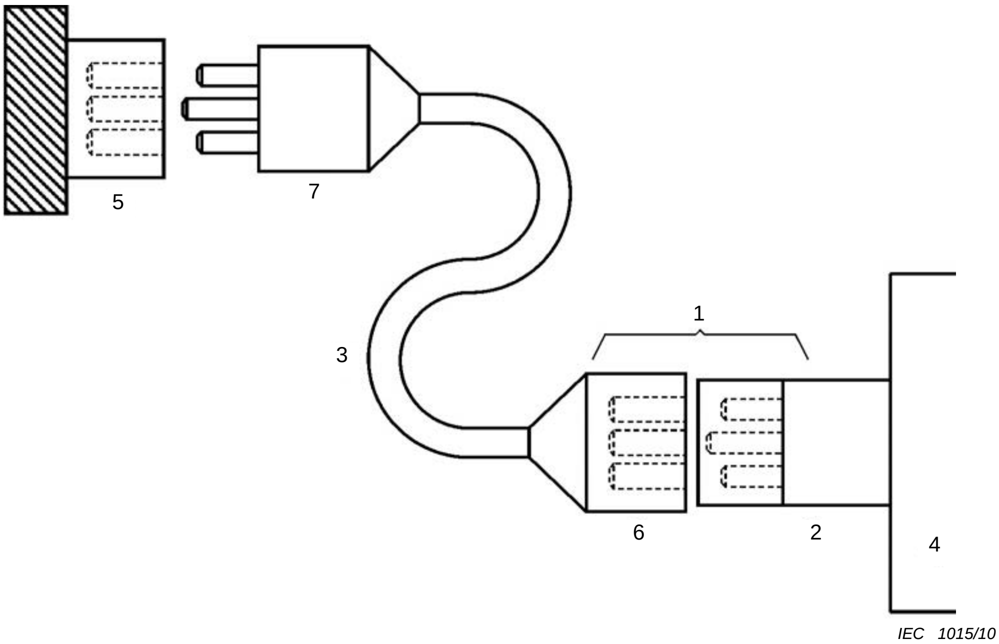
Lorsqu'un cordon amovible est utilisé, le cordon et le socle du connecteur doivent avoir des températures ASSIGNEES compatibles.

Les conducteurs de couleur vert/jaune doivent être uniquement utilisés pour assurer la connexion avec des BORNES DE TERRE DE PROTECTION.

Les cordons d'alimentation RESEAU amovibles avec fiches mobiles RESEAU femelles conformes à l'IEC 60320 doivent, soit correspondre aux exigences de l'IEC 60799, soit être de calibre ASSIGNE au moins pour le courant ASSIGNE de la fiche mobile RESEAU femelle fixée au cordon.

La Figure 9 donne la terminologie pour les cordons d'alimentation RESEAU.

La conformité est vérifiée par examen et, si nécessaire, par mesure.



Légende

1 Connecteur

2 Socle de connecteur

3 Cordon d'alimentation amovible

4 Appareil

5 Socle fixe de prise de courant RESEAU

6 Fiche mobile RESEAU femelle

7 Fiche mobile RESEAU mâle

Figure 9 – Cordons d'alimentation RESEAU amovibles et connexions

6.10.2 Mise en place des cordons d'alimentation RESEAU non détachables

6.10.2.1 Point d'entrée du cordon

Les cordons d'alimentation RESEAU doivent être protégés contre l'abrasion et contre les flexions à faible rayon de courbure, au point où le cordon s'insère dans l'appareil, par l'un des moyens suivants:

a) un orifice d'entrée ou une traversée de cloison avec une ouverture bien arrondie;

b) une protection de cordon souple solidement fixée, en matière isolante, qui dépasse l'orifice d'entrée d'au moins cinq fois le diamètre hors tout du cordon ayant la section la plus importante pouvant être utilisée. Pour ce qui concerne les cordons méplats, la dimension de la section la plus importante est prise comme diamètre hors tout.

La conformité est vérifiée par examen et, si nécessaire, par mesure des dimensions.

6.10.2.2 Fixation du cordon

La fixation du cordon doit protéger les conducteurs du cordon des contraintes, y compris la torsion à l'endroit où ils sont connectés à l'appareil, et doit protéger l'isolation des conducteurs contre l'abrasion. Si le cordon glisse dans sa fixation, le conducteur de terre de protection, s'il existe, doit être le dernier à supporter la contrainte.

La fixation du cordon doit être conforme aux exigences suivantes:

a) le cordon ne doit pas être serré par une vis qui porte directement sur lui;

b) il ne doit pas y avoir de nœuds sur le cordon;

c) le cordon ne doit pas pouvoir être poussé dans l'appareil au point d'entraîner un DANGER;

d) une défaillance de l'isolation du cordon dans une fixation de cordon comportant des parties métalliques ne doit pas porter SOUS TENSION DANGEREUSE des parties conductrices ACCESSIBLES;

e) elle ne doit pas pouvoir être desserrée sans l'aide d'un OUTIL;

f) elle doit être conçue de telle sorte que le remplacement du cordon n'entraîne pas de DANGER et la manière d'empêcher les contraintes doit apparaître nettement.

Un presse-étoupe ne doit pas être utilisé comme fixation de cordon, à moins qu'il ne soit adapté pour une utilisation avec le cordon d'alimentation RESEAU qui est fourni avec ou indiqué par le fabricant.

La conformité est vérifiée par examen et par l'essai de poussée-traction suivant:

Pour chaque association cordon/presse-étoupe, le cordon est poussé manuellement aussi loin que possible à l'intérieur de l'appareil. Il est ensuite soumis 25 fois à une traction constante de la valeur de la force indiquée au Tableau 11, appliquée pendant 1 s dans la direction la moins favorable. Immédiatement après, le cordon est soumis pendant 1 min à une torsion de la valeur du couple indiqué au Tableau 11. La torsion doit être appliquée aussi près que possible de l'extrémité extérieure de la fixation du cordon ou du presse-étoupe.

Tableau 11 – Valeurs des essais mécaniques sur les fixations de cordon

Masse de l'appareil kg	Force N	Couple N·m
≤1	30	0,10
>1 ≤4	60	0,25
>4	100	0,35

Après les essais:

1) *le cordon ne doit pas être endommagé;*

2) *le cordon ne doit pas avoir été déplacé longitudinalement de plus de 2 mm;*

3) *aucun signe de contrainte ne doit apparaître à l'endroit où la fixation serre le cordon;*

4) *les DISTANCES D'ISOLEMENT et les LIGNES DE FUITE ne doivent pas avoir été réduites en dessous des valeurs applicables;*

5) *le cordon doit tenir l'essai en tension alternative de 6.8.3.1 (sans le pré-conditionnement à l'humidité) avec une durée de 1 min au minimum comme suit:*

   i) *pour les appareils ayant un conducteur de terre de protection, l'essai est fait entre le conducteur de protection et les conducteurs de phase et neutre joints ensemble, avec la tension d'essai applicable pour l'ISOLATION PRINCIPALE du Tableau 5 ou du Tableau K.8 pour la tension phase-neutre appropriée;*

ii) pour les appareils sans conducteur de terre de protection, l'essai est fait entre les parties conductrices ACCESSIBLES de l'appareil et les conducteurs de phase et neutre joints ensemble, en utilisant la tension d'essai applicable du Tableau 5 ou du Tableau K.8 pour l'ISOLATION RENFORCEE.

6.10.3 Fiches mobiles mâles et femelles

Les fiches mobiles mâles et femelles destinées au raccordement de l'appareil à l'alimentation RESEAU, y compris les connecteurs utilisés pour le raccordement des cordons d'alimentation RESEAU amovibles à l'appareil, doivent être conformes aux spécifications correspondantes applicables aux fiches mobiles mâles, aux socles de prise de courant et aux fiches mobiles femelles.

Si l'appareil est uniquement conçu pour être alimenté par des tensions inférieures à celles qui sont indiquées en 6.3.2 a) en CONDITION NORMALE ou en CONDITION DE PREMIER DEFAUT, ou alimenté à partir d'une source uniquement utilisée pour alimenter l'appareil en question, les fiches du cordon d'alimentation ne doivent pas s'adapter aux prises de courant des systèmes d'alimentation RESEAU de tensions supérieures à la valeur de la tension d'alimentation ASSIGNEE de l'appareil. Les fiches mobiles mâles et les socles de type RESEAU ne doivent pas être utilisés pour un autre usage que celui de la liaison à l'alimentation RESEAU.

Si les broches des fiches d'un appareil relié par cordon reçoivent une charge d'un condensateur interne, les broches ne doivent pas être sous TENSION DANGEREUSE 5 s après coupure de l'alimentation.

Sur les appareils munis de socles fixes de prises de courant RESEAU auxiliaires:

a) si le socle peut recevoir une fiche de courant RESEAU normalisée, il doit y avoir un marquage conforme au 5.1.3 e);
b) si le socle est muni d'un contact de BORNE pour un conducteur de terre de protection, la connexion de raccordement de l'appareil à l'entrée de l'alimentation RESEAU doit comporter un conducteur de terre de protection branché à une BORNE DE TERRE DE PROTECTION.

La conformité est vérifiée par examen. Pour les fiches recevant une charge d'un condensateur interne, les mesures de 6.3 sont effectués afin de s'assurer que les niveaux de 6.3.1 c) ne sont pas dépassés.

6.11 Sectionnement de la source d'alimentation

6.11.1 Généralités

A part les exceptions indiquées dans le 6.11.2, l'appareil doit être muni d'un dispositif permettant de le déconnecter de chaque source d'alimentation électrique, qu'elle soit interne ou externe à l'appareil. Les dispositifs de sectionnement doivent sectionner tous les conducteurs véhiculant le courant.

NOTE Les appareils peuvent aussi être munis d'un interrupteur ou d'un autre dispositif de sectionnement à des fins fonctionnelles.

La conformité est vérifiée conformément aux 6.11.3.1 à 6.11.4.3.

6.11.2 Exceptions

Un dispositif de sectionnement n'est pas exigé si un court-circuit ou une surcharge ne peut pas entraîner un DANGER.

NOTE Les exemples comprennent:

a) appareils uniquement destinés à être alimentés par une source de basse énergie telle qu'une petite pile ou par les signaux d'entrée/sortie;

b) appareils destinés à être raccordés à une alimentation protégée par impédance. Une telle alimentation possède une impédance telle que, lorsque l'appareil est soumis à un court-circuit ou à une surcharge, les conditions ASSIGNEES d'alimentation ne sont pas dépassées et aucun DANGER ne peut être engendré;

c) appareils constitués par une charge protégée par impédance. Une telle charge est un composant sans protection discrète contre les surintensités ni protection thermique, dont l'impédance est telle que les CARACTERISTIQUES ASSIGNEES ne sont pas dépassées lorsque le circuit, dont le composant fait partie, est soumis à un court-circuit ou à une surcharge.

La conformité est vérifiée par examen. En cas de doute, un court-circuit ou une surintensité est appliqué afin de vérifier qu'aucun DANGER ne peut apparaître.

6.11.3 Exigences selon les types d'appareil

6.11.3.1 APPAREILS BRANCHES EN PERMANENCE et appareils polyphasés

Les APPAREILS BRANCHES EN PERMANENCE et les appareils polyphasés doivent utiliser un interrupteur ou un disjoncteur comme moyen de sectionnement.

Lorsqu'un interrupteur ne fait pas partie de l'appareil, la documentation relative à l'installation de l'appareil doit spécifier qu'il faut:

a) qu'un interrupteur ou un disjoncteur soit inclus dans l'installation électrique;
b) qu'il soit placé convenablement et facilement accessible;
c) qu'il soit marqué comme étant le dispositif de coupure de l'appareil.

La conformité est vérifiée par examen.

6.11.3.2 Appareils monophasés branchés par cordon

Les appareils monophasés branchés par cordon doivent être munis de l'un des dispositifs de sectionnement suivants:

a) un interrupteur ou un disjoncteur;
b) un connecteur qui peut être débranché sans l'utilisation d'un OUTIL;
c) une fiche mobile séparable, sans dispositif de verrouillage, entrant dans un socle de prise de courant du bâtiment.

La conformité est vérifiée par examen.

6.11.4 Dispositifs de sectionnement

6.11.4.1 Généralités

Si un dispositif de sectionnement fait partie de l'appareil, il doit être électriquement situé aussi près que possible de l'alimentation. Les composants consommateurs d'énergie ne doivent pas être situés électriquement entre la source d'alimentation et le dispositif de sectionnement sauf les circuits de suppression des perturbations électromagnétiques qui peuvent se trouver sur le circuit d'alimentation du dispositif de sectionnement.

La conformité est vérifiée par examen.

6.11.4.2 Interrupteurs et disjoncteurs

Tout ~~interrupteur ou~~ disjoncteur utilisé comme dispositif de sectionnement doit ~~correspondre~~ satisfaire aux exigences de ~~l'IEC 60947-1 et de l'IEC 60947-3~~ l'IEC 60947-2 et être adapté à l'application.

Tout interrupteur utilisé comme dispositif de sectionnement doit satisfaire aux exigences applicables de l'IEC 60947-3 et être adapté à l'application.

Si un interrupteur ou un disjoncteur est utilisé comme dispositif de sectionnement, il doit avoir un marquage précisant cette fonction. Dans le cas où il n'y aurait qu'un seul dispositif – un interrupteur ou un disjoncteur – les symboles 9 et 10 du Tableau 1 sont suffisants s'ils sont apposés sur l'interrupteur ou le disjoncteur ou adjacents à ces derniers.

Un interrupteur ne doit pas être intégré à un cordon d'alimentation RESEAU.

Un interrupteur ou disjoncteur ne doit interrompre aucun conducteur de terre de protection.

La conformité est vérifiée par examen.

6.11.4.3 Connecteurs et fiches

Si un connecteur ou une fiche mobile séparable est utilisé comme dispositif de sectionnement, il doit être immédiatement identifiable et à portée de main de l'OPERATEUR. Pour un APPAREIL PORTABLE monophasé, une fiche d'un cordon dont la longueur n'est pas supérieure à 3 m est considérée comme étant à portée de main. Le conducteur de terre de protection d'un connecteur doit être connecté avant les conducteurs d'alimentation et être déconnecté après eux.

La conformité est vérifiée par examen.

7 Protection contre les DANGERS mécaniques

7.1 Généralités

L'équipement ne doit pas causer un DANGER mécanique en UTILISATION NORMALE ou causer un DANGER en CONDITION DE PREMIER DEFAUT qui ne puisse être aisément signalé. Les DANGERS mécaniques sont, entre autres, les suivants:

a) les arêtes tranchantes qui pourraient causer des coupures (voir 7.2);

b) les pièces mobiles qui pourraient écraser des parties du corps ou pénétrer dans la peau (voir 7.3);

c) un appareil instable qui pourrait tomber sur une personne durant son utilisation ou en étant déplacé (voir 7.4);

d) un appareil dont la chute résulterait de la rupture d'un dispositif de transport (voir 7.5), d'un support mural (voir 7.6) ou toute autre pièce de soutien (voir 7.5); et

e) les parties éjectées d'un appareil (voir 7.7).

NOTE Si l'équipement se compose de deux unités ou plus, la valeur de la masse se réfère à la masse de chaque unité. Toutefois, si une ou plusieurs unités sont destinées à être ~~attachées~~ fixées à ou soutenues par une autre unité, ces unités sont traitées comme une seule unité.

La conformité est vérifiée conformément aux 7.2 à 7.7.

7.2 Arêtes tranchantes

Toutes les parties facilement touchées de l'appareil doivent être lisses et arrondies de manière à éviter toute blessure pendant l'UTILISATION NORMALE de l'appareil.

Sauf si le défaut présente un DANGER évident, les parties facilement touchées de l'appareil ne doivent pas causer une blessure en CONDITION DE PREMIER DEFAUT.

La conformité est vérifiée par examen et, si nécessaire, par application d'un objet de même taille, forme et dureté qu'un doigt pour vérifier les éraflures ou les coupures.

NOTE Une procédure acceptable est indiquée dans l'UL 1439.

7.3 Parties mobiles

7.3.1 Généralités

Les DANGERS provoqués par les parties mobiles ne doivent pas dépasser un niveau acceptable, sauf exceptions du 7.3.2. Les niveaux physiques spécifiés en 7.3.4 et 7.3.5 sont considérés comme suffisant pour réduire les RISQUES à un niveau acceptable. Si ces niveaux physiques ne sont pas utilisés, une appréciation du RISQUE devra être réalisée selon 7.3.3 ou l'Article 17.

NOTE Dans ce contexte, les parties mobiles sont des parties mues par une source d'énergie autre qu'une force humaine ou animale directement appliquée.

La conformité est vérifiée comme spécifié en 7.3.2, 7.3.3, 7.3.4, 7.3.5 et à l'Article 17, selon le cas.

7.3.2 Exceptions

S'il n'est pas possible pour des raisons de fonctionnement d'éviter que certaines parties mobiles ne causent un DANGER potentiel, l'accès est autorisé dans les circonstances suivantes.

a) Un appareil comprenant des parties mobiles facilement touchées qui sont manifestement destinées à fonctionner sur des parties ou matériaux extérieurs à l'appareil, comme les appareils de perçage et de malaxage doit être conçu de manière à réduire au minimum tout contact par mégarde avec ces parties mobiles (par exemple, par des dispositifs de protections ou des poignées).

b) Si durant la phase de maintenance habituelle, en dehors de la période d'UTILISATION NORMALE, on ne peut éviter, pour des raisons techniques, que l'OPERATEUR doive exécuter une opération, tel un ajustage, nécessitant l'accès à des parties mobiles dangereuses, cet accès est autorisé lorsque toutes les précautions précisées ci-dessous auront été prises:

   1) l'accès n'est rendu possible qu'avec un OUTIL;

   2) les instructions fournies à l'AUTORITE RESPONSABLE comportent une indication précisant que l'OPERATEUR doit être formé avant d'être autorisé à effectuer l'opération dangereuse;

   3) il y a des avertissements sur les protections et toutes les parties qui doivent être démontées pour laisser l'accès, interdisant l'accès aux OPERATEURS non formés. Comme alternative possible, le symbole 14 du Tableau 1 doit être inscrit sur les protections et les parties concernées, en incluant les avertissements dans la documentation associée.

La conformité est vérifiée par examen.

7.3.3 Appréciation du RISQUE pour les DANGERS mécaniques aux parties du corps

Les RISQUES doivent être réduits à un niveau acceptable en appliquant au moins les mesures de protection minimales du Tableau 12, en tenant compte de la gravité, de la probabilité d'exposition et de la possibilité d'éviter le DANGER.

La conformité est vérifiée par la revue de la documentation sur l'appréciation du RISQUE pour s'assurer que les RISQUES ont été éliminés ou qu'il ne reste seulement que des RISQUES TOLERABLES.

Tableau 12 – Mesures de protection contre les DANGERS mécaniques des parties du corps

Conditions de DANGER mécanique			Mesures de protection minimales [d]
Gravité [a]	**Probabilité d'exposition** [b]	**Possibilité d'éviter le DANGER** [c]	
G	E_2	P_2	C
G	E_2	P_1	C
G	E_1	P_2	C
G	E_1	P_1	B
M	E_2	P_2	B
M	E_2	P_1	A
M	E_1	P_2	A
M	E_1	P_1	Néant

[a] **Gravité de l'exposition:**

M = DANGERS moyens, suffisants pour meurtrir ou égratigner un doit ou une main

G = DANGERS graves, suffisants pour fracturer des os ou démembrer les doigts

[b] **Probabilité d'exposition:**

E_1 = L'exposition n'est pas intentionnelle ni probable durant l'UTILISATION NORMALE

E_2 = L'exposition est intentionnelle ou probable durant l'UTILISATION NORMALE

[c] **Possibilité d'éviter le** DANGER:

P_1 = Possibilité d'éviter:

- Le mouvement est visible et la vitesse est inférieure ou égale à 200 mm/s, ou
- Une alarme sonore ou visible est activée avant qu'un mouvement plus rapide ne puisse atteindre la main.

P_2 = Inévitable:

Conditions autres que P_1.

[d] **Mesures de protection minimales:**

A = Mesures de bas niveau: marquages d'avertissement, avertisseurs sonores ou visibles ou instructions d'utilisation

B = Mesures moyennes: interrupteurs d'urgence, BARRIERES DE PROTECTION ou protections amovibles uniquement avec un OUTIL, distance (voir ISO ~~13852~~ 13857 ~~ou EN 294~~) ou séparation (voir ISO 13854 ou EN 349)

C = Mesures rigoureuses: entrelacements, BARRIERES DE PROTECTION ou protections uniquement démontables à l'aide d'un OUTIL et instructions de déconnexion de la source d'alimentation

7.3.4 Limitation de la force et de la pression

Les niveaux physiques indiqués ci-dessous ne sont pas considérés comme dangereux. Ils sont basés sur une combinaison entre force, temps et surface de zone de contact. Les niveaux ci-dessous doivent être respectés en CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT.

Le maximum tolérable de la pression de contact permanente est de 50 N/cm^2 avec une force maximale de 150 N.

Le maximum tolérable de force temporaire sur des zones d'au moins 3 cm^2 de contact avec le corps est de 250 N pendant 0,75 s.~~ Cette mesure est effectuée avec un capteur de force ayant un rapport d'élasticité d'au moins 25 N/mm.~~

La conformité est vérifiée par examen et, en cas de doute, par des mesures. Pour les besoins du présent paragraphe, la largeur d'un doigt est définie comme étant de 1,2 cm et la largeur de toute autre partie du corps est définie comme étant de 5,0 cm. La zone de contact sera déterminée en multipliant la largeur de la partie du corps par la largeur de la partie mobile ou de la section de contact de la partie mobile, si cette valeur est moins élevée.

EXEMPLE Dans un cas particulier, un doigt pourrait être capable de toucher une partie mobile ayant une largeur de 0,9 mm. Si la partie peut exercer une force continue de 40 N, la pression de contact est alors calculée comme suit:

Surface = 1,2 cm × 0,09 cm = 0,108 cm^2

Pression = 40 N / 0,108 cm^2 = 370 N/cm^2

Dans ce cas, la pression dépasse la limite admissible, même si la force est inférieure à cette limite. La partie mobile est alors considérée comme étant dangereuse.

7.3.5 Limitation des écartements entre les parties mobiles

7.3.5.1 Limitation des écartements entre les parties mobiles – Accès normalement autorisé

Si la force et la pression des parties mobiles excèdent les limites de 7.3.4, et si une partie du corps peut se trouver insérée entre des parties mobiles, la largeur de l'écartement ne doit pas passer d'une valeur supérieure à l'écartement minimal du Tableau 13 pour cette partie du corps à une valeur inférieure à l'écartement minimal en CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT.

La conformité est vérifiée par examen et, en cas de doute, par des mesures.

7.3.5.2 Limitation des écartements entre les parties mobiles – Accès normalement protégé

Lorsque les parties sont en mouvement, les écartements entre les parties mobiles dans lesquelles des parties du corps pourraient être introduites ne doivent pas s'accroître au-delà de l'écartement acceptable du Tableau 14 en CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT.

La conformité est vérifiée par examen et, en cas de doute, par des mesures.

Tableau 13 – Ecartements minimaux maintenus pour éviter l'écrasement de différentes parties du corps

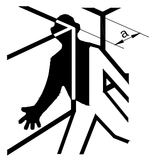
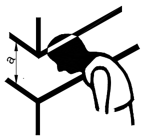
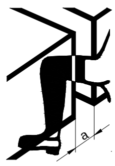
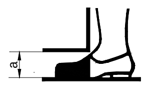
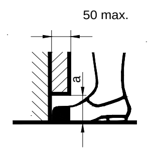
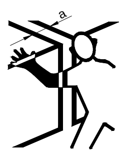
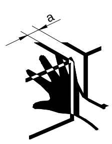
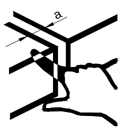
Partie du corps	Ecartement minimal (a) pour éviter l'écrasement mm	Illustration
Torse	500	
Tête	300	
Jambe	180	
Pied	120	
Doigts de pied	50	
Bras	120	
Main, poignet, poing	100	
Doigt	25	
Les valeurs dans ce tableau sont destinées à des adultes. Pour les appareils qui peuvent être utilisés par des enfants et des jeunes gens, il convient de prendre en considération des dimensions plus petites.		

Tableau 14 – Ecartements maximaux pour empêcher l'accès à différentes parties du corps

Partie du corps	Ecartement maximal (a) [a] pour empêcher l'accès mm
Tête	120
Pied	35
Doigt	4
Les valeurs dans ce tableau sont destinées à des adultes. Pour les appareils qui peuvent être utilisés par des enfants et des jeunes gens, il convient de prendre en considération des dimensions plus petites.	
[a] Voir le Tableau 13 pour des exemples d'écartement (a).	

7.4 Stabilité

Les appareils et les ensembles d'appareils qui ne sont pas fixés avant d'être mis en service à la structure du bâtiment doivent être physiquement stables.

Si des moyens sont utilisés pour garantir la stabilité après l'ouverture de tiroirs, etc. par un OPERATEUR, ces moyens doivent être automatiques, ou bien il doit y avoir un marquage d'avertissement.

La charge ASSIGNEE de chaque roulette ou pied de soutien doit être au moins ~~de 4 fois~~ égale à la charge normale, ou bien la roulette ou le pied de soutien doit être ~~testé suivant~~ soumis à l'essai d) ~~et~~ ou e) ci-dessous.

La conformité est vérifiée par examen et en effectuant séparément chacun des essais suivants, lorsqu'ils sont applicables, pour veiller à ce que l'appareil ne perde pas l'équilibre. Les récipients contiennent la quantité ASSIGNEE de substance afin de reproduire les conditions d'UTILISATION NORMALE les moins favorables. Les roulettes sont placées dans la position la plus défavorable d'UTILISATION NORMALE. Les portes, tiroirs, etc., sont fermés, sauf exigence contraire ci-dessous.

a) Les appareils autres que les APPAREILS PORTATIFS sont inclinés dans chaque direction à un angle de 10° par rapport à leur position normale.

b) Une force est appliquée au niveau du bord supérieur ou à une hauteur de 2 m si l'appareil a une hauteur supérieure à 2 m de tout appareil qui a, à la fois, une hauteur de 1 m ou plus et une masse de 25 kg ou plus, et de tous les appareils posés sur le sol. La valeur de la force est égale à 250 N ou à 20 % du poids de l'équipement, en appliquant la valeur la moins élevée; cette force est appliquée dans toutes les directions qui pourraient faire basculer l'appareil. Les vérins employés en UTILISATION NORMALE, et les portes, tiroirs, etc., destinés à être ouverts par un OPERATEUR, sont placés dans leurs positions les moins favorables.

c) Une force de 800 N est appliquée vers le bas au point où le moment de cette force est maximal sur:

   1) *toute surface horizontale de travail;*

   2) *toute autre surface présentant un épaulement évident et qui ne se trouve pas à plus de 1 m au-dessus du niveau du sol.*

   Les tiroirs, portes, etc. sont fermés, sauf ceux prévus pour être ouverts par un OPERATEUR qui sont dans la position la moins favorable.

d) La roulette ou le pied de soutien qui supporte la plus grosse charge (M), est chargé à 4 fois cette charge (4 × M);

e) La roulette ou le pied de soutien qui supporte la plus grosse charge, est ôté de l'appareil et l'appareil est posé sur une surface plane.

NOTE ~~1~~ Pendant cet essai, il convient d'arrimer l'appareil sous test de façon à interdire un renversement complet si cela peut présenter un DANGER pour ceux qui effectuent le test. Cependant, il ne faut pas que cette contrainte empêche de déterminer si l'appareil sous test aurait basculé.

~~NOTE 2 Il convient d'ôter la pièce de soutien d'une distance telle que l'appareil sous test ne puisse présenter un DANGER pendant l'essai.~~

7.5 Moyens de levage et de transport

7.5.1 Généralités

Les appareils ou les parties dont la masse est égale ou supérieure à 18 kg doivent être accompagnés d'un moyen de levage et de transport, ou bien des instructions doivent être données dans la documentation.

La conformité est vérifiée comme spécifié en 7.5.2 et 7.5.3.

7.5.2 Poignées et anses

Lorsque l'appareil est muni de poignées ou anses de transport, ou fourni avec, ces dernières doivent pouvoir supporter une force égale à quatre fois le poids de l'appareil.

La conformité est vérifiée par examen et par l'essai suivant.

Une poignée ou anse unique est soumise à une force correspondant à quatre fois le poids de l'appareil. Sauf si les vis de montage (s'il y en a) comportent un dispositif anti-desserrage, une vis est enlevée avant d'effectuer ces essais. La force est appliquée uniformément sur une largeur de 70 mm, au centre de la poignée, sans serrage. La force est régulièrement accrue de telle sorte que la valeur d'essai soit atteinte au bout de 10 s et qu'elle soit exercée pendant 1 min.

Si l'appareil est équipé de plusieurs poignées ou anses, la force est répartie entre les poignées ou anses dans la même proportion qu'en UTILISATION NORMALE. Si l'appareil est muni de plusieurs poignées ou anses mais qu'il soit conçu de telle sorte qu'il puisse être aisément transporté par une seule poignée ou anse, chaque poignée ou anse doit pouvoir supporter la force totale.

Une fois les essais réalisés, les poignées ou anses ne doivent pas s'être détachées de l'appareil et ne doivent pas présenter de déformation permanente, de fissure ou d'autres signes de détérioration qui pourraient présenter un DANGER.

7.5.3 Dispositifs de levage et parties soutenues

Les parties des dispositifs de levage et les parties qui soutiennent des charges lourdes doivent avoir des CARACTERISTIQUES ASSIGNEES pour la charge maximale ou doivent être testées pour supporter quatre fois la charge statique maximale.

La conformité est vérifiée par examen des CARACTERISTIQUES ASSIGNEES des parties, ou par l'essai suivant:

Une charge totale égale à quatre fois la charge maximale est placée dans la position la moins favorable de la charge ASSIGNEE en UTILISATION NORMALE.

Pendant l'essai, aucune partie d'un dispositif de levage ou d'un support de charge ne doit se casser ou se déformer jusqu'à présenter un DANGER.

7.6 Montage mural

Les équerres de montage des appareils destinés à être montés sur un mur ou au plafond doivent supporter quatre fois le poids de l'équipement.

La conformité est vérifiée après montage de l'appareil selon les instructions du fabricant, en utilisant les attaches et la construction du mur spécifiées. Les équerres ajustables sont ajustées dans la position qui donnera la projection la plus grande à partir du mur.

Si la construction du mur n'est pas spécifiée, une plaque de plâtre (mur sec) épaisse de 10 mm ± 2 mm sur des plots de dimension nominale de 50 mm × 100 mm ± 10 mm espacés de 400 mm ± 10 mm, est utilisée comme surface de support. Les équerres sont appliquées comme spécifié dans les notices de montage; si ce n'est pas spécifié, elles sont positionnées sur la plaque de plâtre entre les plots.

Les équerres de montage sont ensuite soumises à une force correspondante à quatre fois le poids de l'appareil, agissant verticalement par le centre de gravité. La masse d'essai est appliquée progressivement et est augmentée de zéro à la pleine charge de 5 s à 10 s, puis est maintenue 1 min.

S'il est indiqué qu'il faut plus d'une attache pour monter une équerre, alors une attache est enlevée et l'essai est réitéré avec à une force correspondante à deux fois le poids de l'appareil.

Après les essais, il ne doit pas y avoir de dommages sur les équerres et sur la surface de montage qui pourraient présenter un DANGER.

7.7 Parties éjectées

L'appareil doit retenir ou limiter l'énergie des parties qui peuvent provoquer un DANGER si elles sont éjectées en cas de panne.

Les moyens de protection contre les parties éjectées ne doivent pas pouvoir être retirés sans l'aide d'un OUTIL.

NOTE L'Article 8 ne prend pas en compte les DANGERS de parties qui pourraient être éjectées de l'intérieur de l'appareil.

La conformité est vérifiée par examen, après application des conditions de défaut applicables de 4.4.

8 Résistance aux contraintes mécaniques

8.1 Généralités

L'appareil ne doit pas entraîner de DANGER lorsqu'il est soumis à des contraintes mécaniques pouvant se produire en UTILISATION NORMALE.

Le niveau normal d'énergie exigé pour la protection est de 5 J. Des valeurs d'énergies inférieures comprises entre 1 J et 5 J sont autorisées, à condition que tous les critères suivants soient satisfaits:

a) le fabricant justifie le niveau plus faible par une appréciation du RISQUE suivant l'Article 17;

b) lorsque l'appareil est installé pour son usage prévu, il ne peut pas être facilement accessible à des personnes non autorisées ou au public;

c) en UTILISATION NORMALE, l'accès à l'appareil ne se fait que pour des opérations occasionnelles telles que les réglages, la programmation ou l'entretien;

d) l'appareil est marqué avec un indice IK selon l'IEC 62262 ou avec le symbole 14 du Tableau 1, et, dans ce cas, les valeurs ASSIGNEES d'énergie et la méthode d'essai sont indiquées dans la documentation accompagnant l'appareil. La valeur indiquée d'énergie des ENVELOPPES non métalliques, dont la température ambiante ASSIGNEE est inférieure à 2 °C, doit être celle qui est applicable à la température ambiante la plus basse spécifiée. Si les valeurs d'énergie utilisées sont comprises entre les valeurs d'énergie des codes IK de l'IEC 62262, le marquage du code IK sera celui du code IK inférieur le plus proche.

La conformité est vérifiée par examen et en effectuant chacun des essais suivants sur l'ENVELOPPE si applicable:

1) *l'essai statique de 8.2.1;*

2) *pour les appareils autres que les APPAREILS PORTATIFS, l'essai de choc de 8.2.2 avec le niveau d'énergie spécifié ci-dessus. Si le niveau d'énergie spécifié n'est pas de 5 J, l'essai selon l'IEC 62262 est une alternative à l'essai de 8.2.2, en utilisant l'essai Eha (essai pendulaire) ou l'essai Ehc (essai au marteau) décrits dans l'IEC 60068-2-75;*

3) *excepté pour les APPAREILS INSTALLES A POSTE FIXE ou de masse supérieure à 100 kg, l'essai applicable de 8.3.1 ou 8.3.2. L'appareil n'est pas mis en marche durant ces essais.*

Une ENVELOPPE ayant au moins un code IK08 ASSIGNE par le fabricant de l'ENVELOPPE, et qui satisferait clairement aux critères du 8.1 i) au 8.1 vii) après cet essai, n'a pas à subir les essais de 8.2.2.

Les parties qui ne font pas partie de l'ENVELOPPE ne sont pas soumises aux essais de 8.2.1 et de 8.2.2.

Après ces essais, les fenêtres et afficheurs visiblement endommagés doivent être inspectés pour vérifier que les parties sous TENSION DANGEREUSE dépassant les valeurs de 6.3.2 ne sont pas devenues ACCESSIBLES et l'isolation des autres parties de l'ENVELOPPE qui ont pu être affectées par l'essai, doivent subir avec succès les essais de tension de 6.8 (sans le pré-conditionnement à l'humidité) applicables au type d'isolation (voir 6.7). En plus, l'appareil est examiné afin de vérifier que:

i) *il n'y a pas eu de fuite de substances toxiques et corrosives;*

ii) *les ENVELOPPES ne présentent aucune fissure pouvant présenter un DANGER;*

iii) *les DISTANCES D'ISOLEMENT ne sont pas inférieures à leurs valeurs admises;*

iv) *l'isolation du câblage interne n'est pas endommagée;*

v) *les BARRIERES DE PROTECTION nécessaires pour la sécurité n'ont pas été endommagées ni desserrées;*

vi) *aucune partie mobile ne peut être touchée, sauf comme permis en 7.3;*

vii) *il n'y a pas eu de détérioration pouvant provoquer la propagation du feu.*

8.2 Essais de rigidité de l'ENVELOPPE

8.2.1 Essai statique

L'appareil est fermement maintenu contre un support rigide et soumis à une force de 30 N appliquée par l'extrémité hémisphérique d'une tige solide de 12 mm de diamètre. La tige est appliquée à toute partie de l'ENVELOPPE qui est ACCESSIBLE, lorsque l'appareil est prêt à l'emploi, y compris toute partie située à la partie inférieure d'un APPAREIL PORTABLE, et qui pourrait entraîner un DANGER en cas de déformation.

En cas de doute sur la tenue d'une ENVELOPPE non métallique à température élevée, l'essai est effectué après le fonctionnement de l'appareil en régime établi à une température ambiante de 40 °C ou à la température ambiante maximale ASSIGNEE si elle est supérieure, jusqu'à stabilisation. L'appareil est débranché de sa source d'alimentation avant de réaliser l'essai.

8.2.2 Essai de choc

Les vis de fixation des socles, couvercles etc. prévus pour être retirés et remplacés par un OPERATEUR, sont serrées avec le couple prévu en UTILISATION NORMALE. L'appareil étant tenu fermement sur un support rigide, le choc est appliqué sur tous les points des surfaces pouvant être atteintes en UTILISATION NORMALE et pouvant entraîner un DANGER en cas de détérioration.

NOTE Un support est considéré comme suffisamment rigide si son déplacement est inférieur ou égal à 0,1 mm sous l'effet d'un choc direct dont l'énergie correspond au degré de protection.

Les ENVELOPPES non métalliques des appareils dont la température ambiante minimale ASSIGNEE est inférieure à 2 °C sont refroidies à la température ambiante minimale ASSIGNEE et l'essai est réalisé dans les 10 min suivantes.

Les chocs peuvent être appliqués à des ENVELOPPES vides à condition qu'il soit clair que l'appareil aurait réussit l'essai s'il avait été testé en totalité.

Si une ENVELOPPE est endommagée par un choc mais qu'elle répond aux critères de succès, une nouvelle ENVELOPPE peut être utilisée pour le choc suivant.

Les APPAREILS FIXES doivent être montés conformément aux instructions de montage. Les autres appareils sont maintenus fermement contre un support rigide et chaque point d'impact est soumis à un seul choc réalisé en laissant tomber une sphère en acier lisse de 500 g ± 25 g et d'environ 50 mm de diamètre.

L'essai de choc peut être effectué avec l'appareil placé à 90° par rapport à sa position normale pour permettre l'essai suivant le montage de la Figure 10 a) ou celui de la Figure 10 b).

La Figure 10 a) montre le choc sur surface horizontale, la sphère tombant librement d'une hauteur X.

La Figure 10 b) montre le choc sur une surface verticale, la sphère étant suspendue à un fil et tombant comme un pendule d'une hauteur X.

Dans les deux cas, X est déterminé à partir du Tableau 15 suivant le niveau d'énergie à appliquer.

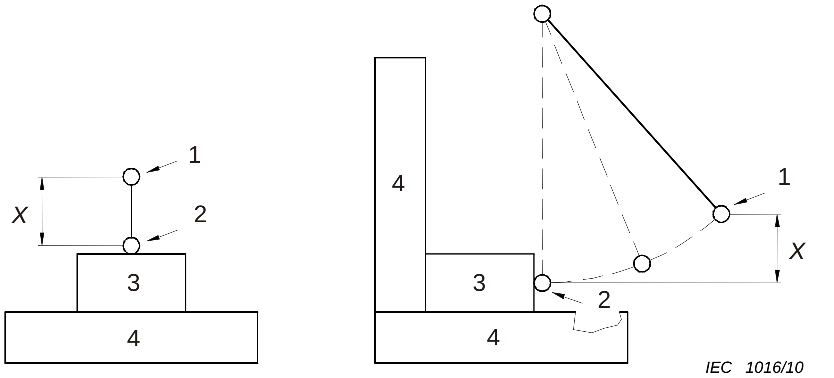


Figure 10 a – Choc sur une surface horizontale **Figure 10 b – Choc sur une surface verticale**

Légende

1	Position de départ de la sphère	2	Point d'impact de la sphère
3	Échantillon en essai	4	Surface rigide de support
X	Hauteur de chute. Voir le Tableau 15 pour les valeurs de *X*.		

Figure 10 – Essai d'impact utilisant une sphère

Tableau 15 – Energie de choc, hauteur d'essai et codes IK correspondant

	Énergie de choc J **et code IK**		
	1 (IK06)	**2 (IK07)**	**5 (IK08)**
hauteur d'essai *X* (mm)	200	400	1 000

8.3 Essai de chute

8.3.1 Appareils autres que les APPAREILS PORTATIFS et les APPAREILS A BRANCHEMENT DIRECT

L'appareil est placé dans sa position d'UTILISATION NORMALE sur une surface lisse, rigide et dure en béton ou en acier. Il est alors incliné autour de l'une des arêtes de sorte que la distance entre l'arête inférieure opposée et la surface d'essai soit de 100 mm pour les appareils d'une masse inférieure ou égale à 20 kg et de 25 mm pour les appareils d'une masse comprise entre 20 kg à 100 kg, ou que l'angle entre le fond et la surface d'essai soit de 30°, si c'est moins sévère. Il est ensuite laissé tomber librement sur la surface d'essai.

Si le nombre d'arêtes du fond dépasse quatre, seulement quatre chutes doivent être effectuées sur quatre arêtes choisies.

NOTE Si l'appareil comporte deux ou plusieurs éléments, la valeur de la masse à prendre en compte est celle de chaque élément. Cependant, si un ou plusieurs des éléments sont prévus pour être attachés ou pour être supportés par un autre élément, ces éléments sont à traiter comme un seul élément.

La méthode d'essai employée doit garantir qu'il n'est pas possible à l'appareil de culbuter sur l'autre face au lieu de tomber sur la face en essai comme souhaité.

8.3.2 APPAREILS PORTATIFS et APPAREILS A BRANCHEMENT DIRECT

L'appareil est lâché une seule fois d'une hauteur de 1 m sur un panneau en bois dur de 50 mm d'épaisseur et d'une densité de plus de 700 kg/m^3, posé à plat sur un socle rigide comme du béton. L'appareil est lâché de manière à se retrouver dans la position supposée présenter la condition la plus sévère.

Les ENVELOPPES *non métalliques des appareils dont la température ambiante minimale est inférieure à 2 °C, sont refroidies à la température ambiante minimale* ASSIGNEE *et l'essai est réalisé dans les 10 min.*

9 Protection contre la propagation du feu

9.1 Généralités

Il ne doit pas y avoir de propagation du feu en dehors de l'appareil, en CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT. Le diagramme de la Figure 11 montre les méthodes de vérification de la conformité.

Un appareil alimenté par un RESEAU doit aussi répondre aux conditions de 9.6.

La conformité est vérifiée par au moins une des méthodes suivantes.

a) *Essai en* CONDITION DE PREMIER DEFAUT *(voir 4.4) qui peut entraîner la propagation du feu en dehors de l'appareil. Le critère de conformité de 4.4.4.3 doit être rempli.*
b) *En vérifiant l'élimination ou la réduction des sources d'allumage à l'intérieur de l'appareil comme spécifié en 9.2.*
c) *En vérifiant, comme spécifié en 9.3, que, si un feu se déclare, il sera retenu à l'intérieur de l'appareil.*

Ces méthodes alternatives peuvent être appliquées à travers tout l'appareil ou séparément pour différentes sources de DANGER *ou pour différentes zones de l'appareil.*

NOTE 1 Les méthodes b) et c) sont basées sur des critères de conception spécifiés accomplis, par opposition à la méthode a) qui repose entièrement sur les essais spécifiés en CONDITIONS DE PREMIER DEFAUT.

NOTE 2 Voir 13.2.2 concernant la protection contre le feu provoqué par des piles ou accumulateurs.

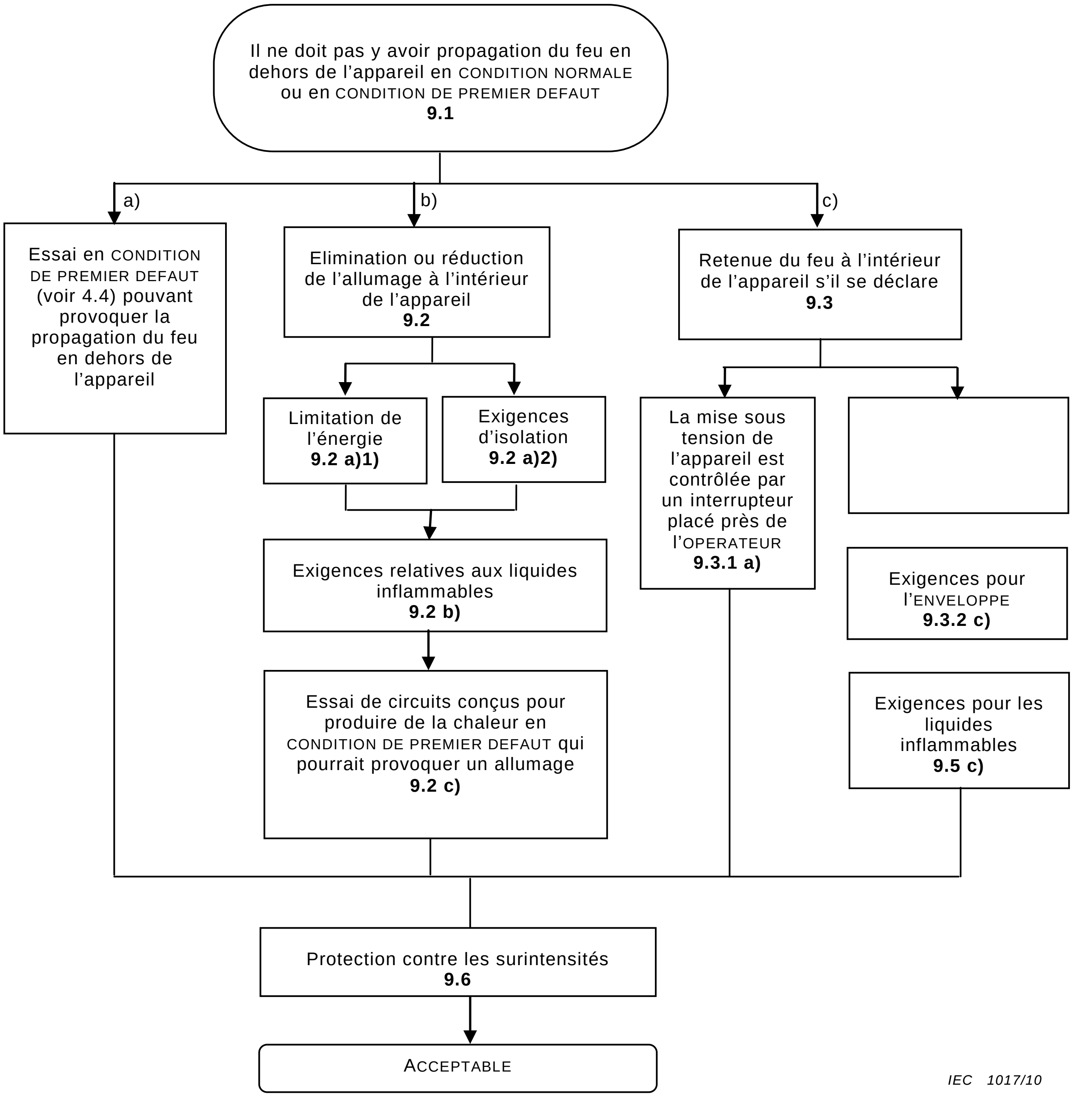


Figure 11 – Diagramme expliquant les exigences pour la protection contre la propagation du feu

9.2 Elimination ou réduction de l'allumage à l'intérieur de l'appareil

L'éventualité de départ et de survenue du feu est considérée comme réduit à un niveau acceptable si toutes les exigences suivantes a), b) et c), si applicables, sont remplies.

a) Soit 1) soit 2):

   1) la tension, le courant et la puissance disponible dans le circuit ou dans une partie de l'appareil, sont limités comme spécifié en 9.4;

      La conformité est vérifiée par la mesure des valeurs des énergies limitées comme spécifié en 9.4.

   2) l'isolation entre les parties à des potentiels différents est conforme aux exigences de l'ISOLATION PRINCIPALE ou il peut être démontré que le pontage de l'isolation ne provoquera pas d'allumage.

La conformité est vérifiée par examen et en cas de doute par essai.

b) Tout DANGER d'allumage lié à un liquide inflammable est réduit à un niveau acceptable comme spécifié en 9.5.

La conformité est vérifiée comme spécifié en 9.5.

c) Dans les circuits conçus pour produire de la chaleur, aucun allumage ne survient après chaque essai en CONDITION DE PREMIER DEFAUT (voir 4.4).

La conformité est vérifiée par les essais applicables de 4.4, en appliquant le critère de 4.4.4.3.

9.3 Retenue du feu à l'intérieur de l'appareil s'il se déclare

9.3.1 Généralités

L'éventualité de la propagation du feu à l'extérieur de l'appareil est considérée comme réduite à un niveau acceptable si une des deux exigences suivantes de construction est remplie:

a) la mise sous tension de l'appareil est contrôlée par un interrupteur qu'un OPERATEUR maintient constamment activé;

b) l'appareil et son ENVELOPPE sont conformes aux exigences de construction de 9.3.2 et les exigences applicables de 9.5 sont remplies.

La conformité est vérifiée par examen et comme spécifié en 9.3.2 et 9.5.

9.3.2 Exigences de construction

Les exigences de construction suivantes doivent être remplies.

a) Les connecteurs et les matières isolants sur lesquels des composants sont montés doivent avoir une classification d'inflammabilité d'un grade V-2 ou meilleur suivant l'IEC 60695-11-10 (voir aussi 14.7 pour les exigences pour les circuits imprimés).

NOTE 1 V-0 est meilleur que V-1, qui est meilleur que V-2.

La conformité est vérifiée par examen des données sur les matières et, en cas de doute, en réalisant les essais de combustion verticale de l'IEC 60695-11-10 sur des échantillons de la matière utilisée dans les parties considérées.

b) Les fils isolés et les câbles doivent retarder la propagation du feu.

NOTE 2 Un fil ayant une classification d'inflammabilité suivant la norme UL 2556 VW-1 ou équivalent, est considéré comme répondant à cette exigence.

La conformité est vérifiée par examen des données sur les matières et, en cas de doute, en réalisant l'un des essais applicables suivants:

1) pour les fils et les câbles ayant une section globale des conducteurs dépassant 0,5 mm^2, l'essai de l'IEC 60332-1-2;

2) pour les fils et les câbles ayant une section globale des conducteurs de 0,5 mm^2 ou moins, l'essai de l'IEC 60332-2-2.

c) L'ENVELOPPE doit satisfaire aux exigences suivantes:

1) Dans les 5° d'arc de la Figure 13, le fond et les cotés de l'ENVELOPPE des circuits qui ne sont pas des circuits à énergie limitée selon 9.4, doivent être conformes à l'une des exigences suivantes:

i) ne doit pas avoir d'ouvertures;

ii) doit être en métal perforé comme spécifié au Tableau 16;

iii) doit être un écran métallique avec un grillage dont la maille ne dépasse pas 2 mm × 2 mm entre centres et avec un diamètre de fil d'au moins 0,45 mm;

iv) doit avoir des ouvertures avec des chicanes selon la Figure 12.

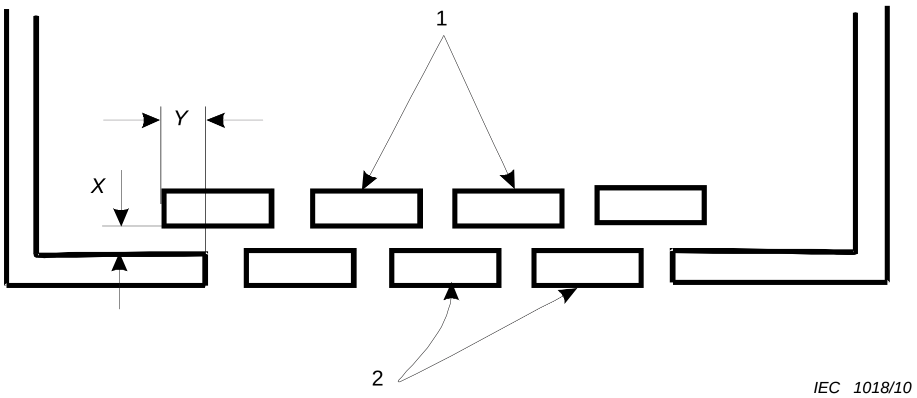
2) L'ENVELOPPE, les chicanes ou les barrières coupe-flamme doivent être en métal (à l'exception du magnésium) ou en matières non métalliques de classe d'inflammabilité V-1 ou meilleure, conformément à l'IEC 60695-11-10.

3) L'ENVELOPPE, les chicanes ou les barrières coupe-flamme doivent avoir une rigidité adaptée.

La conformité est vérifiée par examen. En cas de doute, la classification d'inflammabilité des exigences de c) 2) est vérifiée en réalisant les essais de combustion verticale de l'IEC 60695-11-10 sur les échantillons de matière utilisée dans les parties concernées.

Tableau 16 – Perforation acceptable du fond d'une ENVELOPPE

Epaisseur minimale mm	Diamètre maximal des trous mm	Espacement minimal des trous entre axes mm
0,66	1,14	1,70 (233 trous / 645 mm^2)
0,66	1,19	2,36
0,76	1.15	1,70
0,76	1,19	2,36
0,81	1,91	3,18 (72 trous / 645 mm^2)
0,89	1,90	3,18
0,91	1,60	2,77
0,91	1,98	3,18
1,00	1,60	2,77
1,00	2,00	3,00



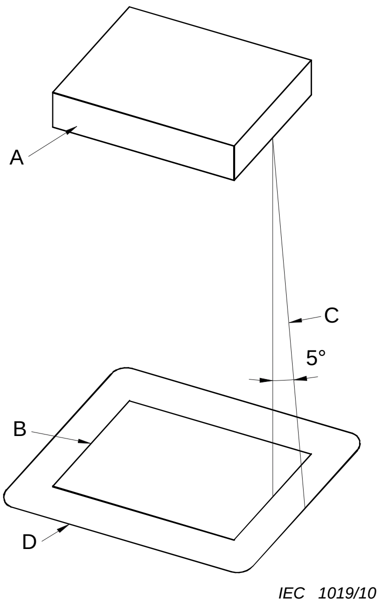
$Y \geq 2 \times X$ mais jamais moins de 25 mm

Légende

1 Plaque de chicane (peuvent être en dessous de l'ENVELOPPE)

2 Fond de l'ENVELOPPE

Figure 12 – Chicane



Légende

A Partie ou composant de l'appareil qui est considéré comme source de DANGER du feu, s'il n'est pas blindé par un autre moyen. Il est constitué de la totalité de la partie de l'appareil ou du composant, mais peut aussi être une partie non blindée du composant si ce dernier est partiellement blindé par son boîtier.

B Projection des dimensions hors tout du composant A sur le plan horizontal.

C Ligne oblique délimitant la surface minimale du fond et des côtés à construire comme spécifié en 9.3.2 c) 1) et en 9.3.2 c) 2). Cette ligne fait un angle de 5° par rapport à la ligne verticale qui part de chaque point du périmètre du composant A et est orientée de manière à définir la plus grande surface possible.

D Surface minimale du fond à construire comme spécifié en 9.3.2 c) 1).

Figure 13 – Emplacement du fond d'une ENVELOPPE à construire comme spécifié en 9.3.2 c) 1)

9.4 Circuit à énergie limitée

Un circuit à énergie limitée est un circuit qui remplit les critères suivants.

a) La valeur de la tension apparaissant dans le circuit ne dépasse pas 30 V efficaces, 42,4 V crête, ou 60 V continus.

b) Le courant qui peut apparaître dans le circuit est limité par un des moyens suivants:

   1) le courant maximal disponible est limité par construction ou par une impédance pour ne pas dépasser les valeurs applicables du Tableau 17;

   2) le courant est limité par un dispositif de protection contre les surintensités à un niveau qui ne dépasse pas les valeurs applicables du Tableau 18;

   3) un circuit de régulation limite les valeurs du courant maximal disponible pour ne pas dépasser les valeurs du Tableau 17 en CONDITION NORMALE ou comme conséquence d'une défaillance dans le circuit de régulation.

c) Il est séparé des autres circuits ~~qui pourraient conduire à dépasser~~ dont les valeurs d'énergie dépassent les critères a) ~~et~~ ou b) ci-dessus, par au moins une ISOLATION PRINCIPALE.

Si un dispositif de protection contre les surintensités est utilisé, ce doit être un élément fusible ou un dispositif électromécanique non réglable et sans réarmement automatique.

La conformité est vérifiée par examen et par mesurage dans les conditions suivantes des potentiels apparaissant dans le circuit et du courant maximal disponible:

i) les potentiels apparaissant dans le circuit sont mesurés dans la condition de charge maximisant la tension;

ii) le courant de sortie est mesuré après 60 s de fonctionnement, avec une charge résistive (y compris un court-circuit) produisant la valeur la plus élevée de courant.

Tableau 17 – Limites du courant maximal disponible

Tension en circuit ouvert (*U ou Û*) V			**Courant maximal disponible** A
Alternative efficace	**Continue**	**Crête** [a]	**Alternatif efficace ou continu**
$U \le 2$	$U \le 2$	$\hat{U} \le 2{,}8$	50
$2 < U \le 12{,}5$	$2 < U \le 12{,}5$	$2{,}8 < \hat{U} \le 17{,}6$	100 / U
$12{,}5 < U \le 18{,}7$	$12{,}5 < U \le 18{,}7$	$17{,}6 < \hat{U} \le 26{,}4$	8
$18{,}7 < U \le 30$	$18{,}7 < U \le 60$	$26{,}4 < \hat{U} \le 42{,}4$	150 / U

[a] La valeur de crête ($\hat{U}$) s'applique aux tensions alternatives non sinusoïdales et aux tensions continues dont le taux d'ondulation dépasse 10 %, et est fournie par commodité. La valeur efficace du courant maximal disponible doit être déterminée en fonction de la chaleur dégagée.

Tableau 18 – Valeurs pour les dispositifs de protection contre les surintensités

Tension apparaissant dans le circuit (*U ou Û*) V			**Courant que le dispositif de protection coupe en moins de 120 s** [b c] A
Alternative efficace	**Continue**	**Crête** [a]	**Alternatif efficace ou continu**
$U \le 2$	$U \le 2$	$\hat{U} \le 2{,}8$	62,5
$2 < U \le 12{,}5$	$2 < U \le 12{,}5$	$2{,}8 < \hat{U} \le 17{,}6$	125 / U
$12{,}5 < U \le 18{,}7$	$12{,}5 < U \le 18{,}7$	$17{,}6 < \hat{U} \le 26{,}4$	10
$18{,}7 < U \le 30$	$18{,}7 < U \le 60$	$26{,}4 < \hat{U} \le 42{,}4$	200 / U

[a] La valeur de crête ($\hat{U}$) s'applique aux tensions alternatives non sinusoïdales et aux tensions continues dont le taux d'ondulation dépasse 10 %, et est fournie par commodité. La valeur efficace du courant maximal disponible doit être déterminée en fonction de la chaleur dégagée.

[b] L'évaluation est basée sur les caractéristiques spécifiées de coupure durée-courant du dispositif de protection, ce qui est différent du courant de coupure ASSIGNE. (Par exemple, un fusible ANSI/UL 248-14 5 A est spécifié pour couper 10 A en 120 s ou moins et un fusible IEC 60127 type T 4 A est spécifié pour couper 8,4 A en 120 s ou moins).

[c] Le courant de coupure des fusibles dépend de la température, et cela doit être pris en compte si la température au voisinage immédiat du fusible est de manière significative plus élevée que la température de la pièce.

9.5 Exigences pour les appareils contenant des liquides inflammables

Les liquides inflammables contenus dans un appareil, ou spécifiés pour être utilisés avec, ne doivent pas provoquer la propagation du feu en CONDITION NORMALE ou en CONDITION DE PREMIER DEFAUT.

Les DANGERS provenant d'un liquide inflammable sont considérés comme réduits à un niveau acceptable si une des exigences suivantes est remplie.

a) La température de surface du liquide et des parties en contact avec la surface, en CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT, est limitée à une température ne dépassant pas *t* – 25 °C, où *t* est le point de feu du liquide (voir 10.3 b)).

   NOTE 1 Le point de feu est la température à laquelle il faut chauffer un liquide (dans des conditions spécifiées) de telle sorte que le mélange vapeur/air à la surface entretienne une flamme pendant au moins 5 s lorsqu'une flamme extérieure est appliquée puis retirée.

b) La quantité de liquide est limitée à une quantité qui ne peut pas provoquer la propagation du feu.

c) Si le liquide peut être enflammé, les flammes sont retenues pour empêcher la propagation du feu en dehors de l'appareil. Des détails de construction pour l'utilisation doivent être donnés pour mettre en place des procédures de réduction du RISQUE.

La conformité de a) et b) est vérifiée par examen et par mesure des températures comme spécifié en 10.4.

La conformité de c) est vérifiée comme spécifié en 4.4.4.3.

NOTE 2 Pour les liquides avec des produits de combustion dangereux, il peut être judicieux d'utiliser un liquide différent avec des caractéristiques similaires de combustion pour les besoins des essais.

9.6 Protection contre les surintensités

9.6.1 Généralités

Les appareils prévus pour être alimentés par le RESEAU doivent être protégés par des fusibles, disjoncteurs, rupteurs thermiques, circuits limiteurs impédants ou dispositifs similaires, afin d'être protégés contre les excès de courant tiré du RESEAU en cas de défaut dans l'appareil.

NOTE 1 Les dispositifs de protection contre les surintensités fournis avec l'appareil ont pour but d'apporter une protection contre les défauts résultant d'une augmentation du flux de courant, et donc d'une augmentation de la chaleur et de la probabilité de départ et de propagation du feu. Ces dispositifs ne sont pas faits pour fournir une protection contre les courts-circuits entre les conducteurs RESEAU et les CONDUCTEURS DE PROTECTION par mise à la terre. L'installation du bâtiment contient des dispositifs de protection contre les surintensités dans chaque conducteur RESEAU non branché à la terre qui sont destinés à la protection contre les courts-circuits entre le conducteur RESEAU et la terre de protection. Il convient que le pouvoir de coupure du dispositif de protection contre les surintensités soit compatible avec les spécifications ASSIGNEES de l'installation.

Au minimum, l'ISOLATION PRINCIPALE est exigée entre les parties connectées au RESEAU de polarité opposée du côté de l'alimentation du dispositif de protection contre les surintensités.

Les dispositifs de protection contre les surintensités ne doivent pas être incorporés dans le conducteur de protection. Les fusibles ou disjoncteurs à pôle unique ne doivent pas être incorporés dans le conducteur du neutre de l'appareil polyphasé.

NOTE 2 Il convient d'insérer des dispositifs de protection contre les surintensités (par exemple: fusibles) sur tous les conducteurs d'alimentation. Lorsque des fusibles sont utilisés comme dispositifs de protection contre les surintensités, il convient de monter les porte-fusible les uns à côté des autres. Il convient d'utiliser des fusibles de même calibre et présentant les mêmes caractéristiques. Il convient de placer les dispositifs de protection contre les surintensités en amont des CIRCUITS RESEAU dans l'appareil, y compris l'interrupteur du RESEAU. Il est reconnu que, dans les appareils produisant des fréquences élevées, il est essentiel que les composants de déparasitage soient placés entre l'alimentation RESEAU et les dispositifs de protection contre les surintensités.

La conformité est vérifiée par examen et par ~~mesure~~ mesurage, et pour l'isolation solide par l'essai en tension alternative de 6.8.3.1 ~~d'une durée d'au moins 1 min (sans le pré-conditionnement à l'humidité)~~ ou par l'essai en tension continue de 6.8.3.2 (sans le préconditionnement à l'humidité) en utilisant la tension d'essai ~~applicable~~ du Tableau 5 pour l'ISOLATION PRINCIPALE pour la tension phase-neutre appropriée pendant 1 min. Les ~~capacités~~

condensateurs CEM qui satisfont ~~à 14.1~~ aux exigences de l'Article 14 peuvent être débranchés pendant l'essai de tension.

9.6.2 APPAREILS BRANCHES EN PERMANENCE

Les dispositifs de protection contre les surintensités sont facultatifs dans les APPAREILS BRANCHES EN PERMANENCE. S'il n'y en a pas, les instructions d'installation doivent spécifier les caractéristiques des dispositifs de protection contre les surintensités requis dans l'installation du bâtiment.

La conformité est vérifiée par examen.

9.6.3 Autres appareils

Lorsqu'un dispositif de protection contre les surintensités est fourni, il doit être situé à l'intérieur de l'appareil.

La conformité est vérifiée par examen.

10 Limites de température de l'appareil et résistance à la chaleur

10.1 Limites de température des surfaces pour la protection contre les brûlures

La température des surfaces qui peuvent être touchées facilement ne doit pas dépasser les valeurs du Tableau 19 en CONDITION NORMALE et 105 °C en CONDITION DE PREMIER DEFAUT, à la température ambiante de 40 °C.

Si la température ambiante ASSIGNEE d'un appareil est supérieure à 40 °C, la température des surfaces qui peuvent être touchées facilement peut dépasser les valeurs du Tableau 19 en CONDITION NORMALE et 105 °C en CONDITION DE PREMIER DEFAUT, mais pas plus que l'écart de la température ambiante ASSIGNEE par rapport à 40 °C.

Si des surfaces chauffées et facilement touchées sont nécessaire pour traiter ou chauffer des matériaux, ou pour d'autres raisons inévitables, il est admis que ces surfaces dépassent les valeurs du Tableau 19 en CONDITION NORMALE et 105 °C en CONDITION DE PREMIER DEFAUT, à condition qu'elles soient identifiables comme telles par l'aspect ou la fonction, ou bien qu'elles soient marquées avec le symbole 13 du Tableau 1. Les appareils chauffés par leur environnement à des températures excédant les valeurs du Tableau 19 en CONDITION NORMALE, et 105 °C en CONDITION DE PREMIER DEFAUT n'ont pas besoin d'être marqués avec le symbole 13.

Les surfaces protégées par des barrières qui les empêchent d'être touchées accidentellement ne sont pas considérées comme des surfaces qui peuvent être facilement touchées, à condition que les barrières ne puissent être enlevées sans l'aide d'un OUTIL.

Tableau 19 – Limites des températures de surface en CONDITION NORMALE

Partie	Limite °C
1 Surface extérieure de l'ENVELOPPE (contact involontaire)	
a) métallique non enduite ou anodisée	65
b) métallique enduite (peinture, revêtement non métallique)	80
c) plastique	85
d) verre et céramique	80
e) petites surfaces (<2 cm^2) qui ne sont pas suceptibles d'être touchées en UTILISATION NORMALE	100
2 Boutons et poignées (contact en UTILISATION NORMALE)	
a) métal	55
b) plastique	70
c) verre et céramique	65
d) parties non métalliques tenues en UTILISATION NORMALE pendant de courtes périodes seulement (1 s – 4 s)	70
NOTE L'~~EN 563~~ ISO 13732-1 donne des informations sur les effets de la durée du contact.	

La conformité est vérifiée par mesurage comme spécifié en 10.4, et par examen des barrières pour vérifier qu'elles protègent contre le toucher accidentel des surfaces qui sont à des températures supérieures à celles du Tableau 19, et qu'elles ne peuvent être enlevées sans l'aide d'un OUTIL.

10.2 Température des bobinages

Si un DANGER peut être provoqué par une température excessive, la température du matériau isolant des bobinages ne doit pas dépasser les valeurs du Tableau 20 en CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT.

La conformité est vérifiée par mesurage comme spécifié en 10.4, en CONDITION NORMALE et dans les CONDITIONS DE PREMIER DEFAUT applicables de 4.4.2.5, 4.4.2.10 et 4.4.2.11, et aussi dans toutes les autres CONDITIONS DE PREMIER DEFAUT qui pourraient provoquer un DANGER suite à une température excessive.

Tableau 20 – Températures maximum des matériaux d'isolation des bobinages

Classe d'isolation (voir l'IEC 60085)	CONDITION NORMALE °C	CONDITION DE PREMIER DEFAUT °C
Class A	105	150
Class B	130	175
Class E	120	165
Class F	155	190
Class H	180	210

10.3 Autres mesures de température

Les autres mesures suivantes sont réalisées, lorsque c'est applicable, à l'intention d'autres paragraphes. Les essais sont réalisés en CONDITION NORMALE sauf autre indication.

a) La température d'une boîte ou d'un compartiment à BORNES à câbler sur place est mesurée si elle peut fonctionner à une température supérieure à 60 °C à une température ambiante de 40 °C ou à la température ambiante maximale ASSIGNEE si elle est supérieure (en liaison avec les exigences de marquage de 5.1.8).

b) La température de surface des liquides inflammables et des parties en contact avec la surface est mesurée dans les CONDITIONS DE PREMIER DEFAUT de 4.4.2.10 et 4.4.2.11 (en liaison avec 9.5 a)).

c) La température des ENVELOPPES non métalliques est mesurée durant l'essai de 10.5.1 (pour établir la température de base pour l'essai de 10.5.2).

d) La température des parties en matériau isolant qui supportent des parties reliées à l'alimentation RESEAU (pour établir la température pour l'essai 1) de 10.5.3).

e) La température des BORNES supportant un courant supérieur à 0,5 A si une quantité importante de chaleur peut être dissipée en cas d'un mauvais contact (pour établir la température pour l'essai 1) de 10.5.3).

10.4 Réalisation des essais de température

10.4.1 Généralités

L'appareil doit être testé dans les conditions d'essais de référence. A moins qu'une CONDITION DE PREMIER DEFAUT le spécifie autrement, les instructions du fabricant concernant l'aération, le liquide de refroidissement, les limitations pour usage intermittent, etc. sont respectées. Tout liquide de refroidissement doit être à la température maximale ASSIGNEE.

La température maximale est déterminée en mesurant la montée en température dans les conditions d'essais de référence et en l'additionnant à 40 °C, ou à la température ambiante maximale ASSIGNEE si elle est supérieure.

En variante, les mesurages de la température sont effectués à la température ambiante la moins favorable dans la plage de températures ambiantes ASSIGNEES de l'appareil si cela représente une condition moins favorable. Des mesures sont prises pour éliminer les erreurs induites par la méthode d'obtention de la température ambiante d'essai (par exemple, enceinte ou enveloppe appropriée si l'essai est réalisé dans une enceinte climatique, les mouvements forcés de l'air refroidissant l'extérieur de l'appareil).

La température des matériaux isolants des enroulements est mesurée comme la température du fil de l'enroulement et du noyau laminé en contact avec le matériau isolant. Elle peut être déterminée par la méthode de résistance ou par l'utilisation de capteurs de mesure de la température choisis et positionnés de telle sorte qu'ils aient un effet négligeable sur la température de la partie soumise à l'essai. Cette dernière méthode doit être utilisée si les enroulements ne sont pas uniformes ou s'il est difficile de mesurer la résistance.

Les températures sont mesurées en régime établi.

10.4.2 Mesure de température sur les appareils de chauffage

Les appareils destinés à produire de la chaleur à des fins fonctionnelles doivent être essayés dans un coin d'essai.

Ce coin d'essai se constitue de deux parois à angle droit, d'un plancher et, si nécessaire, d'un plafond, toutes ces parties étant en contre-plaqué peint en noir mat d'environ 20 mm d'épaisseur. Il convient d'assurer au coin d'essai des dimensions linéaires supérieures d'au moins 15 % à celles des appareils soumis à l'essai. L'appareil est placé aux distances des parois, du plafond ou du plancher, spécifiées par le fabricant. Si aucune distance n'est spécifiée, alors:

a) les appareils normalement utilisés sur un plancher ou sur une table sont placés aussi près que possible des parois;

b) *les appareils normalement fixés à un mur sont installés sur l'une des parois, aussi près de l'autre paroi et du plancher ou du plafond que cela peut se produire en* UTILISATION NORMALE*;*

c) *les appareils normalement fixés à un plafond sont fixés au plafond aussi près des parois que cela peut se produire en* UTILISATION NORMALE*.*

10.4.3 Appareils destinés à l'installation dans une armoire ou dans un mur

Ces appareils sont encastrés conformément aux instructions d'installation, en utilisant des parois de contre-plaqué peint en noir mat d'environ 10 mm, ou 20 mm d'épaisseur lorsqu'il s'agit de représenter respectivement les parois d'une armoire ou les murs d'un bâtiment.

10.5 Résistance à la chaleur

10.5.1 Intégrité des DISTANCES D'ISOLEMENT et des LIGNES DE FUITE

Les DISTANCES D'ISOLEMENT et les LIGNES DE FUITE doivent satisfaire aux exigences de 6.7, lorsque l'appareil fonctionne à une température ambiante de 40 °C ou à la température ambiante maximale ASSIGNEE si elle est supérieure.

La conformité, en cas de doute, lorsque l'appareil produit une quantité appréciable de chaleur, est vérifiée en faisant fonctionner l'appareil dans les conditions de référence pour les essais indiquées en 4.3, excepté que la température ambiante est de 40 °C, ou de la valeur maximale ASSIGNEE *si elle est supérieure. Après cet essai, les* DISTANCES D'ISOLEMENT *et les* LIGNES DE FUITE *ne doivent pas être réduites en dessous des valeurs requises par 6.7.*

Si l'appareil est équipé d'une ENVELOPPE *non métallique, la température des éléments de l'*ENVELOPPE *est mesurée pendant l'essai ci-dessus selon 10.5.2.*

10.5.2 ENVELOPPES non métalliques

Les ENVELOPPES en matière non métallique doivent être résistantes aux températures élevées.

La conformité est vérifiée par essai après l'un des traitements suivants.

a) *Un traitement hors fonctionnement, où l'appareil hors tension est stocké pendant 7 h à une température de 70 °C ± 2 °C ou à 10 °C ± 2 °C au-dessus de la température mesurée durant l'essai de 10.5.1, selon la valeur la plus élevée. Si l'appareil comporte des éléments qui pourraient être endommagés par ce traitement, une* ENVELOPPE *vide peut être soumise au traitement, suivie par un montage de l'appareil à l'issue de l'épreuve.*

b) *Un traitement en fonctionnement, où l'appareil est mis en service dans les conditions de référence pour les essais de 4.3, sauf que la température ambiante de 20 °C ± 2 °C au-dessus de 40 °C, ou au-dessus de la température ambiante maximale* ASSIGNEE *si elle est supérieure à 40 °C.*

Dans les 10 minutes suivant la fin du traitement, l'appareil doit subir les essais applicables des 8.2 et 8.3 et remplir les critères du 8.1.

10.5.3 Matériaux isolants

Les matériaux isolants doivent avoir une tenue à la chaleur adaptée.

a) Les parties en matériau isolant qui sont utilisées pour porter des parties branchées sur l'alimentation RESEAU doivent être constituées de matériaux isolants qui ne provoquent pas de DANGER si des courts-circuits se produisent dans l'appareil.

b) Lorsqu'en UTILISATION NORMALE, des BORNES supportent un courant supérieur à 0,5 A et si une quantité importante de chaleur peut être dissipée en cas d'un mauvais contact, l'isolation qui supporte les BORNES doit être faite dans un matériau qui ne se ramollira pas jusqu'à provoquer un DANGER ou d'être à l'origine de courts-circuits.

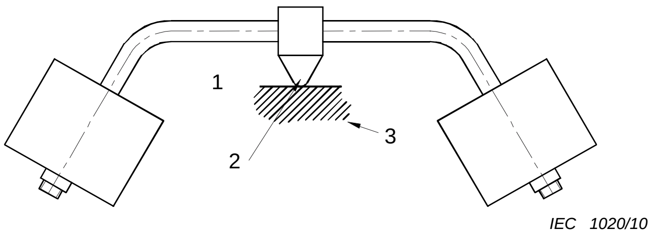
En cas de doute, la conformité est vérifiée par examen des données des matériaux. Si les données des matériaux ne sont pas suffisantes, un des essais suivants est réalisé.

1) *Un échantillon du matériau isolant épais d'au moins 2,5 mm est soumis à l'essai de pression à la bille en utilisant l'appareil d'essai de la Figure 14. L'essai est réalisé dans une étuve à la température mesurée comme spécifié en 10.3 d) ou 10.3 e) ± 2 °C, ou à 125 °C ± 2 °C, selon la température la plus élevée. La partie à tester est supportée pour que sa surface soit horizontale soit mise en contact avec la partie sphérique de l'appareil avec une force de 20 N. Après 1 h, l'appareil est enlevé et l'échantillon refroidi en 10 s à environ la température de la pièce par immersion dans de l'eau froide. Le diamètre de l'impression de la bille ne doit pas être supérieur à 2 mm.*

   NOTE 1 Si c'est nécessaire, l'épaisseur exigée peut être obtenue en utilisant deux ou plus de sections de la partie.

   NOTE 2 Pour les bobines, seulement les parties qui supportent ou retiennent les BORNES sont soumises à l'essai.

   NOTE 3 Plus d'information sur ce test est disponible dans l'IEC 60695-10-2.



Légende

1 Partie à tester

2 Partie sphérique de l'appareil (diamètre: 5 mm)

3 Support

Figure 14 – Appareil d'essai de pression à la bille

2) *L'essai de ramollissement Vicat de l'ISO 306, méthode A120. La température de ramollissement Vicat doit être d'au moins 130 °C.*

11 Protection contre les DANGERS des fluides et des corps solides étrangers

11.1 Généralités

Les appareils doivent être conçus de manière à garantir la protection des OPERATEURS et de la zone périphérique contre les DANGERS des fluides et des corps solides étrangers rencontrés en UTILISATION NORMALE.

NOTE 1 Les liquides pouvant être rencontrés sont classés en trois catégories:

a) ceux qui ont un contact continu, par exemple: dans les récipients destinés à les contenir;
b) ceux qui ont un contact occasionnel, par exemple: fluides de nettoyage;
c) ceux qui ont un contact accidentel (imprévu). Le fabricant ne peut fournir de protection contre de pareilles éventualités.

Les fluides spécifiés par le fabricant, y compris les fluides de nettoyage et de décontamination sont pris en compte. Les autres fluides ne sont pas pris en compte.

NOTE 2 Le terme « fluides » désigne des liquides ou des gaz.

NOTE 3 Toutes les pressions de l'Article 11 sont des pressions manométriques.

La conformité est vérifiée par le traitement et les essais de 11.2 à ~~11.5~~ 11.7 selon ce qui est applicable.

11.2 Nettoyage

Lorsqu'un procédé de nettoyage ou de décontamination est spécifié par le fabricant, cela ne doit entraîner ni DANGER direct pour la sécurité, ni DANGER électrique, ni DANGER résultant de la corrosion ou autre affaiblissement des éléments structurels associés à la sécurité.

La conformité est vérifiée en nettoyant l'appareil trois fois si un procédé de nettoyage est spécifié et en décontaminant l'appareil une fois si un procédé de décontamination est spécifié, selon les instructions du fabricant. Si immédiatement après ce traitement il y a des signes de mouillage de parties pouvant entraîner un DANGER, l'appareil doit passer les essais de tension de 6.8 (sans le pré-conditionnement à l'humidité) applicables au type d'isolation (voir 6.7) et les parties ACCESSIBLES ne doivent pas dépasser les limites de 6.3.1.

11.3 Déversement

Si du liquide peut se répandre dans l'appareil en UTILISATION NORMALE, celui-ci doit être conçu de manière à ne présenter aucun DANGER, par exemple à la suite du mouillage de l'isolation ou de parties internes non isolées, ou en cas de contact de substances potentiellement agressives (telles que corrosives, toxiques ou liquides inflammables) avec des parties de l'appareil.

Si des substances potentiellement agressives (telles que corrosives, toxiques ou liquides inflammables) sont susceptibles d'être déversées sur des parties de l'appareil en UTILISATION NORMALE, l'appareil mouillé devrait être analysé pour déterminer la compatibilité avec la substance agressive.

La conformité est vérifiée par examen. En cas de doute, 0,2 l d'eau est versée en flux continu pendant 15 s d'une hauteur de 0,1 m, successivement sur chaque point où le liquide peut atteindre des parties électriques. Immédiatement après ce traitement, les DISTANCES D'ISOLEMENT et l'isolation solide doivent passer les essais de tension de 6.8 (sans le pré-conditionnement à l'humidité) applicables au type d'isolation (voir 6.7) et les parties ACCESSIBLES ne doivent pas dépasser les limites de 6.3.1.

11.4 Débordement

Le débordement de liquide issu de récipients dans l'appareil ne doit pas présenter de DANGER en UTILISATION NORMALE, par exemple à la suite du mouillage de l'isolation ou de parties sous TENSION DANGEREUSE non isolées.

Un appareil pouvant être déplacé alors qu'un récipient est rempli de liquide doit être protégé contre tout débordement de liquide du récipient.

La conformité est vérifiée par le traitement et par les essais suivants. Le récipient de liquide est complètement rempli. Ensuite, une quantité supplémentaire de liquide, égale à 15 % de la capacité du récipient ou 0,25 l en prenant le volume le plus élevé, est versée en flux continu pendant 60 s. L'appareil pouvant être déplacé alors que le récipient est rempli de liquide est ensuite incliné de 15° dans les directions les moins favorables par rapport à la position d'UTILISATION NORMALE. Immédiatement après ce traitement, les DISTANCES D'ISOLEMENT et l'isolation solide doivent passer les essais de tension de 6.8 (sans le pré-conditionnement à l'humidité) applicables au type d'isolation (voir 6.7) et les parties ACCESSIBLES ne doivent pas dépasser les limites de 6.3.1.

11.5 Electrolyte des piles et accumulateurs

Les piles et accumulateurs doivent être installés de manière à ne pas mettre en défaut la sécurité par la fuite de l'électrolyte.

NOTE Voir aussi 13.2.2.

La conformité est vérifiée par examen.

11.6 Appareils ~~spécialement protégés~~ avec un degré de protection contre la pénétration (code IP) ASSIGNEE

~~Lorsque l'appareil est ASSIGNE et marqué par le fabricant comme conforme à l'un des degrés de protection spécifiés de l'IEC 60529, il doit résister à l'entrée d'eau jusqu'à la valeur spécifiée.~~

~~La conformité est vérifiée par examen et par réalisation sur l'appareil des traitements adaptés de l'IEC 60529, ensuite les DISTANCES D'ISOLEMENT et l'isolation solide doivent passer les essais de tension de 6.8 (sans le pré-conditionnement à l'humidité) applicables au type d'isolation (voir 6.7) et les parties ACCESSIBLES ne doivent pas dépasser les limites de 6.3.1.~~

11.6.1 Généralités

Les appareils, auxquels le fabricant a assigné un des degrés de protection définis dans l'IEC 60529 doivent résister de façon adéquate à la pénétration des corps solides étrangers et de l'eau qui pourrait engendrer un DANGER.

Les appareils peuvent avoir des degrés de protection différents en fonction des dispositions de montage, des ensembles ou des conditions de fonctionnement. Les degrés de protection doivent être spécifiés dans la documentation pour chaque disposition de montage. Si le degré de protection dépend de positions, de couvercles, de joints ou de conditions de fonctionnement spécifiques, ces conditions doivent être spécifiées dans la documentation.

Si les caractéristiques ASSIGNEES sont marquées sur l'appareil, elles doivent l'être d'une manière qui évite toute mauvaise compréhension ou mauvaise utilisation. Les désignations de l'IEC 60529 doivent être utilisées (code IP). Le code IP et les conditions de fonctionnement ou hors fonctionnement doivent être expliqués dans la documentation avec les autres avertissements.

Pour l'essai IPx8, le niveau d'eau au-dessus de l'appareil et la durée de l'essai doivent être appliqués comme cela est spécifié dans la documentation. Les conditions susmentionnées doivent être plus sévères que les spécifications pour le code IPx7 selon l'IEC 60529.

La conformité est vérifiée par examen et comme cela est spécifié de 11.6.2 à 11.6.4 selon ce qui est applicable.

11.6.2 Conditions normales d'essai

L'appareil doit être dans un bon état de propreté et à l'état neuf avec toutes les pièces en place et montées comme cela est défini par le fabricant. S'il est impossible en pratique de soumettre à l'essai l'appareil complet, des pièces représentatives ou un appareil à échelle réduite avec le même niveau de détails de conception que l'original, doivent être soumis à l'essai.

Les APPAREILS PORTATIFS sont placés dans la position la moins favorable. Les appareils portables sont placés dans la position la moins favorable de l'utilisation normale. Les autres appareils sont positionnés ou installés conformément aux instructions d'installation.

Les BORNES sont considérées comme faisant partie intégrante de l'appareil. Cependant, les BORNES équipées d'un capuchon ou d'un couvercle de protection nécessaire au maintien du degré de protection assigné sont montées conformément aux spécifications du fabricant.

L'appareil est en état de fonctionnement (mis sous tension) pendant le traitement, sauf

a) si le fabricant spécifie des degrés de protection pour les appareils hors fonctionnement (mis hors tension), ou
b) si le fait que l'appareil soit en fonctionnement ou non pendant le traitement n'affecte pas les résultats de l'essai.

EXEMPLE 1 Un boîtier de terrain contient des composants électroniques. Dans ce cas, le fait que les composants électroniques situés à l'intérieur du boîtier fonctionnent ou non n'a généralement aucune influence sur les résultats de l'essai. Par conséquent, l'appareil peut également être soumis à l'essai sans composants électroniques intégrés.

EXEMPLE 2 Le boîtier d'un appareil a un arbre sortant rotatif, équipé d'un joint adapté au degré de protection contre la pénétration assigné applicable. Dans ce cas, il est considéré que la rotation de l'arbre affecte les résultats d'essai.

11.6.3 Protection contre les corps solides étrangers (y compris les poussières)

L'essai applicable de l'IEC 60529 pour la protection contre la pénétration de corps solides étrangers est réalisé.

Après l'essai, la conformité est vérifiée par examen de l'échantillon selon les critères d'acceptation de l'IEC 60529.

De plus, l'appareil est examiné afin de détecter la pénétration de corps étrangers. En particulier, ils ne doivent pas:

a) se déposer sur les parties isolantes au risque de provoquer un DANGER;
b) s'accumuler au risque de causer une propagation du feu.

NOTE Un DANGER pourrait apparaître en cas de pontage de parties conductrices par des poussières conductrices ou si des poussières non conductrices sont mouillées sous l'effet de l'humidité.

11.6.4 Protection contre l'eau

L'essai applicable de l'IEC 60529 pour la protection contre la pénétration d'eau est réalisé.

L'appareil est examiné afin de détecter la pénétration d'eau. Une éventuelle pénétration d'eau ne doit pas compromettre la sécurité. En particulier, l'eau ne doit pas:

a) se déposer sur les parties isolantes au risque de provoquer un danger;
b) atteindre les pièces sous tension dangereuse ou les enroulements qui ne sont pas conçus pour fonctionner lorsqu'ils sont humides;
c) s'accumuler à proximité de l'extrémité d'un câble ou pénétrer à l'intérieur de celui-ci à des emplacements où elle pourrait provoquer un danger;
d) s'accumuler à des emplacements où elle pourrait provoquer un DANGER en prenant en compte le mouvement de l'appareil.

11.7 Fluide sous pression et fuites

11.7.1 Pression maximale

La pression maximale, à laquelle une partie de l'appareil est soumise en UTILISATION NORMALE ou en CONDITION DE PREMIER DEFAUT, ne doit pas dépasser la pression maximale ASSIGNEE de service pour cette partie.

La pression maximale à prendre en compte doit être celle qui aura la plus forte valeur des situations suivantes:

a) la pression d'alimentation ASSIGNEE maximale précisée pour une source de fluide externe;

b) la pression programmée d'un dispositif de sécurité de surpression livré comme partie de l'appareil;

c) la pression maximale que peut fournir un dispositif générant une pression faisant partie de l'appareil, sauf si la pression est limitée par un dispositif de sécurité de surpression.

La conformité est vérifiée par examen des CARACTERISTIQUES ASSIGNEES des différentes parties et, si nécessaire, par la mesure des pressions.

NOTE Les appareils conformes aux exigences du 11.7 peuvent ne pas être acceptés comme conformes aux exigences nationales sur les hautes pressions. L'Annexe G décrit les exigences et essais qui sont acceptés comme preuve de conformité avec les obligations nationales aux USA, au Canada et dans quelques autres pays.

11.7.2 Fuites et ruptures à haute pression

Les parties de l'appareil contenant des fluides et qui en UTILISATION NORMALE présentent simultanément les deux caractéristiques ci-dessous, ne doivent pas causer de DANGER, soit par ruptures, soit par fuites:

a) un produit de la pression par le volume supérieur à 200 kPa l;

b) une pression supérieure à 50 kPa.

~~NOTE~~ Les autorités nationales peuvent permettre l'établissement de la sécurité par calcul, par exemple selon la Directive Équipement sous Pression (~~97/23/EC~~ 2014/68/UE).

La conformité est vérifiée par examen et, si un DANGER peut arriver, par l'essai hydraulique suivant.

La pression d'essai (P_{essai}) est ~~égale à~~ la pression de service maximale (P_{max}) multipliée par ~~un coefficient de 1,5 pour l'essai contre les fuites et par un coefficient de 2,0 pour l'essai contre l'explosion~~ le coefficient applicable de la Figure 16. Tout dispositif de sécurité de surpression susceptible de limiter la pression d'essai est désactivé pendant l'essai.

La pression ~~appliquée croît régulièrement jusqu'à la valeur~~ d'essai ~~spécifiée~~ est augmentée progressivement jusqu'à P_{essai} et elle est maintenue à cette valeur durant 1 min. ~~La pièce en essai~~ L'échantillon ne doit pas éclater, ni présenter de déformations (plastiques) permanentes ~~(coefficient 2,0)~~ ou de fuite ~~(coefficient 1,5)~~. À condition que la pression d'essai soit maintenue, une fuite au niveau d'un joint pendant cet essai n'est pas considérée comme une défaillance sauf si elle apparaît à une pression inférieure à ~~1,5 fois la pression de service maximale~~ 75 % de P_{essai}, ou inférieure à P_{max}, en prenant la valeur la plus élevée des deux.

Aucune fuite n'est ~~tolérée~~ admise pour les pièces ~~ou enceintes prévues pour contenir~~ contenant des liquides prévues pour des substances toxiques, inflammables ou ~~dangereuses~~ présentant un autre danger, si cela peut entraîner un DANGER.

Lorsque les parties ~~ou les conduits sans marquage d'information~~ contenant des fluides ne peuvent ~~être essayés par des~~ faire l'objet d'essais hydrauliques, l'intégrité ~~doit~~ peut être vérifiée par d'autres essais adaptés, par exemple des essais pneumatiques en utilisant des moyens adaptés, à la même pression d'essai que celle définie pour l'essai hydraulique.

Par exception aux exigences ci-dessus, les parties des systèmes de réfrigération contenant des fluides doivent être conformes aux exigences de pression applicables de l'~~IEC 60335-2-24~~ EN 378-2 ou de l'IEC 60335-2-89 selon ~~le cas~~ la norme qui est applicable.

La conformité est vérifiée comme cela est spécifié dans l'~~IEC 60335-2-24~~ EN 378-2 ou l'IEC 60335-2-89 selon ~~le cas~~ la norme qui est applicable.

Si aucune autre option n'est disponible, il convient de réaliser des essais de surpression pneumatique. Ces essais peuvent être extrêmement dangereux. La libération soudaine de l'énergie stockée en raison d'une rupture de l'échantillon d'essai peut causer des blessures graves, voire mortelles. Il convient de connaître les dangers liés au stockage de l'énergie dans le système à surpression interne et de mettre en place les mesures de protection appropriées. Il convient de réaliser ces essais uniquement derrière un écran antidéflagrant ou à l'intérieur d'une enveloppe adaptée afin de protéger le personnel de laboratoire contre les projections de débris, les dangers liés à des niveaux sonores élevés et, dans des cas extrêmes, les ondes de souffle.

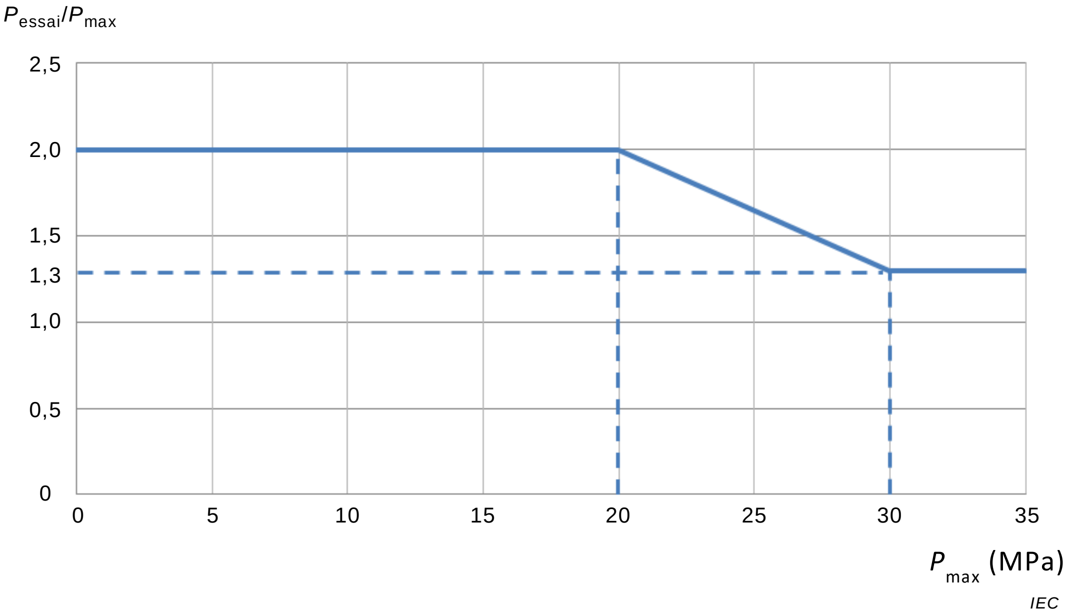


Figure 16 – Rapport entre la pression d'essai et la pression de service maximale

11.7.3 Fuites des parties à basse pression

Les fuites des parties contenant des fluides de pressions inférieures aux niveaux de 11.7.2 ne doivent pas causer de DANGER.

La conformité est vérifiée par examen des CARACTERISTIQUES ASSIGNEES des parties correspondantes et, si nécessaire, en soumettant ces parties à des pressions de fluides égales à deux fois la pression maximale en UTILISATION NORMALE. Aucune fuite ne doit apparaître si elle peut être la cause d'un DANGER.

11.7.4 Dispositif de sécurité de surpression

Un dispositif de sécurité de surpression ne doit pas se déclencher en UTILISATION NORMALE. Il doit satisfaire aux exigences suivantes.

a) Il doit être monté aussi près que possible des parties contenant les fluides sous pression, qu'il est censé protéger.
b) Il doit être installé pour permettre un accès facile lors des opérations d'inspection, de maintenance et de réparation.
c) Il ne doit pas pouvoir être ajusté sans l'aide d'un OUTIL.
d) Son ouverture d'évacuation doit être localisée et dirigée de telle sorte que la matière éjectée ne soit pas dirigée vers une personne.
e) Son ouverture d'évacuation doit être localisée et dirigée de telle sorte que le fonctionnement de ce dispositif ne vienne pas déposer de la matière sur des parties si cela entraînerait un DANGER.

f) Il doit avoir une capacité d'évacuation adaptée afin d'éviter que la pression n'excède la valeur maximale ASSIGNEE de la pression nominale du système.

Il ne doit pas y avoir de vannes de fermeture entre le dispositif de sécurité de surpression et les parties qu'il est censé protéger.

La conformité est vérifiée par examen et par des essais.

12 Protection contre les radiations, y compris les sources laser, et contre la pression acoustique et ultrasonique

12.1 Généralités

L'appareil doit garantir une protection contre les effets des rayonnements générés en interne ultraviolets, ionisants et hyperfréquences ainsi que des sources laser, et de la pression acoustique et ultrasonique.

La conformité est effectuée par des essais si l'appareil peut entraîner de tels DANGERS.

12.2 Appareil produisant un rayonnement ionisant

12.2.1 Rayonnement ionisant

12.2.1.1 Généralités

Un appareil émettant des rayonnements ionisants (soit de sources radioactives, soit de rayons X) doit répondre aux exigences suivantes.

a) S'il est conçu pour émettre des rayonnements, il doit répondre aux exigences de 12.2.1.2. Alternativement, s'il est dans le domaine d'application de l'IEC ~~60405~~ 62598, il doit être testé, classé et marqué selon les exigences de l'IEC ~~60405~~ 62598.

b) S'il utilise ou génère des rayonnements, mais émet seulement des rayonnements parasites, il doit répondre aux exigences de 12.2.1.3.

NOTE 1 Voir l'IEC ~~60405~~ 62598 pour plus d'information sur les exigences des appareils utilisant des rayonnements ionisants.

~~NOTE 2 Pour les rayons X et gamma: 1 µSv/h = 0,1 mR/h et 5 µSv/h = 0,5 mR/h.~~

NOTE ~~3~~ 2 Les appareils qui émettent des rayonnements ionisants sont régis par les autorités sanitaires dans la plupart des pays. Ces réglementations concernent souvent les émissions de radiations de l'appareil et la dose cumulée de radiations reçues par les travailleurs et autres personnes à proximité de l'appareil. Voir la Directive sur les rayonnements ionisants (96/29/EURATOM) ou USA 29 CFR 1910.1096 comme exemple de ces réglementations.

La conformité est vérifiée par examen de la documentation de conformité IEC ~~60405~~ 62598 ou comme spécifié au 12.2.1.2 ou au 12.2.1.3 selon le cas.

12.2.1.2 Appareil conçu pour émettre des rayonnements

Un appareil contenant des substances radioactives ou générant des rayons X et conçu pour émettre des rayonnements ionisants en dehors de l'appareil, doit être testé et marqué de la manière suivante:

Le débit de dose efficace d'un rayonnement doit être mesuré à une distance constante de 50 mm à 1 m de toute surface extérieure de l'appareil. La distance de mesure doit être comprise entre 50 mm à 1 m. Si la mesure est réalisée à une distance différente de 50 mm, le débit équivalent de dose efficace du rayonnement à une distance de 50 mm doit être calculée. Si le débit de dose efficace d'un rayonnement en tout point facilement atteint à 50 mm de la surface extérieure de l'appareil est supérieur à 5 µSv/h, l'appareil doit être marqué comme suit, si applicable:

a) avec le symbole 17 du Tableau 1;

b) pour les appareils contenant une ou plus substances radioactives, avec les abréviations des radionucléides;

c) si le débit de dose maximale à 1 m, ou avec un débit de dose compris entre 1 µSv/h et 5 µSv/h, avec la distance appropriée exprimée en mètres.

NOTE Des exemples de marquages adaptés sont: «2,5 µSv/h à 1 m»; «3 µSv/h à 0,3 m».

La conformité est vérifiée en mesurant le débit de dose du rayonnement dans les conditions qui produiront le rayonnement maximal. La méthode de détermination du débit de dose du rayonnement doit être efficace sur toute la plage des énergies de rayonnement possibles. Les appareils contenant des sources de rayons X sont réglés pour produire le niveau maximal de rayonnement.

12.2.1.3 Appareil non conçu pour émettre des rayonnements

Le débit de dose efficace d'un rayonnement parasite non prévu en tout point facilement atteint à 100 mm de la surface extérieure de l'appareil ne doit pas être supérieur à 1 µSv/h.

NOTE De tels appareils contiennent des substances radioactives, des sources de rayons X ou comportent des tubes à rayon cathodique ou des accélérateurs d'électrons à des tensions supérieures à 5 kV.

La conformité est vérifiée en mesurant le débit de dose du rayonnement dans les conditions qui produiront le rayonnement maximal. La méthode de détermination du débit de dose du rayonnement doit être efficace sur toute la plage des énergies de rayonnement possibles. Les appareils à rayons cathodiques sont testés en affichant une mire pour chaque faisceau ne dépassant pas 30 mm × 30 mm ou le plus petit affichage possible, en prenant le plus grand des deux cas. Les appareils contenant des sources de rayons X sont réglés pour produire le niveau maximal de rayonnement. Le dispositif d'affichage doit être positionné de façon à produire un rayonnement maximal.

12.2.2 Electrons accélérés

L'appareil doit être construit de telle sorte que les compartiments dans lesquels des électrons sont accélérés par des tensions dépassant les 5 kV ne puissent pas être ouverts sans l'utilisation d'un OUTIL.

La conformité est vérifiée par examen.

12.3 Rayonnement ~~ultraviolet (UV)~~ optique

~~Les appareils comportant une source de lumière ultraviolette qui n'est pas destinée à fournir un éclairage ultraviolet externe ne doivent pas permettre la sortie involontaire de rayons ultraviolets pouvant provoquer un DANGER.~~

~~NOTE 1 Le rayonnement UV entraîne notamment des dommages biologiques et des dégradations de matériaux comme ceux des ENVELOPPES plastiques et de l'isolation.~~

~~NOTE 2 D'autres recommandations ou exigences peuvent être prescrites par les autorités nationales chargées de la santé et la sécurité au travail.~~

Les appareils utilisant des lampes et des systèmes de lampes qui émettent un rayonnement ultraviolet, visible ou infrarouge, y compris les diodes électroluminescentes, doivent empêcher toute fuite non intentionnelle de rayonnement susceptible de causer un DANGER.

Les sources de rayonnement doivent être évaluées conformément à l'IEC 62471, à l'exception des sources considérées comme sûres (Tableau 22) ou sûres dans certaines conditions (Tableau 23). Les lampes et systèmes utilisant des lampes classées dans les groupes de risque 1, 2 ou 3 de l'IEC 62471 doivent porter un marquage conforme à l'IEC TR 62471-2. Si la dimension ou la conception de la lampe ou des systèmes utilisant des lampes ne permet pas dans la pratique de réaliser le marquage, le symbole 14 doit être apposé sur l'appareil et le marquage doit être inclus dans la documentation.

Les informations relatives aux mesures de protection, aux restrictions d'utilisation et aux instructions de fonctionnement qui peuvent être nécessaires doivent être fournies, y compris les conditions d'utilisation applicables du Tableau 23.

NOTE L'attention est attirée sur le fait que d'autres lignes directrices ou exigences peuvent être spécifiées par les autorités nationales ou d'autres autorités.

La conformité est vérifiée par examen et ~~par une évaluation de la documentation sur l'appréciation du RISQUE~~ si nécessaire par le mesurage du rayonnement optique afin de confirmer l'absence de danger.

Tableau 22 – Lampes ou systèmes utilisant des lampes considérés comme photobiologiquement sûrs

Lampe ou système utilisant des lampes
LED témoins
Écrans d'assistants numériques
Écrans à affichage à cristaux liquides
Écrans d'ordinateur
Lampes éclair photographiques
Matériel de présentation à tableau blanc interactif
Éclairage direct avec lampes à filament au tungstène, lampes à LED, tubes fluorescents compacts ou tubes fluorescents avec diffuseurs
Tout appareil du "groupe sans risque" (conformément à l'IEC 62471)

Tableau 23 – Lampes ou systèmes utilisant des lampes considérés comme photobiologiquement sûrs dans certaines conditions

Lampe ou système utilisant des lampes	Conditions d'utilisation
Éclairage fluorescent sans diffuseurs au-dessus des lampes	Sûr à des niveaux normaux d'éclairage (~600 lux)
Projecteurs aux halogénures métalliques/au mercure à haute pression	Sûrs si la glace de fermeture est intacte et si la lampe ne se situe pas dans le champ visuel
Projecteurs de bureau	Sûrs si l'opérateur n'observe pas le faisceau
Lumières noires UVA basse pression	Sûres si non situées dans le champ visuel et si les mains ne sont pas irradiées tout en maintenant la lumière noire

12.4 Rayonnement hyperfréquence

En CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT, en tout point situé à 50 mm de l'appareil, la densité de puissance des radiations parasites hyperfréquences à des fréquences comprises entre 1 GHz et 100 GHz ne doit pas dépasser 10 W/m^2. Cette exigence ne s'applique pas aux éléments de l'appareil où les hyperfréquences sont propagées intentionnellement, par exemple aux sorties des guides d'ondes.

La conformité est vérifiée par essai dans des conditions d'essais de référence.

12.5 Pression acoustique et ultrasonique

12.5.1 Niveau acoustique

Si l'appareil produit un bruit sonore à un niveau tel qu'il peut être la cause d'un DANGER, le fabricant doit mesurer le niveau de pression acoustique maximal que l'appareil peut produire (excepté pour les bruits des alarmes et des parties séparées des appareils) et calculer le niveau maximal de puissance acoustique suivant les spécifications de l'ISO 3746 ou de l'ISO 9614-1.

Le fabricant doit spécifier dans les instructions d'installation comment l'AUTORITE RESPONSABLE doit s'assurer que le niveau de puissance acoustique de l'appareil, à son emplacement d'utilisation après installation complète n'atteindra pas une valeur qui pourrait présenter un DANGER. Ces instructions doivent identifier les matériaux de protection disponibles et pratiques, ou les mesures qui peuvent être utilisées, y compris la mise en place de capots ou chicanes d'atténuation de bruit.

NOTE 1 Un niveau de pression acoustique de 80 dBA par rapport à la pression acoustique de référence de 20 µPa est actuellement considéré, par beaucoup d'organismes compétents, comme la limite au-delà de laquelle un DANGER peut exister. Des méthodes spécifiques, telles que l'utilisation de casques de protection, peuvent permettre d'accepter un niveau plus important sans DANGER pour un OPERATEUR.

NOTE 2 Il est recommandé dans les instructions d'utilisation que la mesure ou le calcul du niveau de pression acoustique soit fait par l'AUTORITE RESPONSABLE à la fois pour la position d'un OPERATEUR en UTILISATION NORMALE, et pour une position située à 1 m de l'ENVELOPPE de l'appareil, là où le niveau de pression acoustique est le plus important.

La conformité est vérifiée en mesurant le niveau maximal pondéré A de pression acoustique à la position de l'OPERATEUR et dans d'autres positions et, si nécessaire, en calculant le niveau maximal pondéré A de puissance acoustique produit par l'appareil, suivant les spécifications de l'ISO 3746 ou de l'ISO 9614-1. Les conditions suivantes s'appliquent.

a) *Durant les mesures, toutes les parties nécessaires à une utilisation correcte de l'appareil et fournies par le fabricant comme parties intégrantes d'un tel appareil, par exemple une pompe, sont montées à leur place et fonctionnent comme dans l'UTILISATION NORMALE.*

b) *Les appareils de mesure de niveau acoustique utilisés lors des mesures sont en conformité soit avec le type 1 de l'IEC 61672-1, soit pour un appareil de mesure intégrant le niveau acoustique, avec le type 1 de l'IEC 61672-2.*

c) *La salle est semi-réverbérante et équipée d'un plancher réverbérant rigide. La distance entre tout mur ou tout autre objet et la surface de l'appareil n'est pas inférieure à 3 m.*

d) *L'essai sur l'appareil est réalisé dans la configuration de charge et des autres conditions de fonctionnement (par exemple, la pression, le débit, la température) qui crée le niveau maximal de pression acoustique.*

12.5.2 Pression ultrasonique

Si l'appareil émet des ultrasons à un niveau qui peut présenter un DANGER, alors qu'il n'est pas prévu pour en émettre, le fabricant doit mesurer le niveau maximal de pression ultrasonique que l'appareil peut produire. Lorsque la mesure est effectuée à la position normale de l'OPERATEUR et à 1 m de la position de l'appareil où le niveau de pression acoustique le plus élevé est obtenu, le niveau de pression ultrasonique ne doit pas dépasser 110 dB au-dessus de la valeur de la pression de référence de 20 µPa, pour des fréquences de 20 kHz et 100 kHz.

La conformité est vérifiée en mesurant la pression dans les conditions de référence pour les essais.

Si l'appareil, prévu pour émettre des ultrasons, en émet à un niveau qui peut présenter un DANGER, le fabricant doit mesurer le niveau maximal de pression ultrasonique que l'appareil peut produire. La pression acoustique doit être mesurée à la position normale de l'OPERATEUR et à 1 m de la position de l'appareil où le niveau de pression acoustique est le plus élevé à l'extérieur ou à l'intérieur du faisceau utile.

A l'extérieur du faisceau utile, la pression ultrasonique ne doit pas dépasser 110 dB au-dessus de la pression de référence de 20 μPa pour des fréquences comprises entre 20 kHz et 100 kHz.

Si à l'intérieur du faisceau utile la pression ultrasonique dépasse 110 dB pour des fréquences comprises entre 20 kHz et 100 kHz, l'appareil doit être marqué avec le symbole 14 du Tableau 1 et la documentation doit clairement indiquer les informations suivantes:

a) les dimensions du faisceau utile;
b) la zone du faisceau utile où la pression ultrasonique est supérieure à 110 dB;
c) le niveau maximal de pression acoustique à l'intérieur de la valeur de ladite zone.

La conformité est vérifiée par examen et mesure de la pression dans les conditions d'essai de référence.

12.6 Sources laser

Les appareils faisant appel à des sources laser doivent être conformes à l'IEC 60825-1.

La conformité est vérifiée comme spécifié dans l'IEC 60825-1.

13 Protection contre les émissions de gaz et substances, les explosions et les implosions

13.1 Gaz et substances toxiques et nocifs

L'appareil ne doit pas émettre de quantités dangereuses ~~de gaz ou substances toxiques ou nocifs~~ de substances dangereuses en CONDITION NORMALE et en CONDITION DE PREMIER DEFAUT.

~~La documentation du fabricant doit indiquer quels gaz ou substances potentiellement toxiques et nocifs peuvent être libérés ainsi que leur quantité.~~

Si des substances potentiellement dangereuses sont émises, L'OPERATEUR ne doit pas être directement exposé à une quantité de substance qui pourrait lui être nocive.

Si le fonctionnement NORMAL de l'appareil exige le rejet de substances dangereuses, et si ce rejet est destiné à être contrôlé par L'AUTORITE RESPONSABLE conformément aux instructions du fabricant, ce rejet n'est alors pas considéré comme une émission de substances dangereuses.

NOTE Les limites d'exposition aux produits chimiques et les réglementations encadrant leur manipulation et leur élimination peuvent être consultées dans les publications de l'Agence européenne pour la sécurité et la santé au travail (OSHA) ou dans la documentation réglementaire nationale. Des réglementations locales, nationales ou régionales peuvent s'appliquer.

La conformité est vérifiée par examen de la documentation du fabricant. En raison de la grande diversité des gaz et substances, des essais de conformité fondés sur des valeurs limites ne peuvent pas être spécifiés et, de ce fait, il convient de se référer aux tableaux des valeurs limites des seuils profesionnels.

13.2 Explosion et implosion

13.2.1 Composants

Lorsque des composants pouvant exploser en cas de surchauffe ou de surcharge ne sont pas équipés d'un limiteur de pression, le dispositif de protection pour un OPERATEUR doit être intégré à l'appareil (voir 7.7 pour les parties éjectées).

Les limiteurs de pression doivent être placés de telle sorte qu'une décharge n'engendre pas de DANGER pour les OPERATEURS. La construction doit être telle qu'aucun limiteur de pression ne soit obstrué.

La conformité est vérifiée par examen.

13.2.2 Piles, accumulateurs et charge des accumulateurs

Les piles et accumulateurs ne doivent pas causer d'explosion ou être à l'origine d'un DANGER d'incendie en cas de charge ou de décharge excessive, ou si la pile ou l'accumulateur est installé avec une polarité incorrecte. Si nécessaire, une protection doit être incorporée à l'appareil, sauf si les instructions du fabricant spécifient que l'appareil ne peut être utilisé qu'avec des piles et accumulateurs à protection intégrée.

Si l'installation d'une pile ou d'un accumulateur de type inadéquat peut provoquer un DANGER d'explosion ou d'incendie, (par exemple dans le cas où une pile ou un accumulateur à protection intégrée serait spécifié), il doit y avoir un marquage d'un avertissement sur ou à proximité du logement ou du support de pile ou d'accumulateur, ainsi qu'une mention dans les instructions du fabricant. Un marquage acceptable peut être le symbole 14 du Tableau 1.

Si des piles peuvent être installées et connectées dans le logement des accumulateurs d'un appareil disposant d'un chargeur, le marquage d'un avertissement doit être placé dans ce logement ou à proximité de celui-ci. Le marquage doit prévenir la charge de piles et indiquer le type d'accumulateurs utilisable avec le circuit de recharge. Le symbole 14 du Tableau 1 constitue un marquage acceptable.

Les compartiments des piles et accumulateurs doivent être conçus de telle sorte qu'il n'y ait pas de possibilité d'explosion due à l'accumulation de gaz inflammables.

NOTE Voir aussi 11.5.

La conformité est vérifiée par examen incluant l'examen des spécifications de la pile ou de l'accumulateur, afin d'établir que chaque composant, par lui-même, ne peut entraîner un DANGER d'explosion ou d'incendie. Si nécessaire, un court-circuit et un circuit-ouvert sont effectués sur chaque composant (à l'exception de la pile ou de l'accumulateur) dont une panne éventuelle pourrait entraîner un tel DANGER.

Dans le cas de piles ou d'accumulateurs remplaçables par un OPERATEUR, il faut essayer de brancher la pile ou l'accumulateur en polarité inversée. Aucun DANGER ne doit arriver.

13.2.3 Implosion des tubes cathodiques

Les tubes cathodiques présentant une dimension maximale de face supérieure à 160 mm, doivent être intrinsèquement protégés contre les effets d'implosion et de choc mécanique, à moins que l'ENVELOPPE de l'appareil ne garantisse une protection adéquate.

Tout tube qui n'est pas protégé intrinsèquement doit être muni d'un écran de protection efficace qui ne peut être retiré sans l'utilisation d'un OUTIL. Si un écran de verre séparé est utilisé, il ne doit pas être en contact avec la surface du tube.

Un tube cathodique est considéré comme intrinsèquement protégé contre les effets d'implosion si, lorsqu'il est correctement installé, aucune protection supplémentaire n'est nécessaire.

La conformité pour les tubes cathodiques est vérifiée comme spécifié dans l'IEC 60065.

14 Composants et sous-ensembles

14.1 Généralités

Lorsque la sécurité est concernée, les composants et sous-ensembles tels que les alimentations et appareils de traitement de l'information intégrés, doivent être utilisés dans leurs spécifications ASSIGNEES sauf en cas d'exception spécifique. Ils doivent être conformes à l'une des exigences suivantes:

a) aux exigences de sécurité applicables des normes IEC correspondantes. La conformité avec les autres exigences des normes de composants n'est pas exigée. Lorsque c'est nécessaire pour l'application, les composants doivent être sujets aux essais de cette présente norme, sauf ceux identiques ou équivalents déjà effectués qu'il n'est pas nécessaire de refaire, pour vérifier la conformité aux normes de composants;

   NOTE 1 Par exemple, si les composants répondent aux exigences de sécurité de l'IEC 60950-1 mais ont leurs CARACTERISTIQUES ASSIGNEES pour un environnement moins strict que l'environnement applicable de 1.4, ils doivent aussi répondre aux exigences appropriées de la présente norme.

b) lorsque c'est nécessaire pour l'application, aux exigences et essais de la présente norme, et à toute exigence supplémentaire applicable de sécurité de la norme de composant correspondante IEC, excepté pour les moteurs et transformateurs qui ont passé les essais applicables de 4.4.2.5, 4.4.2.7, 14.2 et 14.6 où aucun essai supplémentaire n'est exigé;

c) lorsque aucune norme IEC correspondante n'existe, aux exigences de la présente norme;

d) si le composant a été approuvé par une autorité d'essai reconnue suivant les exigences de sécurité applicables d'une norme autre que IEC d'un niveau au moins équivalent à celui de la norme IEC.

   NOTE 2 Les essais réalisés par une autorité d'essai reconnue qui confirment la conformité avec les exigences de sécurité applicables n'ont pas besoin d'être recommencés, même si les essais ont été réalisés selon une autre norme qu'une norme de l'IEC.

La Figure 15 est un diagramme montrant les méthodes de vérification de la conformité.

La conformité est vérifiée par examen et, si nécessaire, en effectuant un essai.

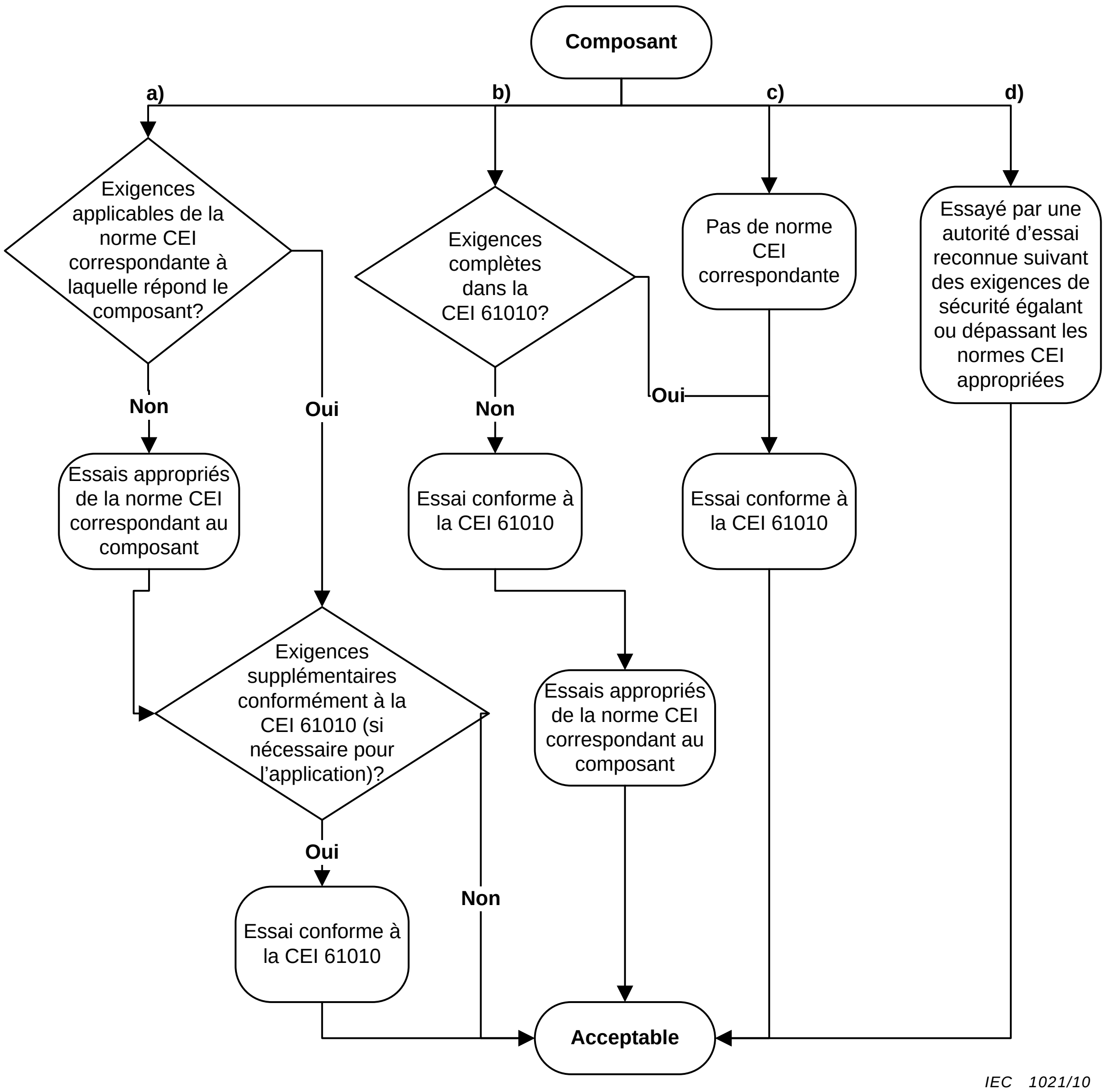


Figure 15 – Diagramme des options de conformité 14.1 a), b), c) et d)

14.2 Moteurs

14.2.1 Températures des moteurs

Les moteurs qui, lorsqu'ils sont arrêtés ou empêchés de démarrer (voir 4.4.2.5), peuvent entraîner un DANGER de choc électrique, un DANGER lié à la température ou un DANGER d'incendie, doivent être protégés par un dispositif de protection contre les surtempératures ou par une protection thermique conformes aux exigences de 14.3.

La conformité est vérifiée par mesurage de la température en CONDITION DE PREMIER DEFAUT de 4.4.2.5.

14.2.2 Moteurs à excitation série

Si un moteur à excitation série en survitesse peut provoquer un DANGER, il doit être directement raccordé aux dispositifs qu'il entraîne.

La conformité est vérifiée par examen.

14.3 Dispositifs de protection contre les sur-températures

Les dispositifs de protection contre les sur-températures sont des dispositifs qui fonctionnent en CONDITION DE PREMIER DEFAUT. Ils doivent satisfaire aux exigences suivantes:

a) être construits et essayés de telle sorte qu'ils assurent un fonctionnement fiable;

b) pouvoir interrompre la tension et l'intensité maximales des circuits dans lesquels ils sont employés selon leurs CARACTERISTIQUES ASSIGNEES;

c) ne pas fonctionner en UTILISATION NORMALE.

Si un dispositif ré-armable de protection contre les sur-températures est utilisé pour prévenir un DANGER en cas de défaillance d'un système de régulation de température (par exemple un thermostat), la partie protégée de l'appareil doit requérir une intervention avant de redevenir fonctionnelle.

La conformité est examinée par inspection du schéma du circuit, de la fiche technique du dispositif de protection contre les sur-températures et de la manière dont l'appareil est installé, et en effectuant les essais suivants avec l'appareil fonctionnant en CONDITION DE PREMIER DEFAUT *(voir 4.4). Le nombre de manœuvres est le suivant:*

1) *les dispositifs de protection contre les sur-températures à réarmement automatique sont mis 200 fois en fonctionnement;*

2) *les dispositifs de protection contre les sur-températures qui ne sont pas à réarmement automatique, à l'exception des fusibles thermiques, sont réarmés après chaque manœuvre et mis ainsi en fonctionnement 10 fois;*

3) *les dispositifs de protection contre les sur-températures sans réarmement sont mis en fonctionnement une seule fois.*

NOTE Afin d'éviter la détérioration de l'appareil, il est possible d'introduire un refroidissement forcé et des périodes de repos.

Pendant l'essai, les dispositifs de protection contre les sur-températures à réarmement doivent fonctionner chaque fois qu'une CONDITION DE PREMIER DEFAUT *est appliquée et les dispositifs de protection contre les sur-températures sans réarmement doivent fonctionner une seule fois. Après l'essai, les dispositifs de protection contre les sur-températures à réarmement ne doivent montrer aucun signe de détérioration pouvant empêcher leur fonctionnement dans une* CONDITION DE PREMIER DEFAUT *ultérieure.*

14.4 Porte-fusibles

S'il est prévu qu'un OPERATEUR remplace un fusible, le porte-fusible ne doit pas permettre que des parties sous TENSION DANGEREUSE soient ACCESSIBLES durant le remplacement du fusible.

La conformité est vérifiée en effectuant un essai au moyen du doigt d'épreuve articulé appliqué sans effort (voir la Figure B.2).

14.5 Sélecteurs de tension RESEAU

Ces dispositifs doivent être construits de telle sorte qu'un passage d'une tension ou d'un type d'alimentation à un autre ne puisse pas se produire accidentellement. Voir 5.1.3 d) pour les exigences de marquage.

La conformité est vérifiée par examen et par essai manuel.

14.6 Transformateurs d'alimentation RESEAU testés en dehors de l'appareil

Si les conditions d'environnement peuvent affecter les résultats des essais, les transformateurs d'alimentation RESEAU essayés en dehors de l'appareil (voir 4.4.2.7) doivent être testés dans les mêmes conditions que celles existant à l'intérieur de l'appareil.

La conformité est vérifiée par les essais de court-circuit et de surcharge spécifiés sous 4.4.2.7, suivis par l'essai de 4.4.4.1 b) et c). S'il y a un doute de tenue du transformateur pour l'essai de 4.4.4 et 10.2 lorsqu'il est installé dans l'appareil, les essais sont répétés avec le transformateur installé dans l'appareil.

14.7 Circuits imprimés

Les circuits imprimés doivent être réalisés avec un matériau ayant une classification d'inflammabilité suivant l'IEC 60695-11-10 de V-1 ou mieux.

Cette exigence ne s'applique pas aux circuits imprimés de cartes qui contiennent seulement des circuits à énergie limitée conformes aux exigences de 9.4.

La conformité du grade d'inflammabilité ASSIGNE est vérifiée par examen des données sur les matériaux ou en réalisant les essais de combustion verticale de l'IEC 60695-11-10 sur trois échantillons des parties considérées. Les échantillons peuvent être des cartes complètes, des parties de cartes ou des spécimens selon l'IEC 60695-11-10.

14.8 Circuits ~~ou composants~~ utilisés ~~comme limiteurs de~~ pour limiter les SURTENSIONS TRANSITOIRES

~~Les SURTENSIONS TRANSITOIRES dans un circuit peuvent être limitées par des circuits ou des composants. Les composants adaptés à cet usage sont notamment les varistances, les éclateurs sur PCB et les capacités en céramique, associés parfois avec des impédances ou des éclateurs à gaz.~~

Tout circuit limiteur de surtensions faisant partie de l'appareil doit ~~avoir~~ présenter la tenue adaptée ~~à limiter les~~ en ce qui concerne la limitation des SURTENSIONS TRANSITOIRES potentielles.

Tableau 21 – Tensions de chocs en CATEGORIE DE SURTENSION II

Tension RESEAU phase-neutre efficace ou continue V	Tension de choc V
≤ 50	500
>50 ≤ 100	800
>100 ≤ 150	1 500
>150 ≤ 300	2 500
>300 ≤ 600	4 000
>600 ≤ 1 000	6 000

La conformité est vérifiée ~~en appliquant~~ par l'essai suivant: 5 impulsions positives et 5 impulsions négatives espacées ~~entre elles~~ de 1 min au maximum sont appliquées avec la tension de choc applicable du Tableau 21 fournie par un générateur de chocs hybride (voir l'IEC 61180-1). Le générateur ~~doit produire~~ produit une tension de forme d'onde 1,2/50 µs en circuit ouvert, un courant de court-circuit de forme d'onde 8/20 µs, avec une impédance de sortie (valeur de crête de la tension en circuit ouvert divisée par la valeur de crête du courant de court-circuit) de 12 Ω (une résistance peut être ajoutée en série si nécessaire pour augmenter l'impédance). La tension de choc ~~doit être~~ est appliquée ~~tandis~~ pendant que le circuit est en condition d'UTILISATION NORMALE en combinaison avec l'alimentation RESEAU. La tension RESEAU est la tension ~~phase-neutre~~ RESEAU maximale ASSIGNEE.

La tension d'essai est appliquée entre chaque paire de BORNES de l'alimentation RESEAU de l'appareil où des circuits limiteurs de surtension sont présents.

~~*Aucun DANGER ne doit survenir dans le cas où le composant surchauffe ou se rompt pendant l'essai. Si une rupture se produit, aucune partie du composant ne doit ponter une isolation de sécurité. Si le composant surchauffe, il ne doit pas chauffer d'autres matériaux à leur point d'auto-allumage. Le déclenchement du disjoncteur de l'alimentation RESEAU est une indication d'échec.*~~

Les composants du circuit limiteur de surtension ne doivent pas enflammer ou chauffer d'autres matériaux jusqu'à leur point d'auto-allumage. Le circuit limiteur de surtension doit éliminer les tensions de choc en toute sécurité et continuer à fonctionner correctement après l'essai.

NOTE La tension ~~d'essai~~ de choc et l'impédance de sortie du générateur spécifiées ci-dessus s'appliquent à l'appareil ~~pour une~~ dont les caractéristiques assignées sont pour la CATEGORIE DE SURTENSION II ~~ASSIGNEE~~. La conformité pour les appareils ~~en~~ dont les caractéristiques assignées sont pour les CATEGORIES DE SURTENSION III et IV ~~ASSIGNEES~~ est spécifiée à l'Article K.4.

15 Protection par systèmes de verrouillage

15.1 Généralités

Des systèmes de verrouillage destinés à protéger un OPERATEUR des DANGERS doivent empêcher l'exposition de l'OPERATEUR au DANGER avant la suppression du DANGER et doivent répondre aux exigences données de 15.2 et 15.3.

La conformité est vérifiée par examen et en réalisant tous les essais applicables de cette présente norme

15.2 Prévention de réactivation

Tant que la cause du déclenchement du système de verrouillage n'a pas été infirmée ou supprimée, un système de verrouillage destiné à la protection de l'OPERATEUR doit être conçu pour que le DANGER ne puisse pas réapparaître lors d'une réactivation sans l'aide d'un OUTIL.

La conformité est vérifiée par examen et, si nécessaire, par action manuelle des parties du système de verrouillage qui peuvent être touchées par le doigt d'épreuve articulé (voir la Figure B.2).

15.3 Fiabilité

Un système de verrouillage pour la protection des OPERATEURS doit être conçu de telle façon qu'un premier défaut du système de verrouillage ne puisse pas se produire au cours de la durée de vie prévue de l'appareil ou ne puisse pas être à l'origine d'un DANGER.

La conformité est vérifiée par l'évaluation du système de verrouillage. En cas de doute, le système de verrouillage ou les parties concernées de ce système sont vérifiées par des cycles de commutation de la charge la moins favorable en UTILISATION NORMALE. Le nombre de cycles est égal à deux fois le nombre maximal pouvant arriver au cours de la durée de vie prévue de l'appareil ou 10 000 cycles d'utilisation selon le plus élevé des deux. Après l'essai, la protection ne devra pas être détériorée.

16 DANGERS résultant de l'application

16.1 MAUVAIS USAGE RAISONNABLEMENT PREVISIBLE

Aucun DANGER ne doit survenir, même si les réglages, boutons et autres organes de commandes logicielles ou matérielles de l'appareil sont positionnés d'une manière non intentionnelle et non décrite dans les instructions. D'autres cas possibles de MAUVAIS USAGES RAISONNABLEMENT PREVISIBLES que ceux pas couverts par des exigences spécifiques de cette norme doivent être abordés par l'appréciation du RISQUE (voir Article 17).

La conformité est vérifiée par examen et par la revue de la documentation sur l'appréciation du RISQUE.

16.2 Aspects ergonomiques

Si les facteurs suivants peuvent conduire à un DANGER, une appréciation du RISQUE doit être documentée en prenant au moins en compte les aspects suivants:

a) limitation des dimensions du corps;

b) affichages et indicateurs;

c) accessibilité et conventions des commandes;

d) dispositions des BORNES.

La conformité est vérifiée par examen et par la revue de la documentation sur l'appréciation du RISQUE.

NOTE L'EN 804-2, EN 894-3, ISO 9241, SEMI S8 et d'autres documents donnent des procédures d'appréciation du RISQUE sur les aspects ergonomiques. Les exigences de ces documents ne seront pas toutes applicables aux appareils du domaine d'application de cette norme.

17 Appréciation du RISQUE

Si l'examen de l'appareil montre que des DANGERS incomplètement couverts par les Articles 6 à 16 (voir 1.2.1) peuvent survenir, alors une appréciation du RISQUE est exigée. Elle doit être effectuée et documentée pour atteindre au moins un RISQUE TOLERABLE par un processus itératif comme suit.

a) L'analyse du RISQUE

L'analyse du RISQUE est le processus d'identification des DANGERS et d'estimation des RISQUES basé sur l'utilisation de l'information disponible.

b) L'évaluation du RISQUE

Chaque analyse de RISQUE exige un plan pour évaluer la gravité estimée et la probabilité d'un niveau de RISQUE et pour juger l'acceptabilité du niveau de RISQUE résultant.

c) Réduction du RISQUE

Si le niveau de RISQUE initial n'est pas acceptable, des mesures doivent être prises afin de réduire le RISQUE. Le processus de l'analyse du RISQUE et l'évaluation du RISQUE doivent alors être répétés en vérifiant qu'aucun nouveau RISQUE n'a été introduit.

Les RISQUES résiduels après une appréciation du RISQUE doivent être identifiés dans les instructions pour l'AUTORITE RESPONSABLE. L'information appropriée sur la manière de réduire ces RISQUES doit être donnée (voir 5.4.1 e)).

En choisissant la méthode la plus appropriée pour réduire le RISQUE, le fabricant doit appliquer les principes suivants dans l'ordre donné:

1) éliminer ou réduire les RISQUES au maximum par une conception et une fabrication intrinsèquement sure;

2) prendre les mesures nécessaires de protection par rapport aux RISQUES qui ne peuvent pas être éliminés (dispositifs de protection);

3) informer les OPERATEURS des RISQUES résiduels dus à toutes les imperfections des mesures de protection adoptées, indiquer si une formation particulière est exigée, et spécifier les équipements de protection individuels nécessaires.

NOTE Une procédure d'appréciation du RISQUE est donnée à l'Annexe J. D'autres procédures d'appréciation du RISQUE sont données dans l'ISO 14971, la SEMI S10-1296, l'IEC 61508, l'ISO 14121-1et l'ANSI B11.TR3. D'autres procédures établies qui mettent en application des mesures similaires peuvent aussi être utilisées.

La conformité est vérifiée par la revue de la documentation sur l'appréciation du RISQUE pour s'assurer que les RISQUES ont été éliminés ou qu'il ne reste seulement que des RISQUES TOLERABLES.

Annexe A
(normative)

Circuits de mesure du courant de contact
(voir 6.3)

NOTE Cette annexe se réfère à l'IEC 60990 qui spécifie les procédures de mesure du courant de contact ainsi que les caractéristiques des voltmètres d'essai.

A.1 Circuit de mesure du courant alternatif de fréquence jusqu'à 1 MHz et du courant continu

Le courant doit être mesuré avec le circuit de la Figure A.1. Il doit être calculé à partir de la relation:

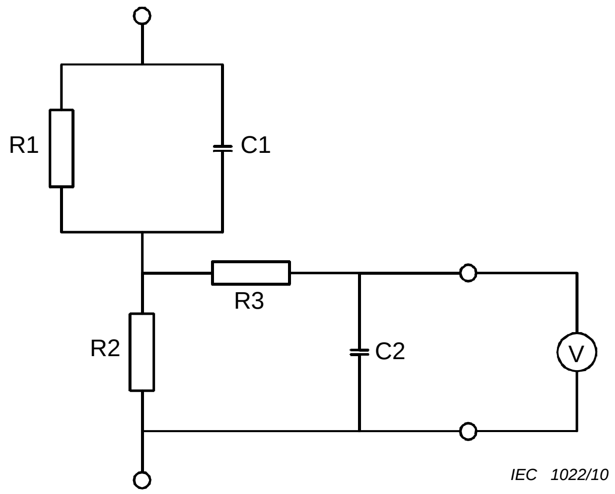
$$I = \frac{U}{500}$$

où

I est le courant en ampères;

U est la tension en volts indiquée par le voltmètre.

Ce circuit représente l'impédance du corps et compense la modification de la réponse physiologique du corps avec la fréquence.



R1 = 1 500 Ω avec une tolérance relative de ±5 %

R2 = 500 Ω avec une tolérance relative de ±5 %

R3 = 10 kΩ avec une tolérance relative de ±5 %

C1 = 0,22 µF avec une tolérance relative de ±10 %

C2 = 0,022 µF avec une tolérance relative de ±10 %

Figure A.1 – Circuit de mesure du courant alternatif de fréquence jusqu'à 1 MHz et du courant continu

A.2 Circuits de mesure du courant alternatif sinusoïdal de fréquence jusqu'à 100 Hz et du courant continu

Lorsque la fréquence ne dépasse pas 100 Hz, le courant peut être mesuré avec le circuit en variante de la Figure A.2. Lorsqu'un voltmètre est utilisé, le courant doit être calculé à partir de la relation:

$$I = \frac{U}{2\,000}$$

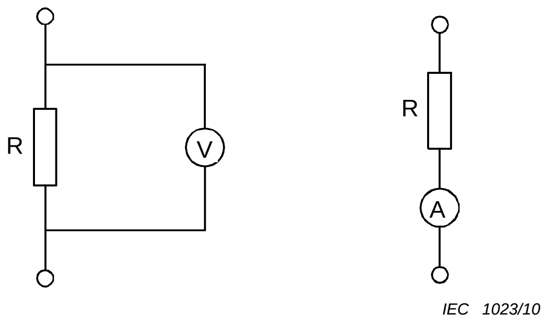
où

I est le courant en ampères;

U est la tension en volts indiquée par le voltmètre.

Ce circuit représente l'impédance du corps pour les fréquences ne dépassant pas 100 Hz.

NOTE La valeur 2 000 Ω tient compte de l’impédance de l’instrument de mesure.



R = 2 000 Ω avec une tolérance relative de ±5 %

Figure A.2 – Circuits de mesure du courant alternatif sinusoïdal de fréquence jusqu'à 100 Hz et du courant continu

A.3 Circuit de mesure du courant pour brûlures électriques à hautes fréquences

Le courant est mesuré avec le circuit de la Figure A.3. Le courant doit être calculé à partir de la relation:

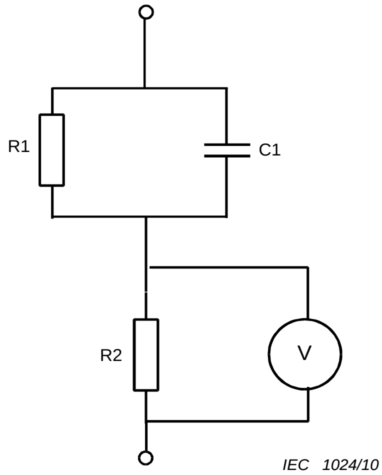
$$I = \frac{U}{500}$$

où

I est le courant en ampères;

U est la tension en volts indiquée par le voltmètre.

Ce circuit compense la modification de la réponse physiologique du corps avec la haute fréquence.



R1 = 1 500 Ω avec une tolérance relative de ±5 %

R2 = 500 Ω avec une tolérance relative de ±5 %

C1 = 0,22 μF avec une tolérance relative de ±10 %

Figure A.3 – Circuit de mesure du courant pour brûlures électriques

A.4 Circuit de mesure du courant pour contact en EMPLACEMENT HUMIDE

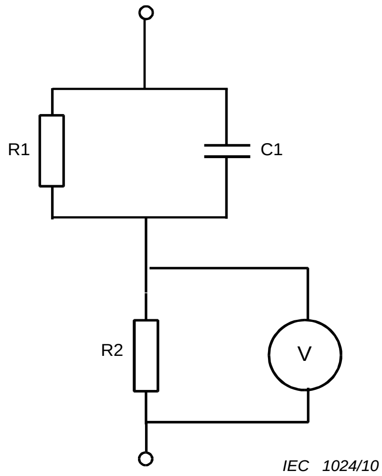
Le circuit de la Figure A.4 doit être utilisé pour les contacts en EMPLACEMENT HUMIDE. Le courant doit être calculé à partir de la relation:

$$I = \frac{U}{500}$$

où

I est le courant en ampères;

U est la tension en volts indiquée par le voltmètre.



R1 = 375 Ω avec une tolérance relative de ±5 %

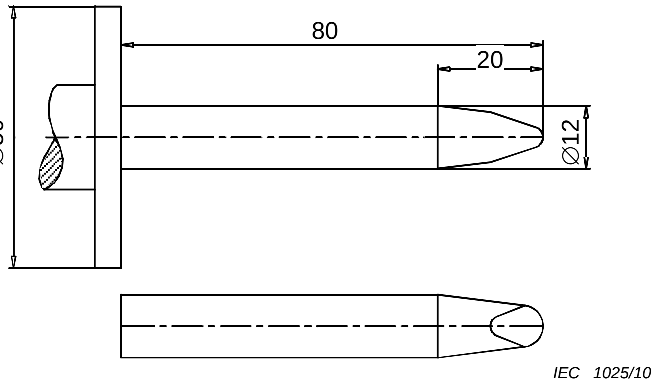
R2 = 500 Ω avec une tolérance relative de ±5 %

C1 = 0,22 μF avec une tolérance relative de ±10 %

Figure A.4 – Circuit de mesure du courant pour contact en EMPLACEMENT HUMIDE

Annexe B
(normative)

Doigts d'épreuve normalisés
(voir 6.2)

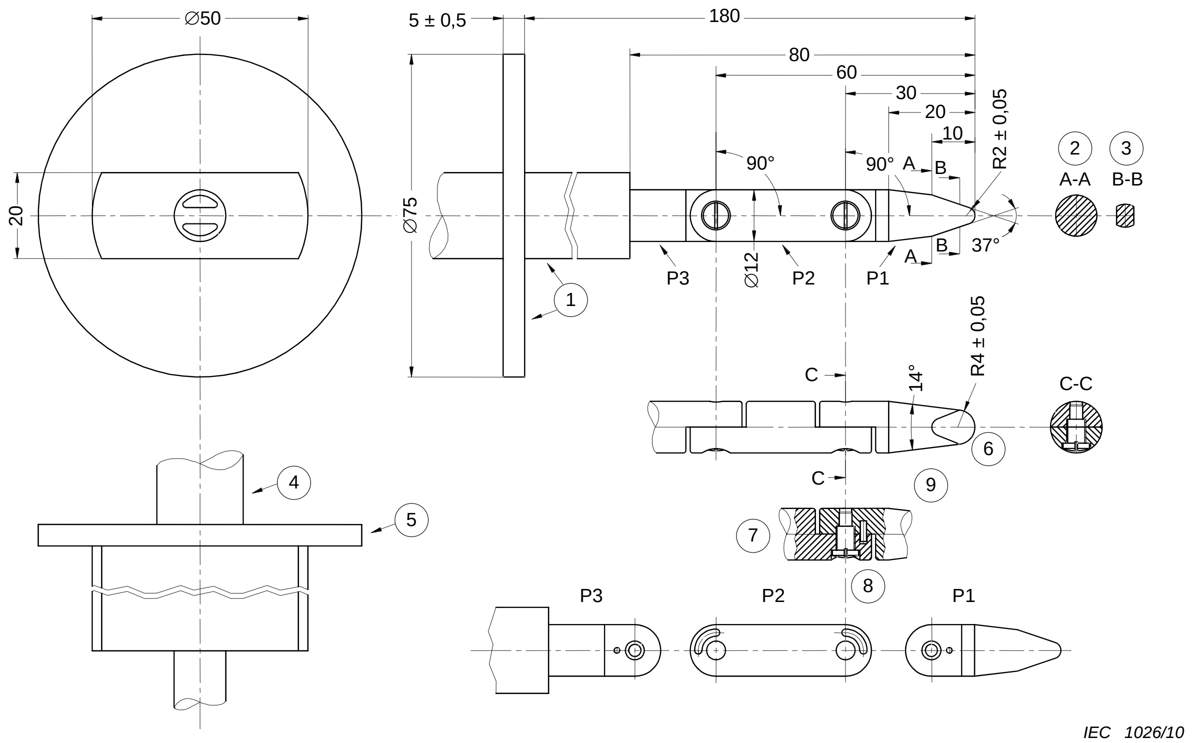


Dimensions en millimètres

Pour les tolérances et les dimensions de la pointe du doigt d'épreuve, voir la Figure B.2.

NOTE Ce doigt d'épreuve est identique à la sonde d'essai 11 de l'IEC 61032, Figure 7.

Figure B.1 – Doigt d'épreuve rigide



Légende

1 matériau isolant
2 section AA
3 section BB
4 poignée
5 plaque d’arrêt
6 sphérique
7 détail x (exemple)
8 vue de côté
9 chanfrein sur toutes les arêtes

Dimensions en millimètres

Tolérances sur les dimensions sans tolérance spécifique:

– sur les angles: $^{0}_{-10'}$

– sur les dimensions linéaires:

jusqu'à 25 mm: $^{0}_{-0,05}$ mm

au-dessus de 25 mm: ± 0,2 mm

Matériau du doigt: acier trempé, etc.

Les deux articulations de ce doigt peuvent être pliées à un angle de $(90\ ^{+10}_{\ 0})°$, mais dans une seule et même direction.

L'utilisation de la solution broche encoche ne représente qu'une des approches possibles permettant de limiter l'angle de pliage à 90°. Pour cette raison, les dimensions et les tolérances de ces détails ne sont pas données dans le plan. La conception réelle doit impérativement garantir un angle de pliage de $(90\ ^{+10}_{\ 0})°$.

NOTE Ce doigt d’épreuve est identique à la sonde d’essai B de l’IEC 61032, Figure 2.

Figure B.2 – Doigt d'épreuve articulé

Annexe C
(normative)

Mesure des DISTANCES D’ISOLEMENT et des LIGNES DE FUITE

Les méthodes de mesure des DISTANCES D’ISOLEMENT et des LIGNES DES FUITES sont indiquées dans les exemples 1 à 11 qui suivent (voir la Figure C.1). Ces exemples ne font pas la différence entre les intervalles et les rainures ou entre les types d'isolation.

Les suppositions suivantes ont été faites:

a) lorsque la distance entre les arêtes supérieures d'une rainure est supérieure ou égale à *X* (voir le Tableau C.1), la LIGNE DE FUITE est mesurée le long des contours de la rainure (voir exemple 2);

b) tout puits est supposé être ponté par une liaison isolante de largeur *X*, placée dans la position la plus défavorable (voir l’exemple 3);

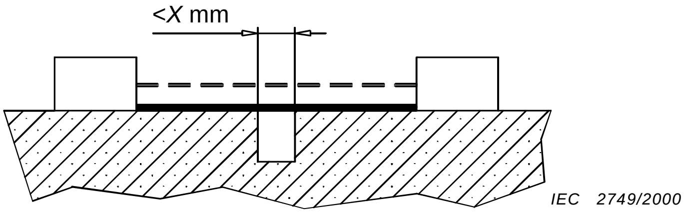
c) les DISTANCES D’ISOLEMENT et les LIGNES DE FUITE mesurées entre les parties pouvant avoir différentes positions l'une par rapport à l'autre, sont mesurées lorsque ces parties se trouvent dans leurs positions les plus défavorables.

Dans les exemples suivants, la dimension *X* prend la valeur spécifiée dans le Tableau C.1 en fonction du DEGRE DE POLLUTION.

Tableau C.1 – Largeur de X

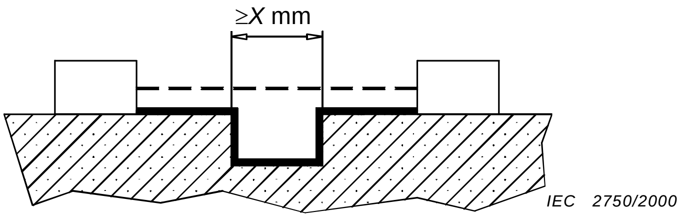
DEGRE DE POLLUTION	Largeur de *X* mm
1	0,25
2	1,0
3	1,5

Si la DISTANCE D’ISOLEMENT associée est inférieure à 3 mm, la dimension *X* de la rainure du Tableau C.1 peut être réduite au tiers de la valeur de cette DISTANCE D’ISOLEMENT.



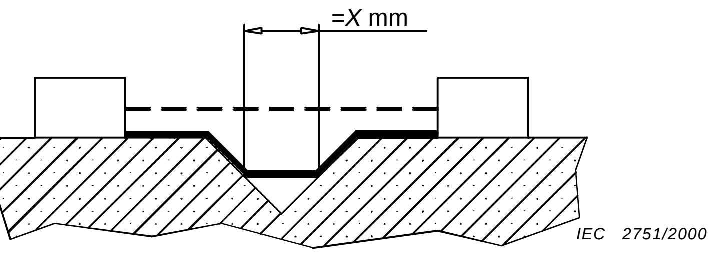
EXEMPLE 1: Ce chemin comprend une rainure à flancs parallèles ou convergents, de profondeur quelconque et de largeur inférieure à *X*.

La DISTANCE D’ISOLEMENT et la LIGNE DE FUITE sont mesurées en ligne droite au-dessus de la rainure, comme indiqué ci-dessus.



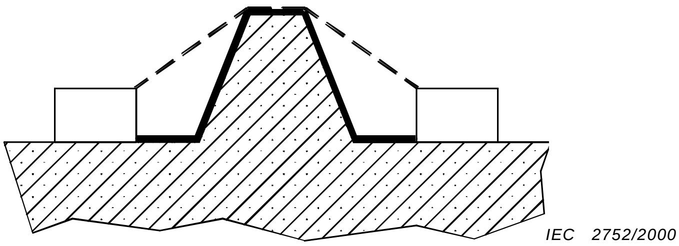
EXEMPLE 2: Ce chemin comprend une rainure à flancs parallèles, de profondeur quelconque et de largeur égale ou supérieure à *X*.

La DISTANCE D'ISOLEMENT est la distance en ligne droite. Le chemin de LIGNE DE FUITE longe le profil de la rainure.



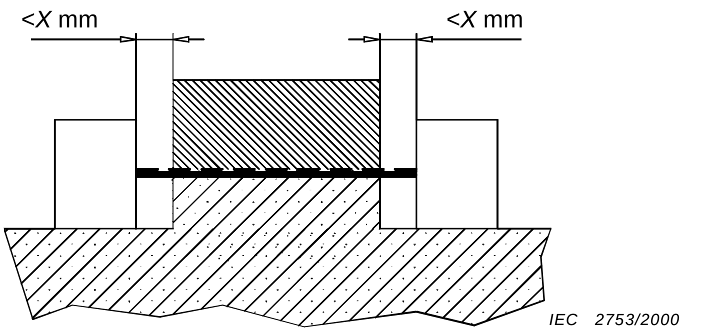
EXEMPLE 3: Ce chemin comprend une rainure en V dont la largeur est supérieure à *X*.

La DISTANCE D'ISOLEMENT est la distance en ligne droite. Le chemin de LIGNE DE FUITE longe le profil de la rainure, mais «court-circuite» le bas de la rainure par un tronçon de *X*.



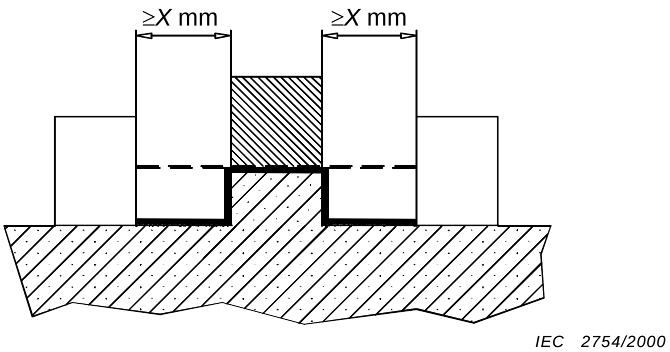
EXEMPLE 4: Ce chemin comprend une nervure.

La DISTANCE D'ISOLEMENT est le chemin dans l'air le plus court par-dessus le sommet de la nervure. Le chemin de LIGNE DE FUITE longe le profil de la nervure.



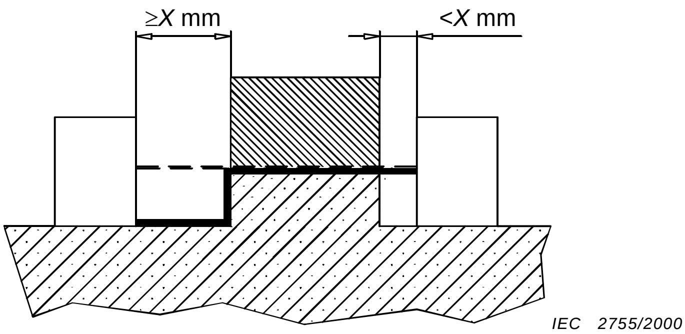
EXEMPLE 5: Ce chemin comprend deux parties non collées avec des rainures de largeur inférieure à *X* de chaque côté.

Le chemin de la DISTANCE D'ISOLEMENT et de la LIGNE DE FUITE est la distance en ligne droite indiquée ci-dessus.



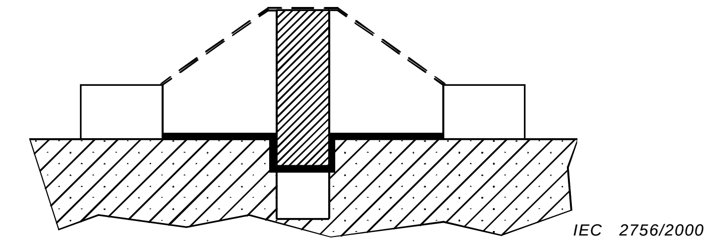
EXEMPLE 6: Ce chemin comprend deux parties non collées avec des rainures de largeur égale ou supérieure à *X* de chaque côté.

La DISTANCE D'ISOLEMENT est la distance en ligne droite. Le chemin de LIGNE DE FUITE longe le profil des rainures.



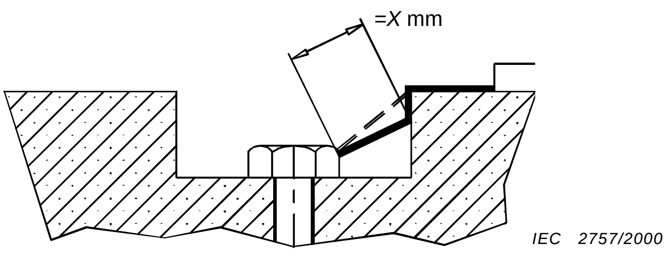
EXEMPLE 7: Ce chemin comprend deux parties non collées avec, d'un côté une rainure de largeur inférieure à *X* et, de l'autre côté, une rainure de largeur égale ou supérieure à *X*.

Les chemins de la DISTANCE D'ISOLEMENT et de la LIGNE DE FUITE sont indiqués ci-dessus.

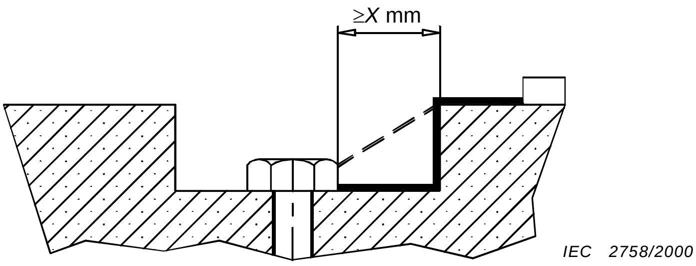


EXEMPLE 8: La LIGNE DE FUITE à travers le joint non collé est inférieure à la LIGNE DE FUITE par-dessus la barrière.

La DISTANCE D'ISOLEMENT est le chemin dans l'air le plus court par-dessus le sommet de la barrière.

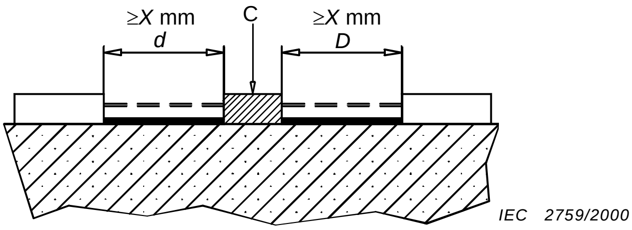


EXEMPLE 9: Distance trop faible entre tête de vis et paroi du logement pour être prise en compte.



EXEMPLE 10: Distance suffisante entre tête de vis et paroi du logement pour être prise en compte.

La mesure de la LIGNE DE FUITE s'effectue de la vis à la paroi quand la distance est égale à *X*.



EXEMPLE 11: C est une partie flottante

La DISTANCE D'ISOLEMENT est la distance *d* + *D*.

La LIGNE DE FUITE est aussi *d* + *D.*

LIGNE DE FUITE

DISTANCE D'ISOLEMENT

Figure C.1 – Exemples de méthodes de mesure des DISTANCES D'ISOLEMENT et des LIGNES DE FUITE

Annexe D
(normative)

Parties entre lesquelles des exigences d'isolement sont spécifiées
(voir 6.4 et 6.5.3)

Les symboles suivants sont utilisés de la Figure D.1 à la Figure D.3 pour indiquer:

a) Exigences:

B L'ISOLATION PRINCIPALE est exigée

D La DOUBLE ISOLATION ou l'ISOLATION RENFORCEE sont exigées

b) Circuits et parties:

A Partie ACCESSIBLE non reliée à la BORNE DE TERRE DE PROTECTION

H Circuit sous TENSION DANGEREUSE en CONDITION NORMALE

R Impédance ~~de forte valeur qui en combinaison avec l'ISOLATION PRINCIPALE constitue l'IMPEDANCE DE PROTECTION (voir 6.5.4)~~ satisfaisant aux exigences de 6.4.4

S Ecran de protection

T_A BORNE externe ACCESSIBLE (ne dépassant pas les niveaux de 6.3.1 en CONDITION NORMALE)

T_N BORNE (qui peut dépasser les niveaux de 6.3.1 en CONDITION NORMALE, et par conséquent ne doit pas être ACCESSIBLE)

Z Impédance du circuit secondaire

Les circuits secondaires peuvent aussi être considérés comme des parties individuelles.

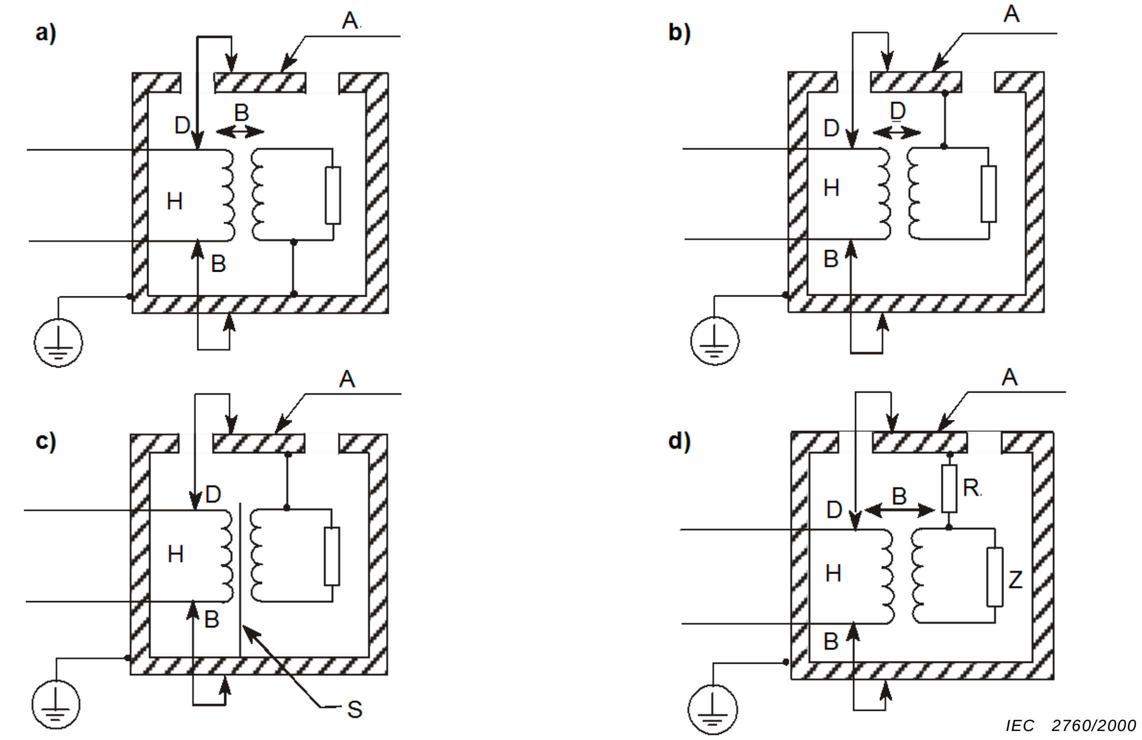
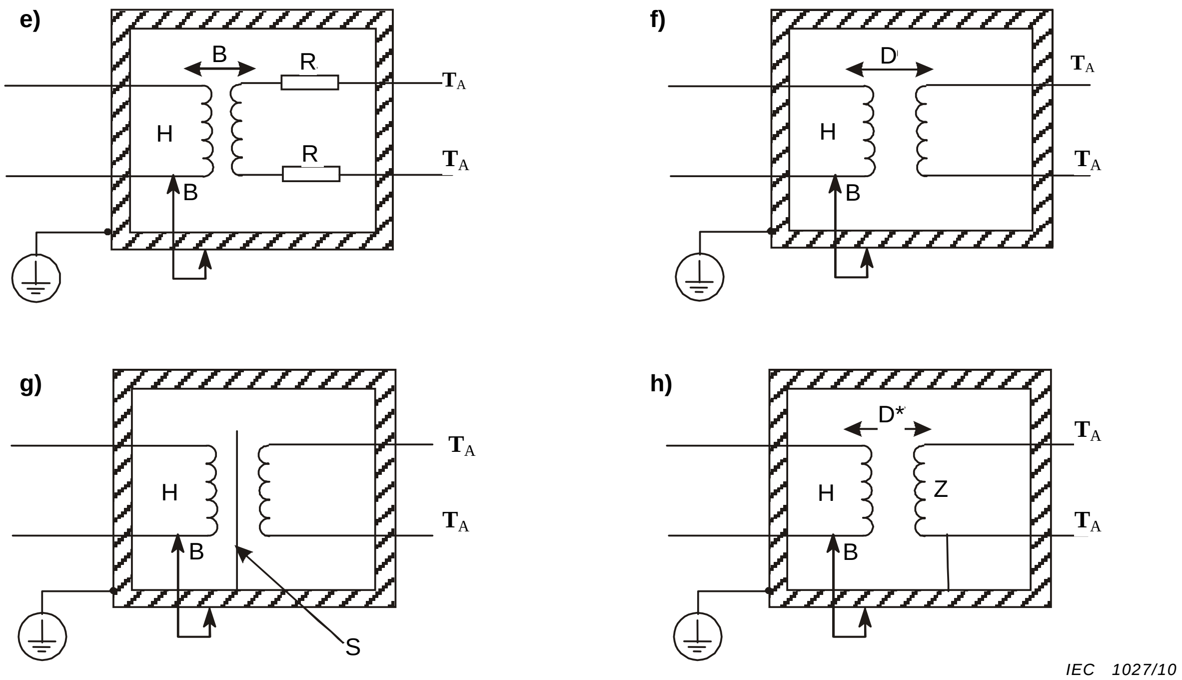


Figure D.1a) à Figure D.1d) – Protection entre des circuits sous TENSION DANGEREUSE et des parties ACCESSIBLES



D* peut être remplacé par B
si Z est suffisamment faible ~~(voir 6.6.1)~~

Figure D.1e) à Figure D.1h) – Protection entre des circuits sous TENSION DANGEREUSE et des circuits qui ont des BORNES externes ACCESSIBLES

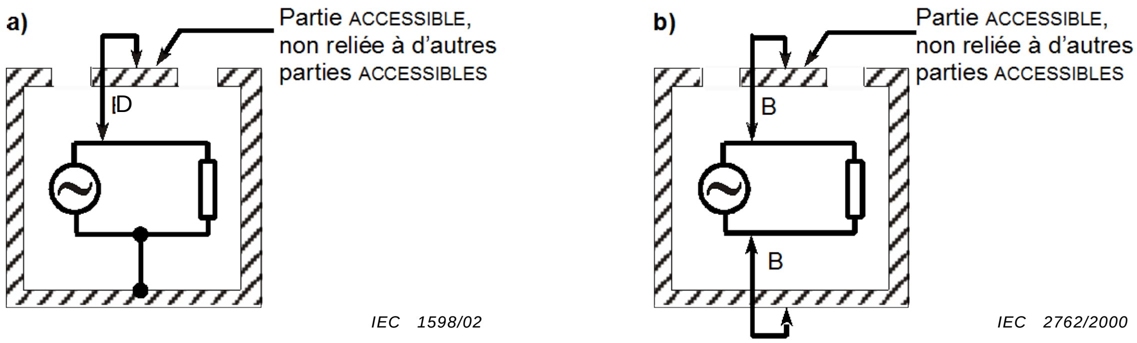


Figure D.2a) et Figure D.2b) – Protection entre un circuit interne sous TENSION DANGEREUSE et une partie ACCESSIBLE qui n'est pas reliée à d'autres parties ACCESSIBLES

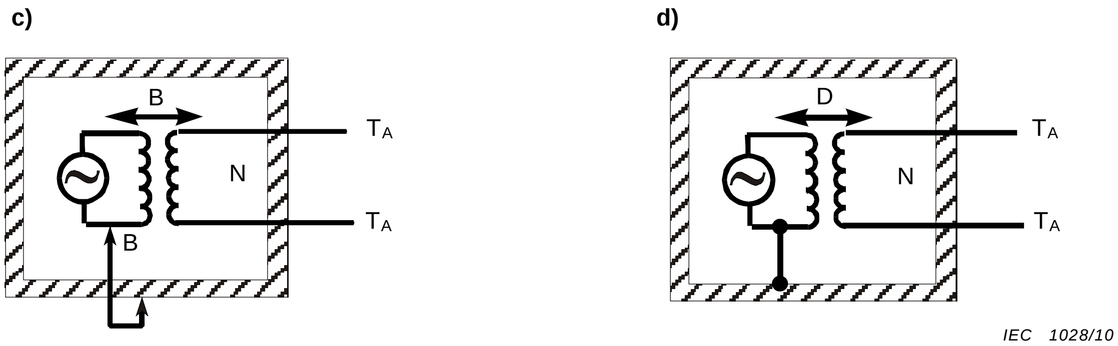


Figure D.2c) et Figure D.2d) – Protection entre des circuits primaires sous TENSION DANGEREUSE et des circuits qui ont des BORNES externes ACCESSIBLES

NOTE 1 D'autres moyens de protection sont également possibles pour les circuits représentés selon la Figure D.2 c) et d), tels les écrans de protection, la LIAISON DE PROTECTION (voir 6.5.2) et l'IMPEDANCE DE PROTECTION (voir 6.5.4).

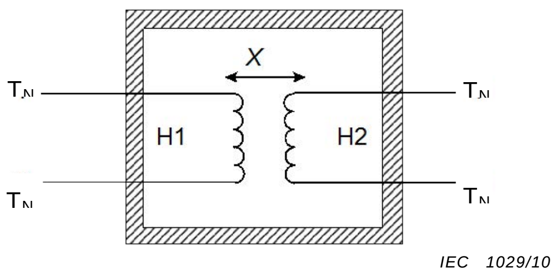


Figure D.3 – Protection des BORNES externes ACCESSIBLES de deux circuits sous TENSION DANGEREUSE

NOTE 2 Voir les Figure D.1 a) à d) pour l'exigence relative à l'isolation entre une partie ACCESSIBLE non reliée à la BORNE DE TERRE DE PROTECTION, et l'un ou l'autre des deux circuits sous TENSION DANGEREUSE.

L'exigence pour l'isolation entre H1 et H2 (*X*) est la plus sévère des conditions suivantes:

B ISOLATION PRINCIPALE – Si H1 et H2 sont connectés, les exigences d'isolation sont basées sur la TENSION DE SERVICE ASSIGNEE la plus élevée qui contraint l'isolation entre les circuits;

D DOUBLE ISOLATION ou ISOLATION RENFORCEE – Si H1 est connecté et les BORNES de H2 sont ACCESSIBLES pour les besoins d'une connexion, l'exigence pour l'isolation est basée sur la TENSION DE SERVICE ASSIGNEE la plus élevée qui contraint l'isolation pour H1;

D DOUBLE ISOLATION ou ISOLATION RENFORCEE – Si H2 est connecté et les BORNES de H1 sont ACCESSIBLES pour les besoins d'une connexion, l'exigence pour l'isolation est basée sur la TENSION DE SERVICE ASSIGNEE la plus élevée qui contraint l'isolation pour H2.

Annexe E
(informative)

Principes directeurs pour la réduction des DEGRES DE POLLUTION

Le microenvironnement à l'intérieur de l'appareil est déterminé par les conditions d'environnement suivant lesquelles l'appareil est exposé au cours de l'utilisation, l'installation, la maintenance, et de toute la POLLUTION produite par l'appareil lui-même ainsi que par l'efficacité des mesures d'étanchéité appliquées.

L'appareil peut être classé suivant les situations environnementales décrites dans le Tableau E.1.

Tableau E.1 – Situations environnementales

Situation environnementale	Appareil utilisé dans un …	Installation ou maintenance de l'appareil dans un …
A	environnement contrôlé[a]	environnement contrôlé
B	environnement non contrôlé	environnement contrôlé ou l'appareil n'est pas ouvert pendant l'installation ou l'entretien
C	environnement non contrôlé	environnement non contrôlé
[a] Un environnement contrôlé est un environnement défini par les conditions de 1.4.1 c) et d).		

NOTE La situation environnementale du Tableau E.1 fournit une classification systématique de l'environnement auquel l'appareil est exposé et si l'appareil peut être ouvert pour des raisons d'installation et de maintenance.

La réduction du DEGRE DE POLLUTION du microenvironnement peut être obtenue en utilisant les méthodes du Tableau E.2.

Tableau E.2 – Réduction du DEGRE DE POLLUTION

DEGRE DE POLLUTION du macro-environnement	DEGRE DE POLLUTION du microenvironnement						
	2			3		4	
	Situation environnementale			Situation environnementale		Situation environnementale	
	A	B	C	B	C	B	C
ENVELOPPE IPx5, IPx6	1	2	2	3	3	4	4
ENVELOPPE IPx7, IPx8	1	1	2	2	3	2	4
Chauffage régulé à l'intérieur de l'appareil ayant une ENVELOPPE IPx4 ou plus	1	2	2	3	3	4	4
Les indices IP sont définis dans l'IEC 60529.							

Annexe F
(normative)

ESSAIS INDIVIDUELS DE SERIE

F.1 Généralités

Le fabricant doit exécuter les essais des Articles F.2 à F.4 sur 100 % des appareils produits qui ont à la fois des parties sous TENSION DANGEREUSE et des parties conductrices ACCESSIBLES. Sauf s'il est clairement démontré que le résultat des essais ne peut être invalidé par les opérations de production ultérieures, les essais doivent être exécutés sur un appareil complètement terminé. Les composants ne doivent pas être débranchés, modifiés ou démontés pour l'essai mais les volets clipsés et les boutons enfichés peuvent être enlevés s'ils risquent d'interférer sur le déroulement des essais. L'appareil ne doit pas être alimenté durant les essais, mais le commutateur d'alimentation RESEAU doit être sur la position «Marche».

L'appareil peut ne pas être emballé dans une feuille métallique et pré-conditionné à l'humidité.

La correction d'altitude de la tension d'essai pour le site d'essai n'est pas nécessaire.

L'appareil d'essai en tension doit être en mesure de maintenir la tension requise pendant la période de temps spécifiée. Il n'y a pas d'autres exigences applicables.

La conformité est vérifiée par examen.

F.2 Terre de protection

Un essai de continuité est exécuté entre d'une part, la broche de terre du socle du connecteur ou de la fiche mobile RESEAU mâle de l'appareil raccordé, ou la BORNE DE TERRE DE PROTECTION des APPAREILS BRANCHES EN PERMANENCE, et d'autre part, toutes les parties conductrices ACCESSIBLES qui, selon 6.5.2, doivent être raccordées à la BORNE DE TERRE DE PROTECTION.

NOTE Aucune valeur de courant d'essai n'est spécifiée.

F.3 CIRCUITS RESEAU

F.3.1 Généralités

La tension d'essai est appliquée entre:

a) les BORNES d'alimentation RESEAU raccordées ensemble, et
b) toutes les parties conductrices ACCESSIBLES, y compris la BORNE DE TERRE DE PROTECTION s'il y en a une, raccordées ensemble.

Au cours de cet essai, l'appareil doit être isolé électriquement de toute terre. Cet essai n'est pas appliqué aux petites parties métalliques telles que les étiquettes signalétiques, les vis ou rivets, si elles sont séparées des parties sous TENSION DANGEREUSE par une ISOLATION RENFORCEE ou équivalente.

NOTE Pour les appareils qui ont des parties conductrices ACCESSIBLES raccordées à la BORNE DE TERRE DE PROTECTION, le raccordement entre elles des parties conductrices ACCESSIBLES n'est pas nécessaire parce que les raccordements corrects sont vérifiés par l'essai de F.2.

La tension d'essai peut être alternative ou continue. Elle est choisie dans le Tableau F.1 pour la CATEGORIE DE SURTENSION appropriée. Pour les essais en tension alternative et continue, la tension d'essai est portée à sa valeur spécifiée en moins de 5 s et maintenue à cette valeur pendant au moins 2 s. L'essai aux ondes de choc est l'essai avec une forme d'onde 1,2/50 µs selon l'IEC 61180 en appliquant au minimum trois impulsions de chaque polarité espacées d'au moins 1 s.Aucun arc dans les DISTANCES D'ISOLEMENT ou claquage partiel de l'isolation solide ne doit se produire durant l'essai et le dispositif de test ne doit pas non plus indiquer de défaut.

Tableau F.1 – Tensions d'essai pour les ESSAIS INDIVIDUELS DE SERIE des CIRCUITS RESEAU

Tension nominale phase-neutre de l'alimentation RESEAU	CATEGORIE DE SURTENSION II			CATEGORIE DE SURTENSION III			CATEGORIE DE SURTENSION IV		
Alternatif efficace ou continu	Alter natif	Conti-nu	Tension de choc 1,2/50 µs	Alter natif	Conti-nu	Tension de choc 1,2/50 µs	Alter natif	Conti-nu	Tension de choc 1,2/50 µs
V	V_{eff}	V	$V_{crête}$	V_{eff}.	V	$V_{crête}$	V_{eff}	V	$V_{crête}$
≤150	840	1 200	1 200	1 400	2 000	2 000	2 200	3 100	3 100
>150 ≤ 300	1 400	2 000	2 000	2 200	3 100	3 100	3 300	4 700	4 700
>300 ≤ 600	2 200	3 100	3 100	3 300	4 700	4 700	4 300	6 000	6 000
>600 ≤ 1 000	3 300	4 700	4 700	4 300	6 000	6 000	5 300	7 500	7 500

F.3.2 CIRCUITS RESEAU avec limiteurs de tension

Pour les CIRCUITS RESEAU avec limiteurs de tension qui satisfont aux exigences de 14.8, l'essai en tension alternative ou continue de F.3.1 peut être réalisé avec une tension d'essai de 0,9 fois la tension d'écrêtage du limiteur de tension, mais pas moins de deux fois la TENSION DE SERVICE du CIRCUIT RESEAU.

F.4 Circuits flottants

Une tension d'essai est appliquée entre

a) les BORNES des circuits flottants d'entrée et de sortie raccordées ensemble, qui peuvent être sous TENSION DANGEREUSE en UTILISATION NORMALE, et

b) les parties conductrices ACCESSIBLES raccordées ensemble.

La valeur des tensions appliquées est égale à 1,5 fois la tension maximale par rapport à la terre, mais elle n'est pas inférieure à 350 V alternatif efficace ou 500 V continu. Si des limiteurs de tensions opèrent en dessous de la tension appliquée, la valeur de tension appliquée est égale à 0,9 fois la tension d'écrêtage, mais elle n'est pas inférieure à la tension maximale par rapport à la terre.

La tension d'essai est portée à la valeur spécifiée en moins de 5 s et maintenue à cette valeur pendant au moins 2 s, le circuit électrique étant isolé de toute terre.

Aucun arc dans les DISTANCES D'ISOLEMENT ou claquage partiel de l'isolation solide ne doit se produire durant l'essai et le dispositif de test ne doit pas non plus indiquer de défaut.

Annexe G
(informative)

Fuite et rupture des fluides sous pression

Les exigences et essais de cette annexe sont acceptés aux USA, au Canada et dans quelques autres pays, comme preuve de conformité avec les législations nationales sur les hautes pressions. Ces exigences ne sont pas adaptées pour les appareils manipulant des substances toxiques, inflammables ou autre substances dangereuses. Reportez-vous aux exigences des autorités nationales pour de tels appareils.

G.1 Généralités

Les parties des appareils contenant des fluides sous pression ne doivent pas causer un DANGER suite à une rupture ou à une fuite en CONDITION NORMALE ou en CONDITION DE PREMIER DEFAUT.

La conformité est vérifiée comme spécifié aux Articles G.2 à G.4.

G.2 Pressions au-dessus de 2 MPa et produit pression fois volume supérieur à 200 kPa·l

G.2.1 Généralités

Les parties des appareils contenant des fluides qui en UTILISATION NORMALE ont les deux caractéristiques suivantes ne doivent pas causer un DANGER en cas de rupture ou de fuite:

a) un produit pression x volume supérieur à 200 kPa·l;

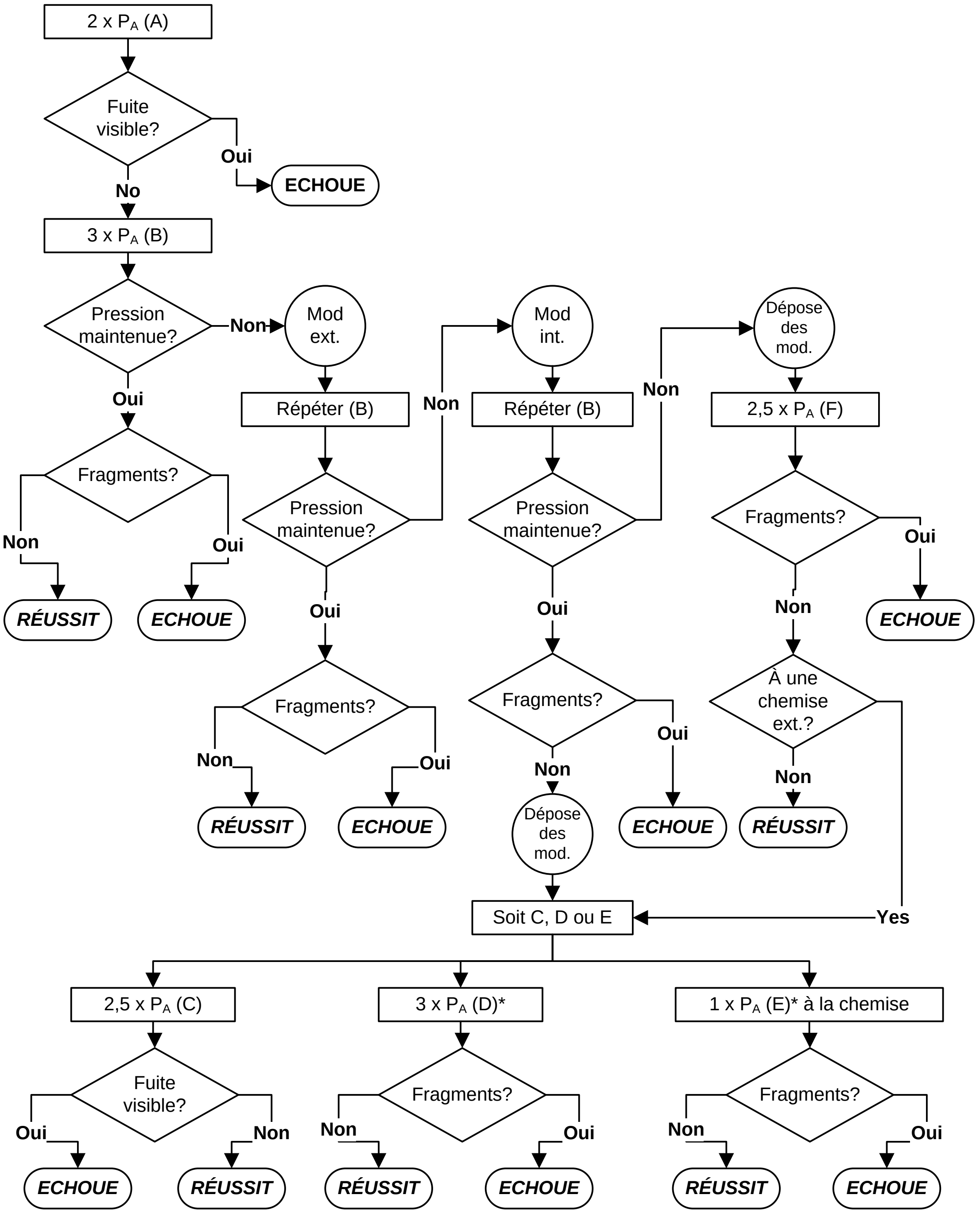
b) une pression supérieure à 2 MPa.

NOTE De tels appareils comprennent les appareils fonctionnant avec des fluides sous pression employant des soufflets flexibles, des diaphragmes, des tubes de Bourdon, etc. et des appareils tels que les débitmètres qui sont branchés aux processus sous pression ASSIGNEE de 2 MPa ou plus.

La conformité est vérifiée par examen et en réalisant les essais hydrostatiques de G.2.2 à G.2.6. Tout dispositif de sécurité de surpression qui est utilisé pour limiter la pression de service maximale est inactif durant les essais.

La Figure G.1 est un diagramme montrant les méthodes de vérification de la conformité.

Tout au long de l’Article G.2, les valeurs sont basées sur la pression ASSIGNEE P_A. C’est la pression maximale marquée sur l’appareil ou, si aucune valeur n’est marquée, la surpression maximale transitoire (pression maximale qui peut être appliquée sans modification permanente du bon fonctionnement). Dans le cas d’un appareil à pression différentielle, la pression ASSIGNEE est supérieure à la pression de service et à la pression statique.



Référence des paragraphes pour les essais de A à F:

A = G.2.3 a) – B = G.2.3 b) – C = G.2.5 a) – D = G.2.5 b) – E = G.2.5 c) – F = G.2.6 – P_A = pression ASSIGNEE

Figure G.1 – Processus de vérification de la conformité (voir G.2)

G.2.2 Réalisation des essais hydrostatiques pour G.2.1

Les parties de l'appareil qui sont normalement soumises au fluide sous pression sont remplies avec un liquide adapté tel que l'eau pour exclure l'air, et sont ensuite reliées à une pompe hydraulique. La pression est augmentée progressivement jusqu'à la valeur spécifiée pour l'essai.

Les parties de l'appareil qui reçoivent normalement une pression de charge indirecte, comme dans les systèmes à couplage hydraulique, sont soumises à l'essai de pression en même *temps, soit à travers le fluide hydraulique de remplissage d'origine ou, en son absence, avec le liquide d'essai.*

Les valeurs des essais de pression sont basées sur la pression ASSIGNEE *P_A.*

Les valeurs de pression d'essai spécifiées de G.2.3 à G.2.6 s'appliquent aux appareils avec une pression ASSIGNEE *jusqu'à 14 MPa. Pour des pressions* ASSIGNEES *plus élevées, les valeurs du Tableau G.1 s'appliquent.*

~~*S'il est spécifié que la pression est appliquée à «l'appareil», ceci fait référence à la partie de l'appareil qui est soumise à la pression en* UTILISATION NORMALE*. S'il est spécifié que la pression est appliquée à «la chemise externe» ceci fait référence à tout boîtier, couvercle ou* ENVELOPPE *non pressurisé qui enferme une ou toutes les parties de l'appareil pressurisé, mais qui n'est pas soumis à la pression en* UTILISATION NORMALE.~~

Lorsqu'il est spécifié dans ces procédures d'essai que la pression doit être appliquée à "l'appareil", la pression doit être appliquée à la partie de l'appareil qui est soumise à la pression en UTILISATION NORMALE*.*

Lorsqu'il est spécifié dans ces procédures d'essai que la pression doit être appliquée à "l'enveloppe extérieure", la pression doit être appliquée à tout boîtier, couvercle, enveloppe ou revêtement non pressurisé qui enferme une ou toutes les parties de l'appareil pressurisé, mais qui n'est pas destiné à être soumis à la pression en UTILISATION NORMALE*.*

G.2.3 Essais initiaux

Les essais suivants sont réalisés.

a) *Une pression égale à 2 $\times$ P_A est appliquée à l'appareil durant 1 min sans aucune fuite visible.*

b) *Une pression égale à 3 $\times$ P_A est appliquée à l'appareil durant 1 min sans aucune rupture ou fuite visible qui résulterait dans la projection de fragments en dehors de l'appareil.*

   Durant l'essai b), une fuite peut arriver à cause d'une fente dans un tube de Bourdon, dans un diaphragme ou dans un soufflet, ou à cause de la défaillance d'un joint ou d'une garniture. Cela n'est pas considéré comme une défaillance de l'essai si la pression peut être maintenue durant 1 min. Cependant, si la fuite a une importance qui empêche la pression d'être maintenue durant 1 min, les modifications spécifiées en G.2.4 sont réalisées et l'essai recommencé.

   1) *Si l'appareil passe l'essai de G.2.3 b) après modification seulement comme spécifié en G.2.4 a), aucun autre essai n'est réalisé*

   2) *Si l'appareil passe l'essai de G.2.3 b) après modification comme spécifié en G.2.4 b)), les modifications sont enlevées et un des essais de G.2.5 est réalisé.*

   3) *Si l'appareil de nouveau ne passe pas l'essai de G.2.3 b), les modifications sont enlevées et l'essai de G.2.6 est réalisé.*

G.2.4 Modifications pour minimiser la fuite

Les modifications suivantes peuvent être réalisées.

a) *Les raccords externes peuvent être modifiés pour réduire la fuite.*

b) *Un joint défaillant ou un joint étanche flexible (ne faisant pas partie de l'élément de mesure) qui réalise une partition structurelle entre la partie de l'appareil qui est sous pression en* UTILISATION NORMALE *et la chemise externe peut être remplacé par un élément non fonctionnel plus résistant pour réduire la fuite.*

G.2.5 Essais additionnels si la modification réussit à minimiser la fuite

Si après la réalisation de toute modification de G.2.4 b)), l'essai de G.2.3 b) a été répété avec succès, l'appareil est remis dans son état d'origine, et un des essais a), b), ou c) ci-dessous est effectué sur l'appareil sans modification. Les appareils conçus pour des substances toxiques, inflammables ou même dangereuses, doivent subir l'essai a) ci-dessous.

a) *Une pression égale à 2,5 × P_A est appliquée à l'appareil durant 1 min sans aucune fuite visible.*

b) *Une pression égale à 3 × P_A est appliquée à l'appareil durant 1 min sans aucune rupture ou fuite visible qui résulterait dans la projection de fragments en dehors de la chemise externe.*

NOTE 1 Dans ce cas, même si la pression de 3 × P_A ne peut être maintenue dans l'appareil, la fuite de la chemise externe est telle qu'elle empêche l'établissement d'une pression dangereuse.

c) *Lorsque l'appareil a une chemise externe pouvant être pressurisée, elle est soumise à une pression de P_A pendant 1 min sans aucune rupture ni défaillance qui causerait la projection de morceaux en dehors de la chemise externe.*

NOTE 2 Dans cette situation, la faculté de la chemise externe de résister à la pression empêche la rupture et les morceaux expulsés.

G.2.6 Essais additionnels si les modifications ne réussissent pas à réduire la fuite

Lorsque l'appareil ne réussit pas avec succès l'essai de G.2.3 b), après les modifications de G.2.4, mais la fuite est utile comme mécanisme de réduction de pression, l'appareil est conforme aux exigences de G.2.3 b) s'il subit avec succès et après dépose des modifications, les essais spécifiés ci-dessous et si l'appareil est équipé d'une chemise externe s'il subit avec succès un des essais de a), b), et c) de G.2.5.

Une pression égale à 2,5 × P_A est appliquée à l'appareil durant 1 min sans aucune rupture ou fuite visible qui résulterait dans la projection de morceaux en dehors de l'appareil.

Tableau G.1 – Pressions d'essai pour les appareils avec des pressions supérieures à 14 MPa

P_A	Pression pour l'essai de G.2.5 c)	Pression pour l'essai de G.2.3 a)	Pression pour l'essai de G.2.5 a) et G.2.6	Pression pour l'essai de G.2.3 b) et G.2.5 b)
>14 ≤ 70 MPa	P_A	1,75 × P_A plus 3,5 MPa	2,0 × P_A plus 7 MPa	2,5 × P_A plus 7 MPa
>70 MPa	P_A	1,3 × P_A plus 35 MPa	1,5 × P_A plus 42 MPa	2,0 × P_A plus 42 MPa

G.3 Pressions entre 50 kPa et 2 MPa, et produit pression fois volume au-dessus de 200 kPa·l

Les parties des appareils contenant des fluides qui en UTILISATION NORMALE ont les deux caractéristiques suivantes ne doivent pas causer un DANGER en cas de rupture ou de fuite:

a) un produit pression x volume supérieur à 200 kPa·l;

d) une pression entre 50 kPa et 2 MPa.

La conformité est vérifiée en réalisant l'essai hydrostatique de G.2.2. Tout dispositif de sécurité de surpression qui est utilisé pour limiter la pression de service maximale est inactif durant les essais.

Une pression égale à 3 × P_A est appliquée à l'appareil durant 1 min sans aucune fuite déformation permanente (plastique) ou éclatement. Cependant pour les appareils non conçus pour des substances toxiques, inflammables ou même dangereuses, une fuite à un joint pour une pression supérieure à 1,2 × P_A est acceptable.

Lorsqu'un essai hydrostatique ne peut être réalisé sur des parties ou des tuyaux non marqués contenant des fluides, leurs intégrités sont vérifiées par des essais équivalents adaptés, tels que l'essai pneumatique à 3 × P_A.

Pour les systèmes de réfrigération, voir les normes nationales applicables comme par exemple ANSI/UL 471 ou CSA C22.2 No 120.

G.4 Pressions en dessous de 50 kPa ou produit pression fois volume inférieur à 200 kPa·l

Les fuites des parties contenant des fluides à pression plus basse ou avec un produit pression × volume inférieur à 200 kPa·l, ne doivent pas causer un DANGER.

La conformité est vérifiée par examen des CARACTERISTIQUES ASSIGNEES des parties et si nécessaire en soumettant la partie à un fluide sous pression à deux fois la pression maximale en UTILISATION NORMALE. La pression est appliquée durant 1 min. Aucune fuite ne doit causer un DANGER.

G.5 Dispositifs de sécurité de surpression

Les dispositifs de sécurité de surpression ne doivent pas agir en UTILISATION NORMALE et doivent satisfaire à toutes les exigences suivantes.

a) Ils doivent être montés aussi près que possible des parties contenant les fluides sous pression, qu'ils sont censés protéger.
b) Ils doivent être installés pour permettre un accès facile lors des opérations d'inspection, de maintenance et de réparation.
c) Ils ne doivent pas pouvoir être ajustés sans l'aide d'un OUTIL.
d) Leurs ouvertures d'évacuation doivent être localisées et dirigées de telle sorte que la matière éjectée ne soit pas dirigée vers une personne.
e) Leurs ouvertures d'évacuation doivent être localisées et dirigées de telle sorte que le fonctionnement de ces dispositifs ne vienne pas déposer la matière sur des parties entraînant de ce fait un DANGER.
f) Ils doivent avoir une capacité d'évacuation adaptée afin d'éviter que, dans le cas d'une panne de régulation de pression du système, la pression n'excède pas 1,1 × P_A.
g) Il ne doit pas y avoir de vannes de fermeture entre les dispositifs de sécurité de surpression et les parties qu'ils sont censés protéger.

Voir aussi 11.7.4.

La conformité est vérifiée par examen et essai.

Annexe H
(normative)

Qualification des revêtements enrobant pour la protection contre la POLLUTION

H.1 Généralités

Cette annexe décrit les exigences relatives aux revêtements enrobant utilisé sur les circuits imprimés pour réduire le DEGRE DE POLLUTION.

Les revêtements enrobant doivent répondre aux exigences des Articles H.2 et H.3.

NOTE 1 Avec les exigences de l'Article H.2, on s'assure que les caractéristiques ASSIGNEES du revêtement enrobant ont été dûment prévues pour des circuits imprimés. Avec les exigences de l'Article H.3, on s'assure que le revêtement continuera à adhérer au circuit imprimé après l'application de contraintes environnementales et physiques.

La conformité est vérifiée comme spécifié aux Articles H.2 et H.3.

NOTE 2 Les revêtements enrobant qui répondent aux exigences de la norme ANSI/UL 746E sont considérés répondre aux exigences de cette annexe.

H.2 Propriétés techniques

Les propriétés techniques des revêtements enrobant doivent être adaptées à l'application prévue. Notamment:

a) le fabricant du matériau de revêtement doit indiquer qu'il s'agit d'un revêtement pour circuits imprimés;
b) la gamme de température ASSIGNEE de fonctionnement doit couvrir la gamme de température de l'application prévue;
c) l'indice de résistance au cheminement (IRC), la résistance d'isolement et la rigidité diélectrique doivent être adaptées à l'application prévue;
d) si le revêtement du circuit imprimé est exposé à la lumière du soleil, il doit avoir une résistance adaptée aux UV;
e) l'inflammabilité ASSIGNEE du revêtement doit être au moins l'inflammabilité ASSIGNEE exigée pour le circuit imprimé sur lequel le revêtement est appliqué.

La conformité est vérifiée par l'examen des données du fabricant.

H.3 Qualification des revêtements

Les revêtements doivent répondre aux exigences de la Figure H.1 après les essais décrits au Tableau H.1.

La conformité est vérifiée comme spécifié dans le Tableau H.1 et la Figure H.1 sur 6 échantillons du circuit imprimé enrobé.

Tableau H.1 – Paramètres d'essai, conditions de l'essai et procédures d'essai

Point	Essai, condition-nement	Paramètres et conditions d'essai	Procédure d'essai
~~1~~	~~Résistance aux rayures~~	~~Température: 15 °C…. 35 °C~~ ~~Humidité: 45 %…. 75 % H.R.~~ ~~Toute combinaison de température et d'humidité à l'intérieur de ces fourchettes est acceptable~~	~~L'essai de tenue aux rayures est réalisé suivant le 5.5 de la IEC 60664-3.~~
~~2~~ 1	Condition-nement au froid	Température de conditionnement: T_{min}. T_{min} est la plus petite des températures minimales ASSIGNEES ambiantes ou de stockage de l'échantillon. Toute valeur d'humidité est acceptable Durée du conditionnement: 24 h	Les échantillons sont placés dans une enceinte thermostatique et maintenus à T_{min} pendant la durée du conditionnement spécifié.
~~3~~ 2	Chaleur sèche	Température de conditionnement: T_{max}. T_{max} est la plus grande des températures maximales ASSIGNEES ambiantes, de surface ou de stockage de l'échantillon. Toute valeur d'humidité est acceptable Durée du conditionnement: 48 h	L'échantillon est placé dans une enceinte thermostatique et maintenu à T_{max} pendant la durée du conditionnement spécifié.
~~4~~ 3	Variation rapide de la température	Température maximale: T_{max}. T_{max} est la plus grande des températures maximales ASSIGNEES ambiantes, de surface ou de stockage de l'échantillon. Température minimale: T_{min}. T_{min} est la plus petite des températures minimales ASSIGNEES ambiante ou de stockage de l'échantillon. Taux de variation en température: dans les 30 s Durée d'un cycle: T_{max} et T_{min} sont chacune maintenues jusqu'à l'obtention d'un état stable, plus 10 min Le cycle démarre quand l'échantillon a atteint la température cible à 2 °C près. Nombre de cycles: 50 cycles	L'essai Na de l'IEC 60068-2-14 est réalisé.
~~5~~ 4	Chaleur humide	Température: 40 °C ± 2 °C Humidité: 90 %…95 % H.R. Durée du conditionnement: 24 h	Les échantillons sont placés dans une enceinte climatique et maintenus à la température et à l'humidité spécifiées pendant la durée spécifiée du conditionnement.
~~6~~ 5	Adhérence du revêtement	Température: 15 °C…. 35 °C Humidité: 45 %…. 75 % H.R. Force de traction: 5 N	L'essai est réalisé suivant le 5.8.2 de l'IEC 60664-3 en utilisant la force de traction spécifiée.
~~7~~ 6	Condition-nement en humidité	Température: 40 °C ± 2 °C Humidité: 90 %…95 % H.R. Durée du conditionnement: 48 h	Les échantillons sont placés dans une enceinte climatique et maintenus à la température et à l'humidité spécifiées pendant la durée spécifiée du conditionnement.
~~8~~ 7	Résistance d'isolement des conducteurs	Température: 40 °C ± 2 °C Humidité: 90 %…95 % H.R. Résistance d'isolement: ≥100 MΩ	La résistance d'isolement doit être mesurée entre tous conducteurs adjacents situés sur la même couche pendant 1 min au moins. La tension d'essai doit être aussi proche que possible de la TENSION DE SERVICE

La Figure H.1 suivante présente le diagramme de la séquence d'essai et de la conformité.

Préparation et résistance aux rayures	
Préparation des échantillons d'essai	Chaque échantillon est assemblé normalement, en utilisant le processus de soudure normal, y compris les étapes de nettoyage et de protection normalement appliquées.
~~Tableau H.1, point 1~~	~~Essai de résistance aux rayures~~
Inspection visuelle	La conformité est vérifiée par examen. Les échantillons ne doivent pas montrer de: • séparation du matériau de base, • fissures, • vides, • espaces avec des parties conductrices adjacentes non protégées où la LIGNE DE FUITE entre les parties est inférieure à la LIGNE DE FUITE exigée pour un circuit imprimé sans revêtement *NOTE Il n'est pas nécessaire d'utiliser les zones des échantillons où l'essai de résistance aux rayures a été appliqué lors des examens et essais ultérieurs.*

Conditionnement des échantillons d'essai	
Tableau H.1, point ~~2~~ 1	Conditionnement au froid
Tableau H.1, point ~~3~~ 2	Chaleur sèche
Tableau H.1, point ~~4~~ 3	Variation rapide de température
Tableau H.1, point ~~5~~ 4	Essai en chaleur humide

Essais mécaniques et électriques après conditionnement	
Tableau H.1, point ~~6~~ 5	Adhérence du revêtement (essai avec bande)
Inspection visuelle	La conformité est vérifiée par examen. Sur tous les échantillons, le revêtement ne doit pas s'être décollé et il ne doit pas y avoir eu de transfert de matière sur la bande visible à l'œil nu. *NOTE Afin d'évaluer s'il y a eu un transfert de matière, la bande peut être placée sur une feuille de papier ou de carton blanc. Si un revêtement blanc ou légèrement teinté est en cours d'essai, une feuille de papier ou un carton de couleur suffisamment contrasté est utilisé à la place.*
Tableau H.1, point ~~7~~ 6	Conditionnement en humidité
Tableau H.1, point ~~8~~ 7	Résistance d'isolement *La conformité est vérifiée par mesure de la résistance d'isolement du Tableau H.1, point ~~8~~ 7. Tous les échantillons doivent être conformes.*
Inspection visuelle	*La conformité est vérifiée par examen.* Aucun échantillon ne doit montrer de • cloquage, • gonflement, • séparation du matériau de base, • fissures, • vides, • espaces avec des parties conductrices adjacentes non protégées où la LIGNE DE FUITE entre les parties est inférieure à la LIGNE DE FUITE exigée pour un circuit imprimé sans revêtement

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Figure H.1 – Séquence d'essai et conformité

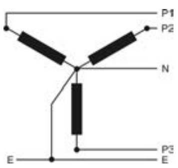
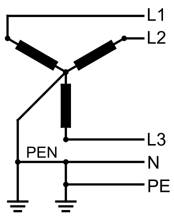
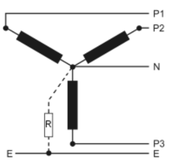
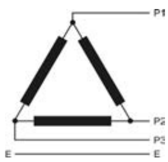
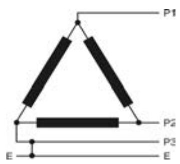
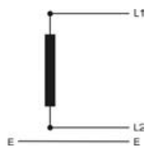
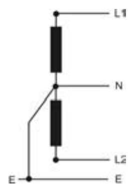
Annexe I
(informative)

Tensions phase-neutre des RESEAUX de distribution généralement utilisés

Pour les besoins de cette norme, le Tableau I.1 donne la tension phase-neutre qu'il convient d'utiliser pour la détermination des DISTANCES D'ISOLEMENT, des LIGNES DE FUITE et les exigences de l'isolation solide des CIRCUITS RESEAU.

Le Tableau I.1 est issu du Tableau B.1 de l'IEC 60664-1. Il est applicable aux RESEAUX de distribution avec situation naturelle de maîtrise (voir IEC 60664-1, 4.3).

Tableau I.1 – Tensions phase-neutre des RESEAUX de distribution utilisés

RESEAUX de distribution et tensions nominales						**Tension phase-neutre pertinente pour le type de RESEAU de distribu-tion et la tension nominale**
Réseaux triphasés 4 fils [a] avec neutre à la terre **Schéma TT**	**Réseaux triphasés 4 fils [a] avec neutre non raccordé à la terre (schémas IT) [b,c]**	**Réseaux triphasés 3 fils non raccordés à la terre**	**Réseaux triphasés 3 fils avec phase à la terre**	**Réseaux monophasés 2 fils alternatifs ou continus**	**Réseaux monophasés (biphasés en opposition de phase/split phase) 3 fils [a] alternatifs ou continus**	
 **Schéma TN-C-S** 						
V	V	V	V	V	V	V

				12,5 à 48	30/60	50
66/115		66		60		100
120/208 127/220	120/208	110, 115 120, 127	100 120	100 110, 115 120, 127	100/200 [d] 110/220 115/230 120/240	150
220/380 230/400 240/415 260/440 277/480	230/400 277/480	200 220, 230, 240 260, 277, 347 380, 400, 415 440, 480	200 240 347 380, 400, 415 440, 480	220 230 240	220/440 240/480	300
347/600 380/660 400/690 417/720 480/830	347/600 400/690	500 577 600	600	480	480/960	600
		660 690, 720 830, 1 000		1 000		1 000

[a] Les tensions indiquées par deux valeurs séparées par un “/” représentent la tension phase-neutre suivie de la tension entre phases. Par exemple, "120/208" indique que la tension entre n'importe quelle phase et le neutre est de 120 V, et que la tension entre n'importe quelle phase est de 208 V. De même, "220/440" indique que la tension phase-neutre est de 220 V, et que la tension entre phases est de 440 V.

[b] *Z* est une impédance qui peut raccorder le neutre à la terre (habituellement 1 500 Ω).

[c] Lorsque l'isolement est surveillé, le neutre de ces réseaux est considéré comme étant raccordé à la terre.

[d] Pratique au Japon.

Annexe J
(informative)

Appréciation du RISQUE

Une méthode d'appréciation du RISQUE basé sur le Guide 51 (1999) de l'ISO/IEC est donnée ci-dessous. D'autres procédures d'appréciation du RISQUE sont données dans l'ISO 14971, la SEMI S10, l'IEC 61508, l'ISO 14121-1 et l'ANSI TR3. D'autres procédures établies qui mettent en application des mesures similaires peuvent aussi être utilisées.

J.1 Méthode d'appréciation du RISQUE

Le RISQUE TOLERABLE est atteint par un processus itératif d'appréciation du RISQUE (analyse du RISQUE et évaluation du RISQUE) et de réduction du RISQUE (voir la Figure J.1).

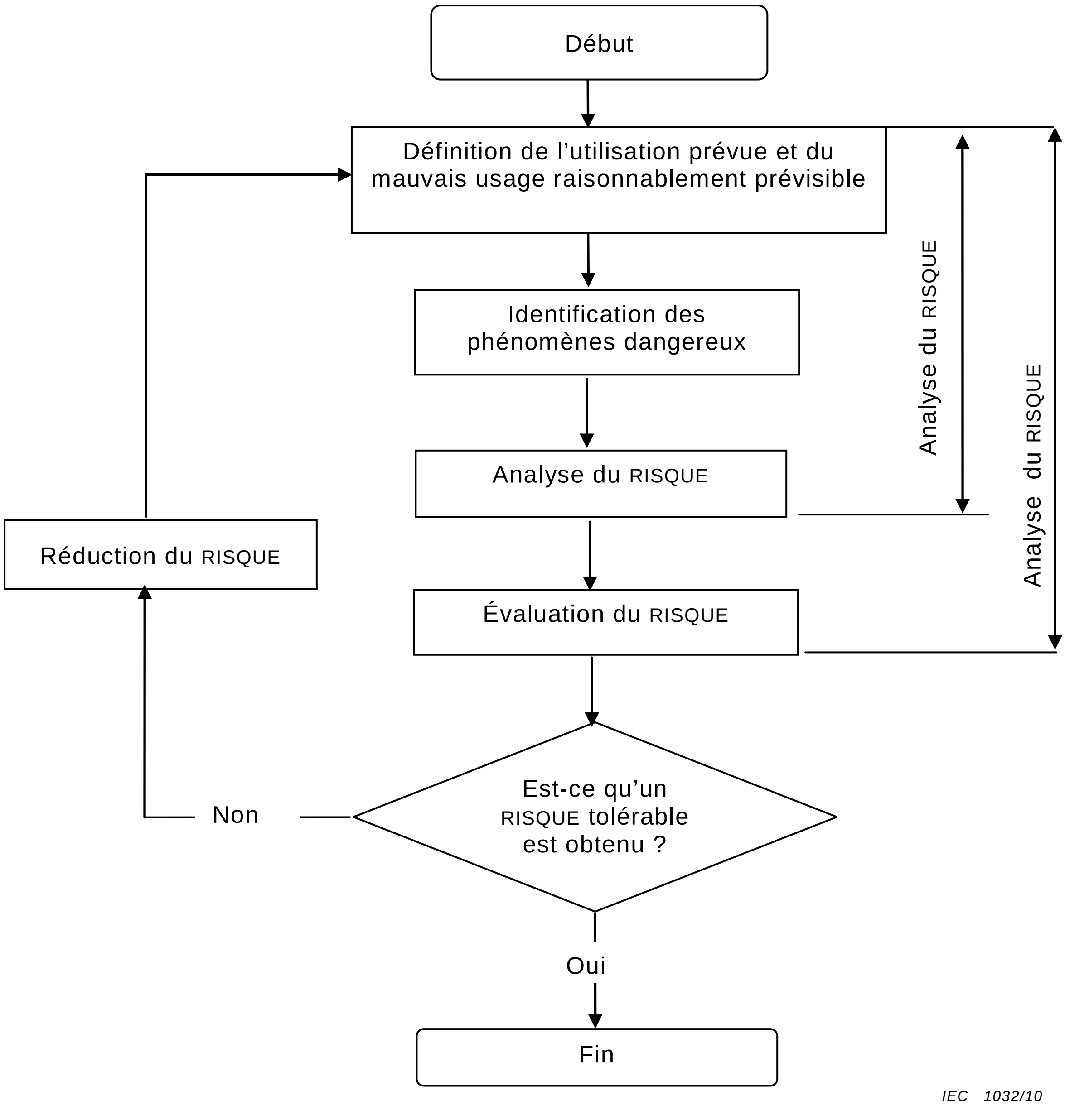


Figure J.1 – Processus itératif d'appréciation du RISQUE et de réduction du RISQUE

J.2 Atteinte du RISQUE TOLERABLE

Il convient d'appliquer la stratégie suivante (voir la Figure J.1) pour réduire le RISQUE à un niveau tolérable:

a) identifier le ou les groupes d'utilisateurs probables pour le produit, le procédé ou le service (y compris les personnes ayant des besoins particuliers et les personnes âgées) et tout autre utilisation connue (par exemple, utilisation/contact par de jeunes enfants);
b) identifier l'utilisation prévue et évaluer les MAUVAIS USAGES RAISONNABLEMENT PREVISIBLES d'un produit, d'un procédé ou d'un service;
c) identifier chaque phénomène dangereux (ou DANGER) (y compris les situations dangereuses et les événements dangereux) survenant à toutes les étapes et dans toutes les conditions d'utilisation du produit, procédé ou service, y compris l'installation, l'entretien, la réparation et la destruction/mise au rebut;
d) estimer et évaluer les RISQUES (voir la Figure J.1) pour chaque groupe d'utilisateurs probables, découlant des phénomènes dangereux (ou DANGERS) identifiés;
e) juger si les RISQUES sont tolérables (par exemple en les comparant à des produits, procédés ou services similaires);
f) si le RISQUE n'est pas tolérable, le réduire jusqu'à ce qu'il devienne tolérable.

Lorsque l'on réduit les RISQUES, il convient d'utiliser l'ordre de priorité suivant:

1) éliminer ou réduire les RISQUES au maximum par une conception et une fabrication intrinsèquement sûre;
2) prendre les mesures nécessaires de protection par rapport aux RISQUES qui ne peuvent pas être éliminés (dispositifs de protection);
3) informer les utilisateurs des RISQUES résiduels dus à toutes les imperfections des mesures de protection adoptées, indiquer si une formation particulière est exigée, et spécifier les équipements de protection individuels nécessaires (information pour la sécurité).

La procédure ci-dessus est fondée sur l'hypothèse que l'utilisateur a un rôle à jouer dans la procédure de réduction du RISQUE en se conformant à l'information mise à sa disposition par le concepteur/fournisseur (voir la Figure J.2).

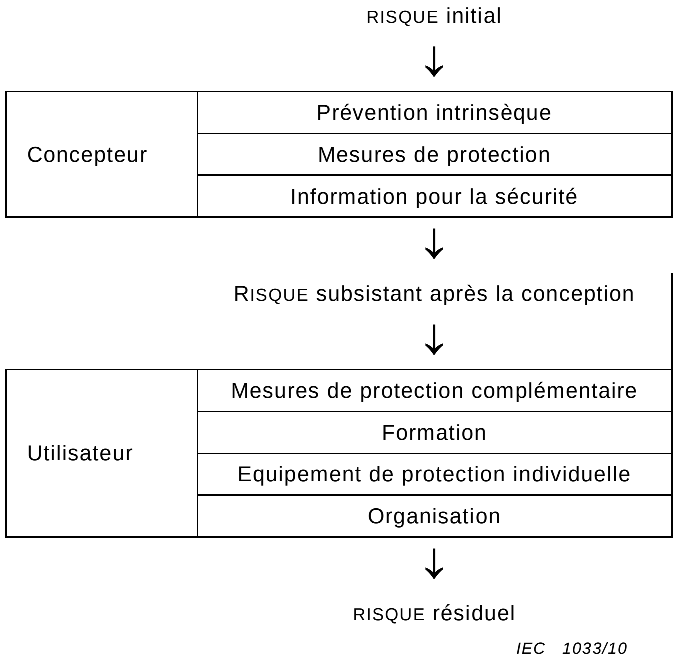


Figure J.2 – Réduction du RISQUE

Les étapes de la conception sont indiquées par ordre de priorité. Les mesures à prendre par l'utilisateur ne sont pas en ordre de priorité car celui-ci dépendra de l'application. Il convient d'insister tout particulièrement sur le fait que les dispositifs de protection, de même que l'information mise à la disposition de l'utilisateur, ne devraient en aucun cas être utilisés pour suppléer aux améliorations que pourrait apporter la conception.

J.3 Une application des procédures d'appréciation du RISQUE

Pour les phénomènes dangereux (ou DANGERS) du domaine d'application de cette norme, des exemples de gravité du dommage sont donnés dans le Tableau J.1. La probabilité du dommage est donnée dans le Tableau J.2. La catégorie du RISQUE, qui est sélectionnée sur la base de la gravité et de la probabilité, est donnée dans le Tableau J.3.

Tableau J.1 – Gravité du dommage

Groupe de gravité	Personnes	Appareil / Installations	Environnement
Catastrophique	Une victime ou plus	Système ou installations perdus	Emission chimique avec impact intense ou sur la santé publique
Grave	Blessure / maladie invalidante	Perte du sous-système principal ou endommagement des installations	Emission chimique avec impact temporaire sur l'environnement ou sur la santé publique
Moyen	Traitement médical ou activité professionnelle réduite	Perte du sous-système secondaire ou endommagement des installations	Emission chimique déclenchant des exigences de rapport externe
Mineur	Premiers secours uniquement	Dégâts légers sur les appareils ou les installations	Emission chimique ne nécessitant qu'un nettoyage d'usage sans rapport

Tableau J.2 – Probabilité du dommage

Probabilité	Fréquence attendue d’occurrence
Fréquent	Plus de cinq fois par an
Probable	Plus d'une fois par an, mais pas plus de cinq fois par an
Possible	Plus d'une fois en cinq ans, mais pas plus d'une fois pas an
Rare	Plus d'une fois en dix ans, mais pas plus d'une fois en cinq ans
Improbable	Moins d'une fois en dix ans

Tableau J.3 – Catégorie du RISQUE

Appréciation du RISQUE / catégorie du RISQUE						
Gravité du dommage		Probabilité dommage				
		Fréquent	Probable	Possible	Rare	Improbable
Gravité	Catastrophique	3	3	3	2	2
	Grave	3	3	2	2	1
	Moyenne	3	2	1	1	1
	Mineure	2	1	1	1	1

Légende	Catégorie	Description
1	Largement acceptable	Répond aux exigences du RISQUE TOLERABLE
2	Aussi bas que raisonnablement possible	Ne répond pas automatiquement aux exigences du RISQUE TOLERABLE. Si possible, ces RISQUES doivent être réduits à la catégorie 1. Si ce n'est pas possible, alors les consignes doivent comporter une description du RISQUE afin que l'AUTORITE RESPONSABLE puisse prendre les mesures appropriées pour protéger la sécurité des OPERATEURS.
3	Intolérable	Comporte des RISQUES qui ne sont pas des RISQUES TOLERABLES.

Annexe K
(normative)

Exigences d'isolation non couvertes par 6.7

K.1 ~~Exigences~~ Isolation pour les CIRCUITS RESEAU

K.1.1 Généralités

Le concept de CATEGORIES DE SURTENSION est développé dans l'IEC 60364 et dans l'IEC 60664-1. Les descriptions ci-dessous ont été établies à partir d'extraits de ces deux normes.

Une CATEGORIE DE SURTENSION est, comme indiqué en 3.5.17, un nombre définissant une condition de SURTENSION TRANSITOIRE. Les CATEGORIES DE SURTENSION sont crées afin d'arriver à une coordination de l'isolation entre différentes parties de l'installation d'alimentation par le RESEAU. L'IEC 60364-4-44 dit que "Les catégories de résistance (surtension) à l'impulsion doivent distinguer différents degrés de disponibilité des appareils en considération des attentes exigées sur la continuité du fonctionnement et sur une probabilité acceptable de panne". Ce qui signifie que la décision du choix de la CARACTERISTIQUE ASSIGNEE appropriée de la CATEGORIE DE SURTENSION d'un appareil peut être prise sur des bases de fiabilité et de sécurité. Dans cette norme, les exigences des Articles 5 à 16 s'appliquent aux appareils ne faisant pas partie de l'installation du bâtiment, et les exigences pour les DISTANCES D'ISOLEMENT et les LIGNES DE FUITE sont basées sur la CATEGORIE DE SURTENSION II avec des tensions RESEAU jusqu'à 300 V.

Les appareils faisant partie de l'installation du bâtiment comprennent les matériels d'installation, les appareils destinés à mesurer ou commander l'alimentation RESEAU dans le bâtiment et les appareils similaires. Tous ces types d'appareils sont branchés en permanence sur le RESEAU, et sont installés en permanence dans le bâtiment. Cependant, les appareils branchés et installés en permanence qui utilisent l'alimentation RESEAU pour fonctionner et les appareils associés ne sont pas considérés comme faisant partie de l'installation du bâtiment.

Si un fabricant caractérise des appareils dans une CATEGORIE DE SURTENSION III ou une CATEGORIE DE SURTENSION IV, les exigences appropriées de cette annexe s'appliquent.

Dans le contexte de l'IEC 60364-4-44, la CATEGORIE DE SURTENSION I est utilisée pour des appareils destinés à être branchés à l'alimentation RESEAU dans laquelle des moyens ont été pris pour réduire substantiellement et avec fiabilité les SURTENSIONS TRANSITOIRES à un niveau où elles ne peuvent causer un DANGER. La CATEGORIE DE SURTENSION I n'est pas appropriée pour cette norme.

La CATEGORIE DE SURTENSION II concerne les appareils prévus pour être alimentés à partir de l'installation électrique du bâtiment. Elle s'applique à la fois aux appareils connectés par prise et aux APPAREILS BRANCHES EN PERMANENCE. Le paragraphe 6.7 ne couvre que les exigences en CATEGORIE DE SURTENSION II avec une tension nominale d'alimentation jusqu'à 300 V. Les exigences pour les CATEGORIES DE SURTENSION plus élevées et pour les tensions nominales d'alimentation au-delà de 300 V en CATEGORIE DE SURTENSION II sont couverts par la présente annexe.

La CATEGORIE DE SURTENSION III concerne les appareils prévus pour faire partie de l'installation électrique d'un bâtiment. Ces appareils comprennent les socles de prise de courant, les tableaux de fusibles, et certains appareils de commande d'installation du RESEAU. Les fabricants peuvent aussi concevoir des appareils en CATEGORIE DE SURTENSION III lorsqu'un degré supérieur de fiabilité et de disponibilité est souhaité.

La CATEGORIE DE SURTENSION IV concerne les appareils installés à l'origine de l'alimentation électrique d'un bâtiment ou à sa proximité, entre l'entrée et le tableau de distribution du RESEAU. Ces appareils peuvent comprendre les compteurs électriques tarifaires et les dispositifs de protection contre les surtensions primaires. Les fabricants peuvent aussi concevoir des appareils en CATEGORIE DE SURTENSION IV lorsqu'un degré encore supérieur de fiabilité et de disponibilité est souhaité.

K.1.2 DISTANCES D'ISOLEMENT et LIGNES DE FUITE des CIRCUITS RESEAU

Les valeurs des DISTANCES D'ISOLEMENT et les LIGNES DE FUITE des CIRCUITS RESEAU sont données dans les tableaux suivants, selon le cas:

a) pour les CIRCUITS RESEAU en CATEGORIE DE SURTENSION II au-delà de 300 V, les valeurs du Tableau K.2;
b) pour les CIRCUITS RESEAU en CATEGORIE DE SURTENSION III, les valeurs du Tableau K.3;
c) pour les CIRCUITS RESEAU en CATEGORIE DE SURTENSION IV, les valeurs du Tableau K.4.

NOTE 1 Voir l'Annexe I pour les tensions nominales des RESEAUX de distribution.

Les valeurs des tableaux suivants sont données pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE. Les valeurs pour l'ISOLATION RENFORCEE doivent être doublées.

Si l'altitude de fonctionnement ASSIGNEE à l'appareil est supérieure à 2 000 m, la DISTANCE D'ISOLEMENT doit être multipliée par le coefficient applicable du Tableau K.1.

NOTE 2 Les matériaux du groupe IIIb ne sont pas recommandés pour les applications en DEGRE DE POLLUTION 3 contraintes par des tensions phase-neutre supérieures à 630 V.

La conformité est vérifiée par examen et ~~mesure~~ mesurage et, en cas de doute, par l'essai de tension de choc de 6.8.3.3 ou l'essai en tension alternative de 6.8.3.1 pendant au moins 5 s en utilisant la tension d'essai applicable du Tableau K.16 pour la DISTANCE D'ISOLEMENT exigée.

Aucun contournement des distances d'isolement ne doit se produire durant l'essai.

Tableau K.1 – Coefficient multiplicateur pour les DISTANCES D'ISOLEMENT pour un fonctionnement jusqu'à 5 000 m d'altitude

Altitude de fonctionnement ASSIGNEE m	Coefficient multiplicateur
Jusqu'à 2 000	1,00
2 001 à 3 000	1,14
3 001 à 4 000	1,29
4 001 à 5 000	1,48

Tableau K.2 – DISTANCES D'ISOLEMENT et LIGNES DE FUITE des CIRCUITS RESEAU en CATEGORIE DE SURTENSION II au-delà de 300 V

Tension phase-neutre alternative efficace ou continue	Valeurs de la DISTANCE D'ISOLEMENT	Valeurs de la LIGNE DE FUITE								
		Circuits imprimés		Autres matériaux isolants						
		DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2	DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2			DEGRE DE POLLUTION 3		
		Tout groupe de matériau	Matériau des groupes I, II et IIIa	Tout groupe de matériau	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
>300 ≤ 600	3,0	3,0	3,0	3,0	3,0	4,3	6,0	7,5	8,3	9,4
>600 ≤ 1 000	5,5	5,5	5,5	5,5	5,5	7,2	10,0	12,5	14,0	16,0

Tableau K.3 – DISTANCES D'ISOLEMENT et LIGNES DE FUITE des CIRCUITS RESEAU en CATEGORIE DE SURTENSION III

Tension phase-neutre alternative efficace ou continue	Valeurs de la DISTANCE D'ISOLEMENT	Valeurs de la LIGNE DE FUITE								
		Circuits imprimés		Autres matériaux isolants						
		DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2	DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2			DEGRE DE POLLUTION 3		
		Tout groupe de matériau	Matériau des groupes I, II et IIIa	Tout groupe de matériau	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
≤150	1,5	1,5	1,5	1,5	1,5	1,5	1,6	2,0	2,2	2,5
>150 ≤ 300	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,8	4,1	4,7
>300 ≤ 600	5,5	5,5	5,5	5,5	5,5	5,5	6,0	7,5	8,3	9,4
>600 ≤ 1 000	8,0	8,0	8,0	8,0	8,0	8,0	10,0	12,5	14,0	16

Tableau K.4 – DISTANCES D'ISOLEMENT et LIGNES DE FUITE des CIRCUITS RESEAU en CATEGORIE DE SURTENSION IV

Tension phase-neutre alternative efficace ou continue	Valeurs de la DISTANCE D'ISOLEMENT	Valeurs de la LIGNE DE FUITE								
		Circuits imprimés		Autres matériaux isolants						
		DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2	DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2			DEGRE DE POLLUTION 3		
		Tout groupe de matériau	Matériau des groupes I, II et IIIa	Tout groupe de matériau	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III	Matériau du groupe I	Matériau du groupe II	Matériau du groupe III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
≤150	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
>150 ≤ 300	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5
>300 ≤ 600	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,3	9,4
>600 ≤ 1 000	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	16,0

Les revêtements appliqués aux surfaces extérieures des circuits imprimés et qui satisfont aux exigences de l'Annexe H réduisent le DEGRE DE POLLUTION de la zone enrobée au DEGRE DE POLLUTION 1.

La conformité des revêtements est vérifiée comme spécifié à l'Annexe H.

K.1.3 Isolation solide dans les CIRCUITS RESEAU

K.1.3.1 Généralités

L'isolation solide dans les CIRCUITS RESEAU doit résister aux contraintes électriques et mécaniques pouvant survenir en UTILISATION NORMALE, dans toutes les conditions d'environnement ASSIGNEES (voir 1.4) pendant la durée de vie prévue de l'appareil.

NOTE 1 Lors du choix des matières isolantes, il convient que le fabricant prenne en compte la durée de vie prévue de l'appareil.

La conformité est vérifiée par les deux essais suivants à la fois:

a) l'essai en tension alternative de 6.8.3.1 d'une durée d'au moins 5 s ou l'essai de tension de choc de 6.8.3.3 en utilisant la tension d'essai applicables du Tableau K.5,, du Tableau K.6 ou du Tableau K.7;

b) l'essai en tension alternative de 6.8.3.1 d'une durée d'au moins 1 min ou, pour les CIRCUITS RESEAU contraints uniquement en tension continue, l'essai en tension continue de 1 min de 6.8.3.2 en utilisant les tensions applicables du Tableau K.8.

NOTE 2 Ces deux essais de tension sont nécessaires pour les raisons suivantes. L'essai a) vérifie la tenue aux SURTENSIONS TRANSITOIRES tandis que l'essai b) vérifie les contraintes électriques de longue durée de l'isolation solide.

NOTE 3 Si l'essai du Tableau K.5, du Tableau K.6 ou du Tableau K.7 est réalisé pendant au moins 1 min, il n'est pas nécessaire de répéter l'essai b) ci-dessus.

Tableau K.5 – Tensions d'essai de l'isolation solide des CIRCUITS RESEAU en CATEGORIE DE SURTENSION II au-delà de 300 V

Tension phase-neutre alternative efficace ou continue V	Tension d'essai			
	Essai de 5 s en tension alternative V_{eff}		Essai de tension de choc $V_{crête}$	
	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE
>300 ≤ 600	2 210	3 510	4 000	6 400
>600 ≤1 000	3 310	5 400	6 000	9 600

Tableau K.6 – Tensions d'essai de l'isolation solide des CIRCUITS RESEAU en CATEGORIE DE SURTENSION III

Tension phase-neutre alternative efficace ou continue V	Tension d'essai			
	Essai de 5 s en tension alternative V_{eff}		Essai de tension de choc $V_{crête}$	
	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE
≤150	1 390	2 210	2 500	4 000
>150 ≤ 300	2 210	3 510	4 000	6 400
>300 ≤ 600	3 310	5 400	6 000	9 600
>600 ≤1 000	4 260	7 400	8 000	12 800

Tableau K.7 – Tensions d'essai de l'isolation solide des CIRCUITS RESEAU en CATEGORIE DE SURTENSION IV

Tension phase-neutre alternative efficace ou continue V	Tension d'essai			
	Essai de 5 s en tension alternative V_{eff}		Essai de tension de choc $V_{crête}$	
	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE
≤ 150	2 210	3 510	4 000	6 400
>150 ≤ 300	3 310	5 400	6 000	9 600
>300 ≤ 600	4 260	7 400	8 000	12 800
>600 ≤ 1 000	6 600	11 940	12 000	19 200

Tableau K.8 – Tensions d'essai des contraintes électriques de longue durée de l'isolation solide des CIRCUITS RESEAU

Tension phase-neutre alternative efficace ou continue V	Tension d'essai			
	Essai de 1 min en tension alternative V eff.		Essai de 1 min en tension continue V continu	
	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE	ISOLATION PRINCIPALE et ISOLATION SUPPLEMENTAIRE	ISOLATION RENFORCEE
≤ 150	1 350	2 700	1 900	3 800
>150 ≤ 300	1 500	3 000	2 100	4 200
>300 ≤ 600	1 800	3 600	2 550	5 100
>600 ≤ 1 000	2 200	4 400	3 100	6 200

L'isolation solide doit aussi satisfaire aux exigences suivantes, selon le cas:

1) pour l'isolation solide utilisée en tant qu'ENVELOPPE ou BARRIERE DE PROTECTION, les exigences de l'Article 8;
2) pour les parties moulées ou empotées, les exigences de K.1.3.2;

3) pour les couches internes des circuits imprimés, les exigences de K.1.3.3;

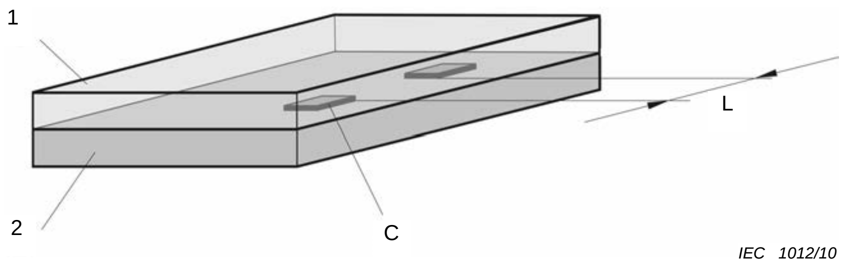
4) pour l'isolation en couche mince, les exigences de K.1.3.4.

La conformité est vérifiée tel que spécifié de K.1.3.2 à K.1.3.4, et à l'Article 8, selon le cas.

K.1.3.2 Pièces moulées et empotées

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches moulées ensemble (voir la Figure K.1, point L), doivent être séparés par au moins la distance minimum applicable du Tableau K.9 après l'application du moulage.

La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.



Légende

1: Couche 1

2: Couche 2

C: Conducteur

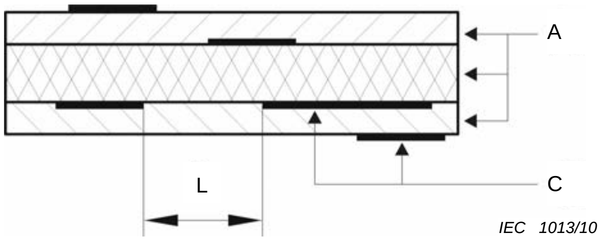
L: Distance entre conducteurs

Figure K.1 – Distance entre conducteurs situés sur l'interface entre deux couches

K.1.3.3 Couches isolantes internes des circuits imprimés

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches (voir la Figure K.2, point L), doivent être séparés par au moins la distance minimum applicable du Tableau K.9.

La conformité est vérifiée par examen, et soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.



Légende

L: Distance entre conducteurs adjacents

A: Couches

C: Conducteurs

Figure K.2 – Distance entre conducteurs adjacents situés sur l'interface entre deux couches internes

Tableau K.9 – Valeurs minimum de la distance ou de l'épaisseur de l'isolation solide

Tension phase-neutre alternative efficace ou continue V	**Epaisseur minimale** [a] mm	**Distance minimale L (voir la Figure K.2)** [a, b] mm
≤ 300	0,4	0,4
> 300 ≤ 600	0,6	0,6
> 600 ≤ 1 000	1,0	1,0

[a] Ces valeurs ne dépendent pas de la CATEGORIE DE SURTENSION.

[b] Ces valeurs s'appliquent pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE.

L'ISOLATION RENFORCEE de couches isolantes internes de circuits imprimés doit aussi avoir une rigidité électrique suffisante au travers des couches respectives. Un des moyens suivants doit être utilisé:

a) l'épaisseur de l'isolation est au moins la distance minimum applicable du Tableau K.9;

La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

b) l'isolation est constituée par au moins deux couches séparées de matière du circuit imprimé, chacune étant spécifiée par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai selon le cas du Tableau K.5, du Tableau K.6 ou du Tableau K.7 pour l'ISOLATION PRINCIPALE;

La conformité est vérifiée par l'examen des spécifications du fabricant.

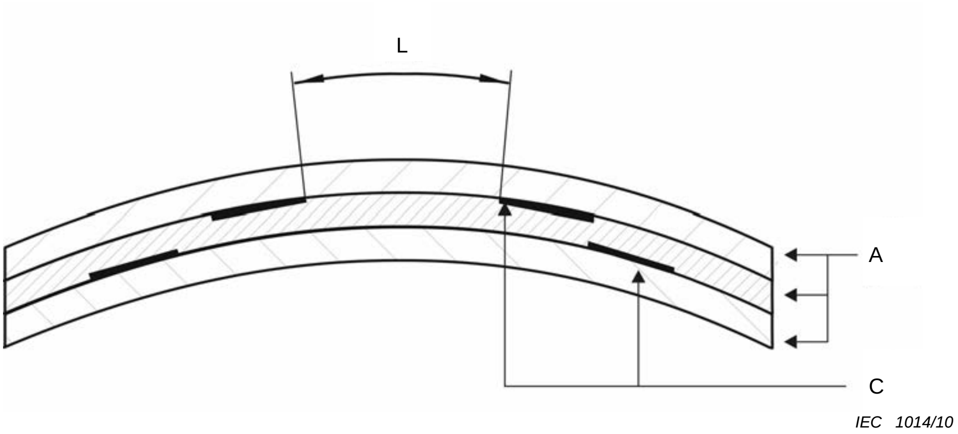
c) l'isolation est constituée par au moins deux couches séparées de matière du circuit imprimé, l'assemblage des couches étant spécifié par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai selon le cas du Tableau K.5, du Tableau K.6 ou du Tableau K.7 pour l'ISOLATION RENFORCEE.

La conformité est vérifiée par l'examen de la pièce ou des spécifications du fabricant.

K.1.3.4 Isolation en couche mince

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches (voir la Figure K.3, point L) doivent être séparés par au moins la DISTANCE D'ISOLEMENT et la LIGNE DE FUITE applicable du K.1.2.

La conformité est vérifiée par examen et, soit par la mesure des distances, soit par l'examen des spécifications du fabricant.



Légende

L: Distance entre conducteurs adjacents

A: Couches du matériau en couche mince comme ruban ou film polyester

C: Conducteurs

NOTE De l'air peut être présent entre les couches.

Figure K.3 – Distance entre conducteurs adjacents situés entre les deux mêmes couches

L'ISOLATION RENFORCEE à travers les couches minces doit aussi avoir une rigidité électrique suffisante. Un des moyens suivants doit être utilisé.

a) L'épaisseur de l'isolant est au moins la distance applicable du Tableau K.9.

   La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

b) L'isolation est constituée par au moins deux couches séparées de matière, chacune étant spécifiée par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai du Tableau K.5, du Tableau K.6 ou du Tableau K.7 selon le cas, pour l'ISOLATION PRINCIPALE.

   La conformité est vérifiée par l'examen des spécifications du fabricant.

c) L'isolation est constituée par au moins trois couches séparées de matière, chaque paire de couches ayant été testée pour la rigidité électrique adéquate.

   La conformité est vérifiée par l'essai en tension alternative de 6.8.3.1 pendant 1 min au moins, ou pour les CIRCUITS RESEAU contraints uniquement en tension continue, l'essai en tension continue de 1 min de 6.8.3.2 effectué sur deux des trois couches en utilisant la tension applicable du Tableau K.5, du Tableau K.6 ou du Tableau K.7.

   NOTE Pour les besoins de cet essai, un échantillon peut être spécialement préparé avec seulement deux couches de matière.

K.2 Isolation des circuits secondaires

K.2.1 Généralités

Dans cette norme, les circuits secondaires sont des circuits où la séparation des CIRCUITS RESEAU est réalisée par un transformateur dont les enroulements primaires sont séparés des enroulements secondaires par une ISOLATION RENFORCEE, une DOUBLE ISOLATION ou un écran connecté à la BORNE DE TERRE DE PROTECTION.

NOTE Ces circuits sont supposés être soumis à des niveaux de SURTENSIONS TRANSITOIRES inférieurs à ceux des CIRCUITS RESEAU.

K.2.2 DISTANCES D'ISOLEMENT

Les DISTANCES D'ISOLEMENT dans les circuits secondaires doivent:

a) être égales aux valeurs des Tableau K.10, Tableau K.11 et Tableau K.12 pour l'ISOLATION PRINCIPALE ou l'ISOLATION SUPPLEMENTAIRE, ou le double pour l'ISOLATION RENFORCEE; ou

b) tenir l'essai de tension de 6.8 en utilisant la tension d'essai applicable du Tableau K.10, du Tableau K.11 ou du Tableau K.12.

Les exigences supplémentaires suivantes sont applicables aux Tableau K.10, Tableau K.11 et Tableau K.12:

1) les valeurs de la tension d'essai pour l'ISOLATION RENFORCEE sont 1,6 fois les valeurs pour l'ISOLATION PRINCIPALE;

2) si l'altitude de fonctionnement ASSIGNEE à l'appareil est supérieure à 2 000 m, les valeurs des DISTANCES D'ISOLEMENT sont multipliées par le coefficient applicable du Tableau K.1.

3) la valeur minimale de la distance d'isolement est de 0,2 mm en DEGRE DE POLLUTION 2 et de 0,8 mm en DEGRE DE POLLUTION 3.

La conformité est vérifiée par examen et mesure, et pour b) par l'essai en tension alternative de 6.8.3.1 pendant 5 s au moins ou par l'essai en tension continue de 6.8.3.2 pendant 1 min, avec la valeur applicable de la tension d'essai du Tableau K.10, du Tableau K.11 ou du Tableau K.12. La valeur de la tension d'essai continue est de $\sqrt{2}$ *fois la tension d'essai alternative efficace.*

Tableau K.10 – DISTANCES D'ISOLEMENT et tensions d'essai dans les circuits secondaires dérivés des CIRCUITS RESEAU en CATEGORIE DE SURTENSION II au-delà de 300 V

TENSION DE SERVICE au secondaire		Tension RESEAU >300 ≤ 600 V alternatif efficace		Tension RESEAU >600 ≤ 1 000 V alternatif efficace	
Alternative efficace	Continue ou alternative crête	DISTANCE D'ISOLEMENT	Tension d'essai alternative efficace	DISTANCE D'ISOLEMENT	Tension d'essai alternative efficace
V	V	mm	V	mm	V
16	22,6	1,5	1 390	2,9	1 590
33	46,7	1,5	1 390	3,0	2 210
50	70	1,5	1 390	3,0	2 210
100	140	1,6	1 450	3,1	2 260
150	210	1,6	1 450	3,2	2 300
300	420	1,8	1 540	3,4	2 400
600	840	2,4	1 620	3,9	2 630
1 000	1 400	3,5	2 450	5,0	3 110
1 250	1 750	4,2	2 770	5,8	3 430
1 600	2 240	5,2	3 190	6,9	3 850
2 000	2 800	6,5	3 700	8,2	4 330
2 500	3 500	8,1	4 300	9,8	4 920
3 200	4 480	10	4 950	12	5 780
4 000	5 600	12	5 780	15	7 000
5 000	7 000	16	7 400	18	8 200
6 300	8 820	20	8 980	22	9 700
8 000	11 200	26	11 200	28	11 900
10 000	14 000	33	13 800	35	14 500
12 500	17 500	42	16 900	44	17 600
16 000	22 400	55	21 200	57	21 900
20 000	28 000	71	26 300	73	27 000
25 000	35 000	91	32 600	93	33 200
32 000	44 800	120	41 600	122	42 200
40 000	56 000	154	52 200	157	53 100
50 000	70 000	199	66 100	202	67 000
63 000	88 200	261	85 300	262	85 600
L'interpolation linéaire est permise.					

Tableau K.11 – DISTANCES D'ISOLEMENT et tensions d'essai dans les circuits secondaires dérivés des CIRCUITS RESEAU en CATEGORIE DE SURTENSION III

TENSION DE SERVICE au secondaire		Tension RESEAU ≤150 V alternatif efficace		Tension RESEAU >150 ≤ 300 V alternatif efficace		Tension RESEAU >300 ≤ 600 V alternatif efficace		Tension RESEAU >600 ≤ 1 000 V alternatif efficace	
Alternatif efficace V	Continu ou alternatif crête V	DISTANCE D'ISOLEMENT mm	Tension d'essai V alternatif efficace	DISTANCES D'ISOLEMENT mm	Tension d'essai V alternatif efficace	DISTANCE D'ISOLEMENT mm	Tension d'essai V alternatif efficace	DISTANCE D'ISOLEMENT mm	Tension d'essai V alternatif efficace
16	22,6	0,48	1 100	1,5	1 800	2,9	2 820	5,4	4 240
33	~~47,3~~ 46,7	0,50	1 100	1,5	1 800	3,0	2 900	5,4	4 240
50	70	0,53	1 120	1,5	1 800	3,0	2 900	5,5	4 300
100	140	0,61	1 170	1,6	1 880	3,1	2 960	5,6	4 360
150	210	0,69	1 200	1,6	1 880	3,2	3 020	5,7	4 420
300	420	0,94	1 360	1,8	2 040	3,4	3 140	6,0	4 600
600	840	1,6	1 880	2,4	2 440	3,9	3 440	6,6	4 860
1 000	1 400	2,5	2 500	3,5	3 200	5,0	4 000	7,4	5 240
1 250	1 750	3,2	3 020	4,2	3 620	5,8	4 480	8,1	5 560
1 600	2 240	4,1	3 560	5,2	4 120	6,9	5 040	9,3	6 120
2 000	2 800	5,3	4 180	6,5	4 800	8,2	5 620	11	7 000
2 500	3 500	6,9	5 040	8,1	5 560	9,8	6 320	12	7 500
3 200	4 480	9,2	6 080	10	6 400	12	7 500	15	9 100
4 000	5 600	12	7 500	12	7 500	15	9 100	17	10 100
5 000	7 000	15	9 100	16	9 600	18	10 600	20	11 600
6 300	8 820	19	11 200	20	11 600	22	12 600	25	14 100
8 000	11 200	25	14 100	26	14 600	28	15 500	31	16 900
10 000	14 000	32	17 400	33	17 800	35	18 700	38	20 000
12 500	17 500	41	21 500	42	21 900	44	22 800	47	24 200
16 000	22 400	54	27 200	55	27 600	57	28 400	60	29 700
20 000	28 000	69	33 500	71	34 300	73	35 200	76	36 400
25 000	35 000	89	41 600	91	42 400	93	43 200	96	44 400
32 000	44 800	118	53 000	120	53 700	122	54 500	125	55 600
40 000	56 000	153	66 100	154	66 500	157	67 600	160	68 700
50 000	70 000	198	82 400	199	82 700	202	83 800	205	84 900
63 000	88 200	260	104 000	261	104 400	262	104 700	265	105 700
L'interpolation linéaire est permise.									

Tableau K.12 – DISTANCES D'ISOLEMENT et tensions d'essai dans les circuits secondaires dérivés des CIRCUITS RESEAU en CATEGORIE DE SURTENSION IV

TENSION DE SERVICE au secondaire		Tension RESEAU ≤150 V alternatif efficace		Tension RESEAU >150 ≤ 300 V alternatif efficace		Tension RESEAU >300 ≤ 600 V alternatif efficace		Tension RESEAU >600 ≤ 1 000 V alternatif efficace	
Alternatif efficace V	Continu ou alternatif crête V	DISTANCE D'ISO-LEMENT mm	Tension d'essai V alternatif efficace	DISTANCE D'ISO-LEMENT mm	Tension d'essai V alternatif efficace	DISTANCE D'ISO-LEMENT mm	Tension d'essai V alternatif efficace	DISTANCE D'ISO-LEMENT mm	Tension d'essai V alternatif efficace
16	22,6	1,5	1 800	2,9	2 820	5,4	4 240	8,3	5 680
33	46,7	1,5	1 800	3,0	2 900	5,4	4 240	8,3	5 680
50	70	1,5	1 800	3,0	2 900	5,5	4 300	8,4	5 740
100	140	1,6	1 880	3,1	2 960	5,6	4 360	8,5	5 800
150	210	1,6	1 880	3,2	3 020	5,7	4 420	8,6	5 860
300	420	1,8	2 040	3,4	3 140	6,0	4 600	8,9	5 960
600	840	2,4	2 440	3,9	3 440	6,6	4 860	9,6	6 240
1 000	1 400	3,5	3 200	5,0	4 000	7,4	5 240	10	6 400
1 250	1 750	4,2	3 620	5,8	4 480	8,1	5 560	11	7 000
1 600	2 240	5,2	4 120	6,9	5 040	9,3	6 120	12	7 500
2 000	2 800	6,5	4 800	8,2	5 620	11	7 000	13	8 100
2 500	3 500	8,1	5 560	9,8	6 320	12	7 500	15	9 100
3 200	4 480	10	6 400	12	7 500	15	9 100	17	10 100
4 000	5 600	12	7 500	15	9 100	17	10 100	19	11 200
5 000	7 000	16	9 600	18	10 600	20	11 600	23	13 100
6 300	8 820	20	11 600	22	12 600	25	14 100	27	15 100
8 000	11 200	26	14 600	28	15 500	31	16 900	33	17 800
10 000	14 000	33	17 800	35	18 700	38	20 000	40	21 000
12 500	17 500	42	21 900	44	22 800	47	24 200	50	25 500
16 000	22 400	55	27 600	57	28 400	60	29 700	63	31 000
20 000	28 000	71	34 300	73	35 200	76	36 400	79	37 600
25 000	35 000	91	42 400	93	43 200	96	44 400	99	45 400
32 000	44 800	120	53 700	122	54 500	125	55 600	129	57 100
40 000	56 000	154	66 500	157	67 600	160	68 700	164	70 100
50 000	70 000	199	82 700	202	83 800	205	84 900	209	86 300
63 000	88 200	261	104 400	262	104 700	265	105 700	268	106 800
L'interpolation linéaire est permise.									

K.2.3 LIGNES DE FUITE

Pour l'ISOLATION PRINCIPALE ou l'ISOLATION SUPPLEMENTAIRE, les LIGNES DE FUITE des circuits secondaires doivent avoir les valeurs spécifiées dans le Tableau K.13 basées sur la valeur de la TENSION DE SERVICE qui contraint l'isolation. Les valeurs pour l'ISOLATION RENFORCEE sont le double des valeurs pour l'ISOLATION PRINCIPALE.

La conformité est vérifiée par examen et mesure.

Les revêtements appliqués aux surfaces extérieures des circuits imprimés et qui satisfont aux exigences de l'Annexe H réduisent le DEGRE DE POLLUTION de la zone enrobée au DEGRE DE POLLUTION 1.

La conformité des revêtements est vérifiée par examen comme spécifié à l'Annexe H.

Tableau K.13 – LIGNES DE FUITE des circuits secondaires

TENSION DE SERVICE alternative efficace ou continue au secondaire	Circuits imprimés		Autres matériaux isolants						
	DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2	DEGRE DE POLLUTION 1	DEGRE DE POLLUTION 2			DEGRE DE POLLUTION 3		
	Tout groupe de matériaux	Matériaux des groupes I, II et IIIa	Tout groupe de matériaux	Matériaux du groupe I	Matériaux du groupe II	Matériaux du groupe III	Matériaux du groupe I	Matériaux du groupe II	Matériaux du groupe III [b]
V	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	0,025	0,04	0,08	0,40	0,40	0,40	1,00	1,00	1,00
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05
16	0,025	0,04	0,10	0,45	0,45	0,45	1,10	1,10	1,10
20	0,025	0,04	0,11	0,48	0,48	0,48	1,20	1,20	1,20
25	0,025	0,04	0,125	0,50	0,50	0,50	1,25	1,25	1,25
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3
40	0,025	0,04	0,16	0,56	0,80	1,10	1,4	1,6	1,8
50	0,025	0,04	0,18	0,60	0,85	1,20	1,5	1,7	1,9
63	0,040	0,063	0,20	0,63	0,90	1,25	1,6	1,8	2,0
80	0,063	0,10	0,22	0,67	0,95	1,3	1,7	1,9	2,1
100	0,10	0,16	0,25	0,71	1,00	1,4	1,8	2,0	2,2
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4
160	0,25	0,40	0,32	0,80	1,1	1,6	2,0	2,2	2,5
200	0,40	0,63	0,42	1,00	1,4	2,0	2,5	2,8	3,2
250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0
320	0,75	1,6	0,75	1,60	2,2	3,2	4,0	4,5	5,0
400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0
630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0
800	2,4	4,0	2,4	4,0	5,6	8,0	10,0	11	12,5
1 000	3,2 [a]	5,0 [a]	3,2	5,0	7,1	10,0	12,5	14	16
1 250			4,2	6,3	9,0	12,5	16	18	20
1 600			5,6	8,0	11	16	20	22	25
2 000			7,5	10,0	14	20	25	28	32
2 500			10,0	12,5	18	25	32	36	40
3 200			12,5	16	22	32	40	45	50
4 000			16	20	28	40	50	56	63
5 000			20	25	36	50	63	71	80
6 300			25	32	45	63	80	90	100
8 000			32	40	56	80	100	110	125
10 000			40	50	71	100	125	140	160
12 500			50	63	90	125			
16 000			63	80	110	160			
20 000			80	100	140	200			
25 000			100	125	180	250			
32 000			125	160	220	320			
40 000			160	200	280	400			
50 000			200	250	360	500			
63 000			250	320	450	600			

[a] Pour les tensions supérieures à 1 000 V, les LIGNES DE FUITE sur les circuits imprimés sont les mêmes que celles des autres matériaux isolants du même groupe de matériaux.

[b] Les matériaux du groupe IIIb ne sont pas recommandés pour les applications au-dessus de 630 V en DEGRE DE POLLUTION 3.

L'interpolation linéaire est permise.

K.2.4 Isolation solide

K.2.4.1 Généralités

L'isolation solide des circuits secondaires doit résister aux contraintes électriques et mécaniques pouvant survenir en UTILISATION NORMALE, dans toutes les conditions d'environnement ASSIGNEES (voir 1.4) pendant la durée de vie prévue de l'appareil.

NOTE Lors du choix des matières isolantes, il convient que le fabricant prenne en compte la durée de vie prévue de l'appareil.

La conformité est vérifiée par les deux essais suivants à la fois:

a) par l'essai de tension de 6.8.3.1 pendant 5 s avec la valeur applicable de la tension d'essai du Tableau K.10, du Tableau K.11 ou du Tableau K.12 pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE. La valeur de la tension d'essai est multipliée par 1,6 pour l'ISOLATION RENFORCEE;

b) en plus, si la TENSION DE SERVICE dépasse 300 V, par l'essai de tension de 6.8.3.1 pendant 1 min. La tension d'essai vaut 1,5 fois la TENSION DE SERVICE pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE et deux fois la TENSION DE SERVICE pour l'ISOLATION RENFORCEE.

Selon le cas, l'isolation solide doit satisfaire aux exigences suivantes:

1) pour l'isolation solide utilisée en tant qu'ENVELOPPE ou BARRIERE DE PROTECTION, les exigences de l'Article 8;
2) pour les pièces moulées ou empotées, les exigences de K.2.4.2;
3) pour les couches internes des circuits imprimés, les exigences de K.2.4.3;
4) pour l'isolation en couche mince, les exigences de K.2.4.4.

La conformité est vérifiée tel que spécifié de K.2.4.2 à K.2.4.4, et à l'Article 8, selon le cas.

K.2.4.2 Pièces moulées et empotées

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches moulées doivent être séparés par la distance minimale applicable du Tableau K.14 (voir la Figure K.1, point L).

La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par examen des spécifications du fabricant.

Tableau K.14 – Valeurs minimales de la distance ou de l'épaisseur (voir K.2.4.2 à K.2.4.4)

Valeur crête de la TENSION DE SERVICE alternative ou continue ou tension de crête répétitive kV	Valeur minimale mm	Valeur crête de la TENSION DE SERVICE alternative ou continue ou tension de crête répétitive kV	Valeur minimale mm
>0,046 7 ≤ 0,33	0,05	>8 ≤ 10	3,5
>0,33 ≤ 0,8	0,1	>10 ≤ 12	4,5
>0,8 ≤ 1,0	0,15	>12 ≤ 15	5,5
>1,0 ≤ 1,2	0,2	>15 ≤ 20	8
>1,2 ≤ 1,5	0,3	>20 ≤ 25	10
>1,5 ≤ 2,0	0,45	>25 ≤ 30	12,5
>2,0 ≤ 2,5	0,6	>30 ≤ 40	17
>2,5 ≤ 3,0	0,8	>40 ≤ 50	22
>3,0 ≤ 4,0	1,2	>50 ≤ 60	27
>4,0 ≤ 5,0	1,5	>60 ≤ 80	35
>5,0 ≤ 6,0	2	>80 ≤ 100	45
>6,0 ≤ 8,0	3		

K.2.4.3 Couches isolantes internes des circuits imprimés

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches doivent être séparés par la distance minimale applicable du Tableau K.14 (voir la Figure K.2, point L).

La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par examen des spécifications du fabricant.

L'ISOLATION RENFORCEE des couches isolantes internes des circuits imprimés doit avoir une rigidité électrique suffisante entre les couches respectives. Un des moyens suivants doit être utilisé:

a) l'épaisseur de l'isolation est au moins la distance minimale applicable du Tableau K.14;

   La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

b) l'isolation est constituée par au moins deux couches séparées de matière du circuit imprimé, chacune étant spécifiée par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai du Tableau K.10, du Tableau K.11 ou du Tableau K.12 selon le cas, pour l'ISOLATION PRINCIPALE;

   La conformité est vérifiée par l'examen des spécifications du fabricant.

c) l'isolation est constituée par au moins deux couches séparées de matière du circuit imprimé, et l'assemblage des couches est ASSIGNE par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai du Tableau K.10, du Tableau K.11 ou du Tableau K.12 selon le cas, multipliée par 1,6 fois pour l'ISOLATION RENFORCEE.

   La conformité est vérifiée par l'examen des spécifications du fabricant.

K.2.4.4 Isolation en couche mince

Pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE, les conducteurs situés entre les deux mêmes couches (voir la Figure K.3, point L) doivent être séparés par au moins la DISTANCE D'ISOLEMENT et la LIGNE DE FUITE applicables des K.2.2 et K.2.3.

La conformité est vérifiée par examen et, soit par la mesure des distances, soit par examen des spécifications du fabricant.

L'ISOLATION RENFORCEE à travers les couches minces doit aussi avoir une rigidité électrique suffisante. Un des moyens suivants doit être utilisé:

a) l'épaisseur de l'isolation est au moins la distance minimale applicable du Tableau K.14;

   La conformité est vérifiée par examen et, soit par la mesure de la distance, soit par l'examen des spécifications du fabricant.

b) l'isolation est constituée par au moins deux couches séparées de matière, chacune étant spécifiée par le fabricant de la matière pour une rigidité électrique valant au moins la tension d'essai du Tableau K.10, du Tableau K.11 ou du Tableau K.12 pour l'ISOLATION PRINCIPALE;

   La conformité est vérifiée par l'examen des spécifications du fabricant.

c) l'isolation est constituée par au moins trois couches séparées de matière, chaque paire de couches ayant été testée pour la rigidité électrique adéquate.

   La conformité est vérifiée par l'essai en tension alternative de 6.8.3.1 d'une durée d'au moins 1 min ou, pour les circuits contraints uniquement en tension continue, l'essai en tension continue de 1 min de 6.8.3.2 effectué sur deux des trois couches en utilisant 1,6 fois la tension applicable du Tableau K.10, du Tableau K.11 ou du Tableau K.12.

   NOTE Pour les besoins de l'essai du point c), un échantillon peut être spécialement préparé avec seulement deux couches de matière.

K.3 Isolation des circuits autres que ceux couverts par 6.7, l'Article K.1 ou l'Article K.2

K.3.1 Généralités

Ces circuits ont une ou plusieurs des caractéristiques suivantes:

a) la SURTENSION TRANSITOIRE maximale possible est limitée par la source d'alimentation ou à l'intérieur de l'appareil (voir l'Article K.4) à une valeur connue inférieure aux valeurs supposées pour les CIRCUITS RESEAU;
b) la SURTENSION TRANSITOIRE maximale possible est supérieure aux valeurs supposées pour les CIRCUITS RESEAU;
c) la TENSION DE SERVICE est la somme des tensions de plusieurs circuits ou est une tension mixte;
d) la TENSION DE SERVICE comporte une tension de crête répétitive avec une forme d'onde périodique non sinusoïdale ou avec une forme d'onde non périodique survenant régulièrement;
e) la fréquence de la TENSION DE SERVICE est supérieure à 30 kHz.

Dans les cas a) à c), les DISTANCES D'ISOLEMENT pour une ISOLATION PRINCIPALE et pour UNE ISOLATION SUPPLEMENTAIRE sont déterminées suivant K.3.2.

Dans les cas d) et e), les DISTANCES D'ISOLEMENT sont déterminées suivant K.3.3.

Dans tous les cas, K.3.4 concerne les LIGNES DE FUITE et K.3.5 concerne l'isolation solide.

NOTE Les exigences pour l'isolation des circuits de mesure sont dans l'IEC 61010-2-030.

K.3.2 Calcul de la DISTANCE D'ISOLEMENT

Les DISTANCES D'ISOLEMENT pour une ISOLATION PRINCIPALE et pour UNE ISOLATION SUPPLEMENTAIRE sont déterminées par le calcul suivant:

$$\text{DISTANCE D'ISOLEMENT} = D_1 + F \times (D_2 - D_1)$$

où

F est un coefficient déterminé par les équations:

$F = (1{,}25 \times U_w/U_m) - 0{,}25$ si $U_w/U_m > 0{,}2$

$F = 0$ si $U_w/U_m \leq 0{,}2$

où

$U_m = U_w + U_t$;

U_w = TENSION DE SERVICE crête maximale;

U_t = SURTENSION TRANSITOIRE maximale additionnelle;

D_1 et D_2 sont les DISTANCES D'ISOLEMENT tirées du Tableau K.15 pour U_m

avec

D_1 est la DISTANCE D'ISOLEMENT qui serait applicable à une SURTENSION TRANSITOIRE ayant la forme de l'onde de choc 1,2 × 50 µs.

D_2 est la DISTANCE D'ISOLEMENT qui serait applicable à une TENSION DE SERVICE crête sans aucune SURTENSION TRANSITOIRE.

Les DISTANCES D'ISOLEMENT pour l'ISOLATION RENFORCEE sont le double des valeurs de l'ISOLATION PRINCIPALE.

Si l'altitude de fonctionnement ASSIGNEE à l'appareil est supérieure à 2 000 m, la DISTANCE D'ISOLEMENT doit être multipliée par le coefficient dérivé du Tableau K.1.

La valeur minimale de la DISTANCE D'ISOLEMENT pour l'ISOLATION PRINCIPALE, L'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE est de 0,2 mm en DEGRE DE POLLUTION 2 et de 0,8 mm en DEGRE DE POLLUTION 3.

NOTE 1 L'isolation entre l'enroulement primaire et l'enroulement secondaire d'un transformateur connecté au RESEAU subit les contraintes de la composante de tension en mode commun transférée pendant un événement transitoire provenant du côté primaire et la TENSION DE SERVICE à travers l'isolation. Cette tension en mode commun exprimée comme SURTENSION TRANSITOIRE supplémentaire avec la valeur de crête maximale de la TENSION DE SERVICE U_w forme la tension de choc maximale U_m.

Par exemple pour un CIRCUIT RESEAU avec une tension phase neutre de 230 V en valeur efficace et une tension de choc de 2 500 V_{CRETE}, la tension en mode commun (SURTENSION TRANSITOIRE supplémentaire) est calculée comme suit:

U_w = 1,414 × 230 V valeur efficace = 325 V_{CRETE}

U_t = 2 500 V_{CRETE} – 325 V_{CRETE} = 2 175 V_{CRETE}

La conformité est vérifiée par examen et mesure, ou par l'essai en tension alternative de 6.8.3.1 d'une durée d'au moins 5 s, ou par l'essai de tension de choc de 6.8.3.3 en utilisant la tension applicable du Tableau K.16 pour la DISTANCE D'ISOLEMENT exigée.

Tableau K.15 – Valeurs de la DISTANCE D'ISOLEMENT pour le calcul de K.3.2

Tension maximale	DISTANCE D'ISOLEMENT		Tension maximale	DISTANCE D'ISOLEMENT	
U_m	D_1	D_2	U_m	D_1	D_2
V	mm	mm	V	mm	mm
14,1 à 266	0,010	0,010	4 000	2,93	6,05
283	0,010	0,013	4 530	3,53	7,29
330	0,010	0,020	5 660	4,92	10,1
354	0,013	0,025	6 000	5,37	10,8
453	0,027	0,052	7 070	6,86	13,1
500	0,036	0,071	8 000	8,25	15,2
566	0,052	0,10	8 910	9,69	17,2
707	0,081	0,20	11 300	12,9	22,8
800	0,099	0,29	14 100	16,7	29,5
891	0,12	0,41	17 700	21,8	38,5
1 130	0,19	0,83	22 600	29,0	51,2
1 410	0,38	1,27	28 300	37,8	66,7
1 500	0,45	1,40	35 400	49,1	86,7
1 770	0,75	1,79	45 300	65,5	116
2 260	1,25	2,58	56 600	85,0	150
2 500	1,45	3,00	70 700	110	195
2 830	1,74	3,61	89 100	145	255
3 540	2,44	5,04	100 000	165	290
L'interpolation linéaire est permise.					

Tableau K.16 – Tensions d'essai en fonction des DISTANCES D'ISOLEMENT

DISTANCE D'ISOLEMENT exigée	Tension d'essai	
	Essai de tension de choc	Essai de 5 s en tension alternative
mm	$V_{crête}$	V_{eff}
0,010	330	230
0,025	440	310
0,040	520	370
0,063	600	420
0,1	810	500
0,2	1 150	620
0,3	1 310	710
0,5	1 550	840
1,0	1 950	1 060
1,5	2 560	1 390
2,0	3 090	1 680
2,5	3 600	1 960
3,0	4 070	2 210
4,0	4 930	2 680
4,5	5 330	2 900
5,0	5 720	3 110
6,0	6 460	3 510
8,0	7 840	4 260
10,0	9 100	4 950
12,0	10 600	5 780
15,0	12 900	7 000
20	16 400	8 980
25	19 900	10 800
30	23 300	12 700
40	29 800	16 200
50	36 000	19 600
60	42 000	22 800
80	53 700	29 200
100	65 000	35 400
L'interpolation linéaire est permise.		

NOTE 2 Deux exemples de calculs sont proposés:

EXEMPLE 1:

DISTANCE D'ISOLEMENT pour une ISOLATION RENFORCEE avec une TENSION DE SERVICE de 3 500 V de crête et une SURTENSION TRANSITOIRE additionnelle de 4 500 V (cela peut être réalisé par un circuit de commutation électronique):

Tension maximale U_m $U_m = U_w + U_t$ = (3 500 + 4 500) V = 8 000 V

U_w/U_m = 3 500/8 000 = 0,44 > 0,2

donc $F = (1{,}25 \times U_w/U_m) - 0{,}25 = (1{,}25 \times 3\,500/8\,000) - 0{,}25 = 0{,}297$

Suivant les valeurs obtenues du Tableau K.15 à 8 000 V:

D_1 = 8,25 mm, D_2 = 15,2 mm

DISTANCE D'ISOLEMENT = $D_1 + F \times (D_2 - D_1)$ = 8,25 + 0,297 × (15,2 – 8,25) = 8,25 + 2,05 = 10,3 mm

Pour l'ISOLATION RENFORCEE, la valeur est doublée. DISTANCE D'ISOLEMENT = 20,6 mm

EXEMPLE 2:

DISTANCE D'ISOLEMENT pour l'ISOLATION PRINCIPALE d'un circuit piloté par un transformateur RESEAU branché sur le RESEAU 230 V en CATEGORIE DE SURTENSION II. Le circuit comprend un limiteur de surtensions (voir 14.8 et K.3.4) qui limite la tension maximale dans le circuit, y compris les transitoires à 1 000 V.

La valeur crête de la tension U_w est de 150 V.

La valeur maximale de la tension U_m est donc de 1 000 V.

U_m = 1 000 V

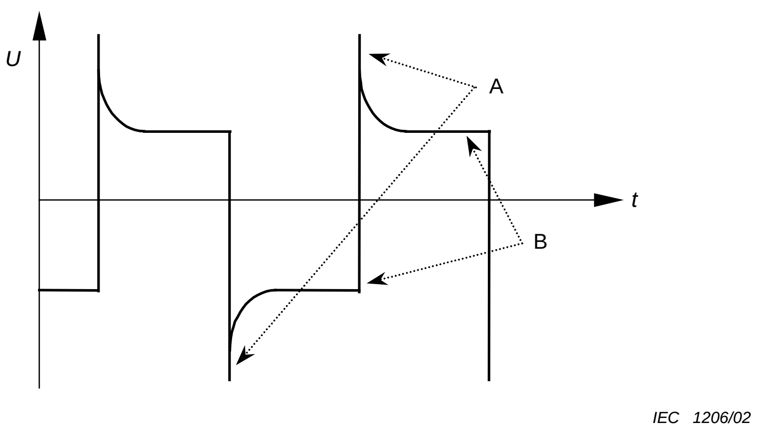
U_w/U_m = 150/1 000 = 0,15 < 0,2, donc F = 0

La DISTANCE D'ISOLEMENT interpolée du Tableau K.15 est égale à D_1 = 0,15 mm

La DISTANCE D'ISOLEMENT est alors corrigée pour l'altitude de fonctionnement et vérifiée pour les valeurs minimales des DISTANCES D'ISOLEMENT suivant le DEGRE DE POLLUTION.

K.3.3 DISTANCES D'ISOLEMENT dans les circuits ayant des tensions de crête répétitives ou dont la fréquence de la TENSION DE SERVICE est supérieure à 30 kHz

Les DISTANCES D'ISOLEMENT pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE des circuits ayant des tensions de crête répétitives de fréquence ne dépassant pas 30 kHz doivent être dimensionnées en utilisant les valeurs de la deuxième colonne du Tableau K.17 pour la tension de crête répétitive correspondante (voir aussi un exemple de tension de crête répétitive donné à la Figure K.4).



Légende

A: Valeur de la tension de crête répétitive

B: Valeur de la TENSION DE SERVICE

Figure K.4 – Exemple de tension de crête répétitive

Les DISTANCES D'ISOLEMENT pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE des circuits soumis à des tensions de fréquence supérieure à 30 kHz doivent être dimensionnées en utilisant les valeurs de la troisième colonne du Tableau K.17 pour la TENSION DE SERVICE crête correspondante.

Les DISTANCES D'ISOLEMENT pour l'ISOLATION PRINCIPALE et l'ISOLATION SUPPLEMENTAIRE des circuits soumis à des tensions de crête répétitives et de fréquence supérieure à 30 kHz doivent être dimensionnées en utilisant la valeur la plus élevée de ces deux exigences.

Les DISTANCES D'ISOLEMENT pour l'ISOLATION RENFORCEE sont le double des valeurs de l'ISOLATION PRINCIPALE.

Si l'altitude de fonctionnement ASSIGNEE à l'appareil est supérieure à 2 000 m, les DISTANCES D'ISOLEMENTS sont multipliées par le coefficient applicable du Tableau K.1.

La valeur minimale de la DISTANCE D'ISOLEMENT pour l'ISOLATION PRINCIPALE, l'ISOLATION SUPPLEMENTAIRE et l'ISOLATION RENFORCEE est de 0,2 mm en DEGRE DE POLLUTION 2 et de 0,8 mm en DEGRE DE POLLUTION 3.

La conformité est vérifiée par examen et mesure.

Tableau K.17 – DISTANCES D'ISOLEMENT des circuits ayant des tensions de crête répétitives ou dont la fréquence de la TENSION DE SERVICE est supérieure à 30 kHz

Tension crête	DISTANCES D'ISOLEMENT	
	Fréquences jusqu'à 30 kHz	Fréquences au-delà de 30 kHz
V	mm	mm
0 à 330	0,01	0,02
400	0,02	0,04
500	0,04	0,07
600	0,06	0,11
800	0,13	0,26
1 000	0,26	0,48
1 200	0,42	0,76
1 500	0,76	1,1
2 000	1,27	1,8
2 500	1,8	2,6
3 000	2,4	3,5
4 000	3,8	5,7
5 000	5,7	8
6 000	7,9	10
8 000	11	15
10 000	15,2	20
12 000	19	25
15 000	25	32
20 000	34	44
25 000	44	58
30 000	55	72
40 000	77	100
50 000	100	
L'interpolation linéaire est permise.		

K.3.4 LIGNES DE FUITE

Les exigences de K.2.3 s'appliquent.

La conformité est vérifiée comme spécifiée en K.2.3.

K.3.5 Isolation solide

Les exigences de K.2.4 s'appliquent excepté pour K.2.4.1 a), K.2.4.3 b) et c) et K.2.4.4 b) et c) où les valeurs de la tension d'essai du Tableau K.16 sont utilisée à la place des valeurs applicables du Tableau K.10, du Tableau K.11 ou du Tableau K.12.

Pour connaître la tension d'essai exigée du Tableau K.16, la méthode suivante doit être utilisée:

a) Calcul de la DISTANCE D'ISOLEMENT théoriquement nécessaire en fonction de K.3.2 en tenant compte des exigences du K.3.3. La valeur minimale de la DISTANCE D'ISOLEMENT pour les DEGRES DE POLLUTION 2 et 3 ne s'appliquent pas.

b) La tension d'essai est déduite du Tableau K.16 pour la valeur calculée de la DISTANCE D'ISOLEMENT théorique.

La conformité est vérifiée comme spécifiée en K.2.4 avec la tension d'essai déduite ci-dessus à la place de la tension d'essai du Tableau K.10, du Tableau K.11 ou du Tableau K.12.

K.4 Réduction des SURTENSIONS TRANSITOIRES par l'utilisation de limiteurs de surtensions

Les SURTENSIONS TRANSITOIRES dans un circuit peuvent être limitées par des circuits ou des composants. Les composants adaptés à cet usage sont notamment les varistances et les éclateurs à gaz.

Si le limiteur de surtensions ou le circuit est prévu pour réduire les SURTENSIONS TRANSITOIRES de sorte que le circuit en aval peut avoir des DISTANCES D'ISOLEMENT réduites, une appréciation du RISQUE (voir l'Article 17) doit être réalisée, en prenant en compte les deux aspects suivants:

a) le circuit doit réduire les SURTENSIONS TRANSITOIRES au niveau inférieur, y compris en CONDITIONS DE PREMIER DEFAUT;

b) le circuit doit fonctionner comme prévu, même après avoir subi des SURTENSIONS TRANSITOIRES répétées.

La conformité est vérifiée par la revue de la documentation sur l'appréciation du RISQUE pour s'assurer que les RISQUES ont été éliminés ou qu'il ne reste seulement que des RISQUES TOLERABLES.

Annexe L
(informative)

Index des termes définis

Terme **Définition**

Bibliographie

IEC 60050 (toutes les parties), *Vocabulaire Electrotechnique International*

IEC 60050-151, *Vocabulaire Electrotechnique International – Partie 151: Dispositifs électriques et magnétiques*

IEC 60050-195, *Vocabulaire Electrotechnique International – Partie 195: Mise à la terre et protection contre les chocs électriques*

IEC 60050-604, *Vocabulaire Electrotechnique International – Chapitre 604: Production, transport et distribution de l'énergie électrieque – Exploitation*

IEC 60050-826, *Vocabulaire Electrotechnique International – Partie 826: Installation électriques*

IEC 60079 (toutes les parties), *Atmosphères explosives*

IEC 60085, *Isolation électrique – Evaluation et désignation thermiques*

IEC 60112:1979, *Méthode pour déterminer les indices de résistance et de tenue au cheminement des matériaux isolants solides dans des conditions humides*

IEC 60127 (toutes les parties), *Coupe-circuit miniatures*

IEC 60204 (toutes les parties), *Sécurité des machines – Equipement électrique des machines*

IEC 60332-1 (toutes les parties), *Essais des câbles électriques et à fibres optiques soumis au feu*

IEC 60332-2 (toutes les parties), *Essais des câbles électriques et à fibres optiques soumis au feu*

IEC 60335 (toutes les parties), *Appareils électrodomestiques et analogues – Sécurité*

IEC 60364 (toutes les parties), *Installations électriques à basse tension*

IEC 60439 (toutes les parties), *Ensembles d'appareillage à basse tension*

IEC 60439-1:1999, *Ensembles d'appareillage à basse tension – Partie 1: Ensembles de série et ensembles dérivés de série*

IEC 60445:1999, *Principes fondamentaux et de sécurité pour les interfaces homme-machines, le marquage et l'identification – Identification des bornes de matériels et des extrémités de certains conducteurs désignés et règles générales pour un système alphanumérique*

IEC 60447:1993, *Interface homme-machine (IHM) – Principes de manœuvre*

IEC 60601 (toutes les parties), *Appareils électromédicaux*

IEC 60664-1, *Coordination de l'isolement des matériels dans les systèmes (réseaux) à basse tension – Partie 1: Principes, exigences et essais*

IEC 60695-10-2, *Essais relatifs aux risques du feu – Partie 10-2: Chaleurs anormales – Essai à la bille*

IEC 60950, *Matériels de traitement de l'information – Sécurité*

IEC 60950-1, *Matériels de traitement de l'information – Sécurité – Partie 1: Exigences générales*

IEC 60990, *Méthodes de mesure du courant de contact et du courant dans le conducteur de protection*

IEC 61010-2-030, *Règles de sécurité pour appareils électriques de mesurage, de régulation et de laboratoire – Partie 2-030: Exigences particulières pour les circuits de test et de mesure*

IEC 61032, *Protection des personnes et des matériels par les enveloppes – Calibres d'essai pour la vérification*

IEC 61243-3, *Travaux sous tension – Détecteurs de tension – Partie 3: Type bipolaire basse tension*

IEC 61326 (toutes les parties), *Matériel électrique de mesure, de commande et de laboratoire – Exigences relatives à la CEM*

IEC 61508 (toutes les parties), *Sécurité fonctionnelle des systèmes électriques/électroniques/ électroniques programmables relatifs à la sécurité*

IEC 61558 (toutes les parties), *Sécurité des transformateurs, bobines d'inductance, blocs d'alimentation et produits analogues pour des tensions d'alimentation jusqu'à 1 100 V*

IEC 62366, *Dispositifs médicaux – Application de l'ingénierie de l'aptitude à l'utilisation aux dispositifs médicaux*

ISO 9241 (toutes les parties), *Ergonomie de l'interaction homme-système*

ISO 13732-1, *Ergonomie des ambiances thermiques – Méthodes d'évaluation de la réponse humaine au contact avec des surfaces – Partie 1: Surfaces chaudes*

~~ISO 13852, *Sécurité des machines – Distances de sécurité pour empêcher l'atteinte des zones dangereuses par les membres supérieurs*~~

ISO 13854, *Sécurité des machines – Ecartements minimaux pour prévenir les risques d'écrasement de parties du corps humain*

ISO 14121-1, *Sécurité des machines – Appréciation du risque – Partie 1: Principes*

ISO 14738, *Sécurité des machines – Prescriptions anthropométriques relatives à la conception des postes de travail sur les machines*

ISO 14971, *Dispositifs médicaux – Application de la gestion des risques aux dispositifs médicaux*

ISO/IEC Guide 117, *Electrotechnical equipment – Temperatures of touchable hot surfaces* (disponible en anglais seulement)

ANSI B11.TR3, *Risk Assessment and Risk Reduction – A Guide to Estimate, Evaluate and Reduce Risks Associated with Machine Tools*

ANSI/UL 94, *Standard for safety of flammability of plastic materials for parts in devices and appliances testing*

ANSI/UL 248-14, *Low-Voltage Fuses – Part 14: Supplemental Fuses*

ANSI/UL 471, *Standard for Commercial Refrigerators and Freezers*

ANSI/UL 746E, *Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used In Printed-Wiring Boards*

ANSI/UL 2556, *Wire and Cable Test Methods*

~~EN 294, *Safety of machinery. Safety distances to prevent danger zones being reached by the upper limbs*~~

EN 349, *Safety of machinery. Minimum gaps to avoid crushing of parts of the human body*

~~EN 563, *Safety of machinery – Temperatures of touchable surfaces – Ergonomics data to establish temperature limit values for hot surfaces*~~

EN 894-2, *Safety of machinery. Ergonomics requirements for the design of displays and control actuators. Displays*

EN 894-3, *Safety of machinery. Ergonomics requirements for the design of displays and control actuators. Control actuators*

SEMI S8, *Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment*

SEMI S10, *Safety guideline for risk assessment*

UL 1439, *Standard for Tests for Sharpness of Edges on Equipment*

Directive équipement sous pression (2014/68/UE)

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FINAL VERSION

VERSION FINALE

colour inside

Safety requirements for electrical equipment for measurement, control, and laboratory use –
Part 1: General requirements

Règles de sécurité pour appareils électriques de mesurage, de régulation et de laboratoire –
Partie 1: Exigences générales

IEC 61010-1:2010-06+AMD1:2016-12 CSV(en-fr)

TC 66/Publication 61010-1 (2010), Third edition/I-SH 01

SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR MEASUREMENT, CONTROL, AND LABORATORY USE –

Part 1: General requirements

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by IEC technical committee 66: Safety of measuring, control and laboratory equipment.

The text of this interpretation sheet is based on the following documents:

ISH	Report on voting
66/497A/ISH	66/505/RVD

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

IEC 61010-1:2010 contains a requirement in 6.8.3.1 pertaining to voltage testers for type tests as follows:

“The generator shall be able to supply a power of at least 500 VA.”

This has given rise to the following questions:

How does one interpret the requirement for voltage testers in 6.8.3.1 of IEC 61010-1:2010? Specifically, this subclause requires that “The generator shall be able to supply a power of at least 500 VA.” Does this requirement apply throughout the rated output range of the voltage tester? What is meant by the word “generator”? Is the “generator” the power supply within the voltage tester, or the voltage tester output, or something else?

Interpretation:

“A voltage tester used for type tests must be able to deliver at least 500 VA at its full-rated output voltage. It does not necessarily need to deliver 500 VA if set for lower voltages.

For example, a voltage tester that can deliver 100 mA at any test output voltage up to 5 000 V (and a current corresponding to 500 VA above 5 000 V) would meet the requirement.

The requirements for voltage testers used for routine (production line) tests are included in Annex F. The requirements of 6.8.3.1 do not apply to these voltage testers.”

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR MEASUREMENT, CONTROL, AND LABORATORY USE –

Part 1: General requirements

FOREWORD

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This Consolidated version of IEC 61010-1 bears the edition number 3.1. It consists of the third edition (2010-06) [documents 66/414/FDIS and 66/423/RVD], its corrigenda 1 (2011-05) and 2 (2013-10) and its interpretation sheet (2013-02), and its amendment 1 (2016-12) [documents 66/612/FDIS and 66/620/RVD]. The technical content is identical to the base edition and its amendment.

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

International Standard IEC 61010-1 has been prepared by IEC technical committee 66: Safety of measuring, control and laboratory equipment.

It has the status of a group safety publication, as specified in IEC Guide 104.

This edition includes the following significant changes from the second edition, as well as numerous other changes.

- The scope of the standard has been expanded to include all locations where these products may be used, so that both professional and non-professional versions of these products are within the scope.
- The requirements for testing and measuring circuits (in various subclauses and the entirety of Clause 16) have been removed and included in a particular standard IEC 61010-2-030.
- Insulation requirements (6.7) have been completely rewritten.
  - Specific requirements have been added for solid insulation and thin-film insulation.
  - Subclause 6.7 now contains only the insulation requirements for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V, and for secondary circuits.
  - The insulation requirements for all other circuits have been moved to a new Annex K.
- Additional requirements for protection against mechanical HAZARDS (Clause 7) have been included.
- Surface temperature limits (Clause 10) have been modified to conform to the limits of EN 563.
- Radiation requirements (Clause 12) have been modified, and take into account a distinction between intended emission and unintended emission.
- Requirements for reasonably foreseeable misuse and ergonomic aspects have been added (Clause 16).
- A new clause (Clause 17) has been added to deal with HAZARDS and environments not covered by the standard, along with a new informative annex (Annex J) dealing with RISK assessment.
- A new informative annex (Annex E) addresses methods of reducing the POLLUTION DEGREE of a micro-environment.
- Requirements for the qualification of coatings for protection against POLLUTION have been added (Annex H).
- A new informative annex (Annex I) has been added to further explain how to determine the WORKING VOLTAGE of a MAINS CIRCUIT.

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

A list of all parts of the IEC 61010 series, under the general title: *Safety requirements for electrical equipment for measurement, control, and laboratory use*, may be found on the IEC website.

In this standard, the following print types are used:

– requirements and definitions: in roman type;
– NOTES: in smaller roman type;
– *conformity and tests: in italic type;*
– terms used throughout this standard which have been defined in Clause 3: SMALL ROMAN CAPITALS.

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

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

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

INTRODUCTION

This International Standard specifies the safety requirements that are generally applicable to all equipment within its scope. For certain types of equipment, these requirements will be supplemented or modified by the special requirements of one, or more than one, particular part 2 of the standard which must be read in conjunction with the part 1 requirements.

SAFETY REQUIREMENTS FOR ELECTRICAL EQUIPMENT FOR MEASUREMENT, CONTROL, AND LABORATORY USE –

Part 1: General requirements

1 Scope and object

1.1 Scope

1.1.1 Equipment included in scope

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

This part of IEC 61010 specifies general safety requirements for the following types of electrical equipment and their accessories, wherever they are intended to be used.

a) Electrical test and measurement equipment

This is equipment which by electromagnetic means tests, measures, indicates or records one or more electrical or physical quantities, also non-measuring equipment such as signal generators, measurement standards, power supplies for laboratory use, transducers, transmitters, etc.

NOTE 1 This includes bench-top power supplies intended to aid a testing or measuring operation on another piece of equipment. Power supplies intended to power equipment are within the scope of IEC 61558 (see 1.1.2 h)).

This standard also applies to test equipment integrated into manufacturing processes and intended for testing manufactured devices.

NOTE 2 Manufacturing test equipment is likely to be installed adjacent to and interconnected with industrial machinery in this application.

b) Electrical industrial process-control equipment

This is equipment which controls one or more output quantities to specific values, with each value determined by manual setting, by local or remote programming, or by one or more input variables.

c) Electrical laboratory equipment

This is equipment which measures, indicates, monitors, inspects or analyses materials, or is used to prepare materials, and includes in vitro diagnostic (IVD) equipment.

This equipment may also be used in areas other than laboratories; examples include self-test IVD equipment to be used in the home and inspection equipment to be used to check people or material during transportation.

1.1.2 Equipment excluded from scope

This standard does not apply to equipment within the scope of:

a) IEC 60065 (Audio, video and similar electronic apparatus);

b) IEC 60204 (Safety of machinery – Electrical equipment of machines);

c) IEC 60335 (Household and similar electrical appliances);

d) IEC 60364 (Electrical installations of buildings);

e) IEC 60439 (Low-voltage switchgear and controlgear assemblies);

f) IEC 60601 (Medical electrical equipment);

g) IEC 60950 (Information technology equipment including electrical business equipment, except as specified in 1.1.3);

h) IEC 61558 (Power transformers, power supply units and similar);

i) IEC 61010-031 (Hand-held probe assemblies);

j) IEC 61243-3 (Live working – Voltage detectors – Part 3: Two-pole low-voltage type).

1.1.3 Computing equipment

This standard applies only to computers, processors, etc. which form part of equipment within the scope of this standard or are designed for use exclusively with the equipment.

NOTE Computing devices and similar equipment within the scope of IEC 60950 and conforming to its requirements are considered to be suitable for use with equipment within the scope of this standard. However, some of the requirements of IEC 60950 for resistance to moisture and liquids are less stringent than those in this standard (see 5.4.4 second paragraph)).

1.2 Object

1.2.1 Aspects included in scope

The purpose of the requirements of this standard is to ensure that HAZARDS to the OPERATOR and the surrounding area are reduced to a tolerable level.

Requirements for protection against particular types of HAZARD are given in Clauses 6 to 13, as follows:

a) electric shock or burn (see Clause 6);

b) mechanical HAZARDS (see Clauses 7 and 8);

c) spread of fire from the equipment (see Clause 9);

d) excessive temperature (see Clause 10);

e) effects of fluids and fluid pressure (see Clause 11);

f) effects of radiation, including lasers sources, and sonic and ultrasonic pressure (see Clause 12);

g) liberated gases, explosion and implosion (see Clause 13).

Requirements for protection against HAZARDS arising from REASONABLY FORESEEABLE MISUSE and ergonomic factors are specified in Clause 16.

RISK assessment for HAZARDS or environments not fully covered above is specified in Clause 17.

NOTE Attention is drawn to the existence of additional requirements regarding the health and safety of labour forces.

1.2.2 Aspects excluded from scope

This standard does not cover:

a) reliable function, performance, or other properties of the equipment not related to safety;

b) effectiveness of transport packaging;

c) EMC requirements (see the IEC 61326 series);

d) protective measures for explosive atmospheres (see the IEC 60079 series).

1.3 Verification

This standard also specifies methods of verifying that the equipment meets the requirements of this standard, through inspection, TYPE TESTS, ROUTINE TESTS, and RISK assessment.

1.4 Environmental conditions

1.4.1 Normal environmental conditions

This standard applies to equipment designed to be safe at least under the following conditions:

a) indoor use;

b) altitude up to 2 000 m;

c) temperature 5 °C to 40 °C;

d) maximum relative humidity 80 % for temperatures up to 31 °C decreasing linearly to 50 % relative humidity at 40 °C;

e) MAINS supply voltage fluctuations up to ±10 % of the nominal voltage;

f) TRANSIENT OVERVOLTAGES up to the levels of OVERVOLTAGE CATEGORY II;

NOTE 1 These levels of transient overvoltage are typical for equipment supplied from the building wiring.

g) TEMPORARY OVERVOLTAGES occurring on the MAINS supply.

h) applicable POLLUTION DEGREE of the intended environment (POLLUTION DEGREE 2 in most cases).

NOTE 2 Manufacturers may specify more restricted environmental conditions for operation; nevertheless the equipment must be safe within these normal environmental conditions.

1.4.2 Extended environmental conditions

This standard applies to equipment designed to be safe not only in the environmental conditions specified in 1.4.1, but also in any of the following conditions as RATED by the manufacturer of the equipment:

a) outdoor use;

b) altitude above 2 000 m;

c) ambient temperatures below 5 °C or above 40 °C;

d) relative humidity above the levels specified in 1.4.1;

e) MAINS supply voltage fluctuations exceeding ±10 % of the nominal voltage;

f) WET LOCATION;

g) TRANSIENT OVERVOLTAGES up to the levels of OVERVOLTAGE CATEGORY III or IV (see Annex K).

2 Normative references

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

IEC 60027 (all parts), *Letter symbols to be used in electrical technology*

IEC 60065, *Audio, video and similar electronic apparatus – Safety requirements*

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

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

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

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

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

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

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

IEC 60332-1-2, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*

IEC 60332-2-2, *Tests on electric and optical fibre cables under fire conditions – Part 2-2: Test for vertical flame propagation for a single small insulated wire or cable – Procedure for diffustion flame*

IEC 60335-2-24, *Household and similar electrical appliances – Safety – Part 2-24: Particular requirements for refrigerating appliances, ice-cream appliances and ice-makers.*

IEC 60335-2-89, *Household and similar electrical appliances – Safety – Part 2-89: Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor*

IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*
IEC 60364-4-44:2007/AMD1:2015

IEC 60417, *Graphical symbols for use on equipment*

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

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

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

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

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

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

IEC 60947-2, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

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

IEC 61010-031, *Safety requirements for electrical equipment for measurement, control and laboratory use – Part 031: Safety requirements for hand-held probe assemblies for electrical measurement and test*

IEC 61180 (all parts), *High-voltage test techniques for low-voltage equipment*

IEC 61180-1, *High-voltage test techniques for low-voltage equipment – Part 1: Definitions, test and procedure requirements*

IEC 61180-2, *High-voltage test techniques for low-voltage equipment – Part 2: Test equipment*

IEC 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

IEC 61672-2, *Electroacoustics – Sound level meters – Part 2: Pattern evaluation tests*

IEC 62262, *Degrees of protection provided by enclosures for electrical equipment against external impacts (IK code)*

IEC 62471, *Photobiological safety of lamps and lamp systems*

IEC TR 62471-2*, Photobiological safety of lamps and lamp systems – Part 2: Guidance on manufacturing requirements relating to non-laser optical radiation safety*

IEC 62598, *Nuclear instrumentation – Constructional requirements and classification of radiometric gauges*

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

ISO/IEC Guide 51, *Safety aspects – Guidelines for their inclusion in standards*

ISO 306:2013, *Plastics – Thermoplastic materials – Determination of Vicat softening temperature (VST)*

ISO 361, *Basic ionizing radiation symbol*

ISO 3746, *Acoustics – Determination of sound power levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane*

ISO 7000, *Graphical symbols for use on equipment*

ISO 9614-1, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 1: Measurement at discrete points*

ISO 13857, *Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs*

EN 378-2, *Refrigerating systems and heat pumps – Safety and environmental requirements. Design, construction, testing, marking and documentation*

3 Terms and definitions

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

3.1 Equipment and states of equipment

3.1.1

FIXED EQUIPMENT

equipment fastened to a support, or otherwise secured in a specific location

[IEC 60050-826:2004, 826-16-07, modified]

3.1.2

PERMANENTLY CONNECTED EQUIPMENT

equipment that is electrically connected to a supply by means of a permanent connection which can be detached only by the use of a TOOL

3.1.3

PORTABLE EQUIPMENT

equipment intended to be carried by hand

3.1.4

HAND-HELD EQUIPMENT

PORTABLE EQUIPMENT intended to be supported by one hand during NORMAL USE

3.1.5

TOOL

external device, including keys and coins, used to aid a person to perform a mechanical function

3.1.6

DIRECT PLUG-IN EQUIPMENT

equipment with a MAINS plug that is attached to the equipment housing without the use of a MAINS supply cord so that the equipment is supported by the MAINS socket-outlet

3.2 Parts and accessories

3.2.1

TERMINAL

component provided for the connection of a device to external conductors

[IEC 60050-151:2001, 151-12-12, modified]

NOTE TERMINALS can contain one or several contacts and the term therefore includes sockets, connectors, etc.

3.2.2

FUNCTIONAL EARTH TERMINAL

TERMINAL by which electrical connection is made directly to a point of a measuring or control circuit or to a screening part and which is intended to be earthed for any functional purpose other than safety

NOTE For measuring equipment, this TERMINAL is often called the measuring earth TERMINAL.

3.2.3

PROTECTIVE CONDUCTOR TERMINAL

TERMINAL which is bonded to conductive parts of equipment for safety purposes and is intended to be connected to an external protective earthing system

3.2.4
ENCLOSURE
part providing protection of equipment against certain external influences and, in any direction, protection against direct contact

NOTE ENCLOSURES may also provide protection against the spread of fire (see 9.3.2 c)).

3.2.5
PROTECTIVE BARRIER
part providing protection against direct contact from any usual direction of access

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

NOTE Depending on its construction, a PROTECTIVE BARRIER can be called a casing, cover, screen, door, guard, etc.

A PROTECTIVE BARRIER can act alone; it is then only effective when it is in place. A PROTECTIVE BARRIER can also act in conjunction with an interlocking device with or without guard locking; in this case, protection is ensured whatever the position of the PROTECTIVE BARRIER.

3.3 Quantities

3.3.1
RATED (value)
quantity value assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment

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

3.3.2
RATING
set of RATED values and operating conditions

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

3.3.3
WORKING VOLTAGE
highest r.m.s. value of the a.c. or d.c. voltage across any particular insulation which can occur when the equipment is supplied at RATED voltage

NOTE 1 Transients and voltage fluctuations are not considered to be part of the WORKING VOLTAGE.

NOTE 2 Both open-circuit conditions and normal operating conditions are taken into account.

3.4 Tests

3.4.1
TYPE TEST
test of one or more samples of equipment (or parts of equipment) made to a particular design, to show that the design and construction meet one or more requirements of this standard

NOTE This is an amplification of the IEC 60050-151:2001, 151-16-16 definition to cover design as well as construction.

3.4.2
ROUTINE TEST
conformity test made on each individual item during or after manufacture

[IEC 60050-151:2001, 151-16-17]

3.5 Safety terms

3.5.1
ACCESSIBLE (of a part)
able to be touched with a standard test finger or test pin, when used as specified in 6.2

3.5.2
HAZARD
potential source of harm

3.5.3
HAZARDOUS LIVE
capable of rendering an electric shock or electric burn

3.5.4
MAINS
low-voltage electricity supply system to which the equipment concerned is designed to be connected for the purpose of powering the equipment

3.5.5
MAINS CIRCUIT
circuit which is intended to be directly connected to the MAINS for the purpose of powering the equipment

3.5.6
PROTECTIVE IMPEDANCE
component or assembly of components whose impedance, construction and reliability are suitable to provide protection against electric shock

3.5.7
PROTECTIVE BONDING
electrical connection of ACCESSIBLE conductive parts or protective screening to provide electrical continuity to the means for connection of an external protective conductor

3.5.8
NORMAL USE
operation, including stand-by, according to the instructions for use or for the obvious intended purpose

3.5.9
NORMAL CONDITION
condition in which all means for protection against HAZARDS are intact

3.5.10
SINGLE FAULT CONDITION
condition in which one means for protection against HAZARD is defective or one fault is present which could cause a HAZARD

NOTE If a SINGLE FAULT CONDITION results unavoidably in one or more other fault conditions, all the failures are considered as one SINGLE FAULT CONDITION [IEC Guide 104].

3.5.11
OPERATOR
person operating equipment for its intended purpose

3.5.12
RESPONSIBLE BODY
individual or group responsible for the safe use and maintenance of equipment

3.5.13
WET LOCATION
location where water or another conductive liquid may be present and is likely to cause reduced human body impedance due to wetting of the contact between the human body and the equipment, or wetting of the contact between the human body and the environment

3.5.14
REASONABLY FORESEEABLE MISUSE
use of a product in a way not intended by the supplier, but which may result from readily predictable human behaviour

3.5.15
RISK
combination of the probability of occurrence of harm and the severity of that harm

3.5.16
TOLERABLE RISK
RISK which is accepted in a given context based on the current values of society

[ISO/IEC Guide 51:1999, 3.7]

3.5.17
OVERVOLTAGE CATEGORY
numeral defining a TRANSIENT OVERVOLTAGE condition (see Annex K)

3.5.18
TRANSIENT OVERVOLTAGE
short duration overvoltage of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped

[IEC 60050-604, Amendment 1:1998, 604-03-13]

3.5.19
TEMPORARY OVERVOLTAGE
power frequency overvoltage of relatively long duration

[IEC 60050-604, Amendment 1:1998, 604-03-12]

3.6 Insulation

3.6.1
BASIC INSULATION
insulation of HAZARDOUS LIVE parts which provides basic protection

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

NOTE BASIC INSULATION may serve also for functional purposes.

3.6.2
SUPPLEMENTARY INSULATION
independent insulation applied in addition to BASIC INSULATION in order to provide protection against electric shock in the event of a failure of BASIC INSULATION

[IEC 60050-195:1998, 195-06-07, modified]

3.6.3
DOUBLE INSULATION
insulation comprising both BASIC INSULATION and SUPPLEMENTARY INSULATION

[IEC 60050-195:1998, 195-06-08]

3.6.4
REINFORCED INSULATION
insulation which provides protection against electric shock not less than that provided by DOUBLE INSULATION

NOTE REINFORCED INSULATION may be composed of several layers which cannot be tested singly as SUPPLEMENTARY INSULATION or BASIC INSULATION.

[IEC 60050-195:1998, 195-06-09, modified]

3.6.5
POLLUTION
addition of foreign matter, solid, liquid or gaseous (ionized gases), that may produce a reduction of dielectric strength or surface resistivity

3.6.6
POLLUTION DEGREE
numeral indicating the level of POLLUTION that may be present in the environment

3.6.7
POLLUTION DEGREE 1
no POLLUTION or only dry, non-conductive POLLUTION occurs, which has no influence

3.6.8
POLLUTION DEGREE 2
only non-conductive POLLUTION occurs except that occasionally a temporary conductivity caused by condensation is expected

3.6.9
POLLUTION DEGREE 3
conductive POLLUTION occurs, or dry, non-conductive POLLUTION occurs which becomes conductive due to condensation which is expected

NOTE In such conditions, equipment is normally protected against exposure to direct sunlight, precipitation, and full wind pressure, but neither temperature nor humidity is controlled.

3.6.10
POLLUTION DEGREE 4
continuous conductivity occurs due to conductive dust, rain or other wet conditions

3.6.11
CLEARANCE
shortest distance in air between two conductive parts

3.6.12
CREEPAGE DISTANCE
shortest distance along the surface of a solid insulating material between two conductive parts

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

4 Tests

4.1 General

Tests in this standard are TYPE TESTS to be carried out on samples of equipment or parts. Their only purpose is to check that the design and construction ensure conformity with this standard. In addition, manufacturers shall perform the ROUTINE TESTS of Annex F on 100 % of equipment produced which has both HAZARDOUS LIVE parts and ACCESSIBLE conductive parts.

The equipment shall at least meet the requirements of this standard. It is permissible to exceed the requirements. If, in this standard, a lower limit is specified for a conformity value, then the equipment may demonstrate a larger value. If an upper limit is specified for a conformity value, the equipment may demonstrate a lower value.

Tests on subassemblies that meet the requirements of the relevant standards specified in this standard, and used in accordance with them, need not be repeated during TYPE TESTS of the whole equipment.

Conformity with the requirements of this standard is checked by carrying out all applicable tests, except that a test may be omitted if examination of the equipment and design documentation demonstrates conclusively that the equipment would pass the test. Tests are carried out both under reference test conditions (see 4.3) and under fault conditions (see 4.4).

Where conformity statements in this standard require inspection, this may include examination of the equipment by measurement, examination of the markings on the equipment, examination of the instructions supplied with the equipment, examination of the data sheets of the materials or components from which the equipment is manufactured, etc. In each case, the inspection will either demonstrate that the equipment meets the applicable requirements, or will indicate that further testing is required.

Tests needed to support a RISK assessment (see Clause 17) are carried out in the combinations of conditions and operations determined during the RISK assessment.

If, when carrying out a conformity test, there is any uncertainty about the exact value of an applied or measured quantity (for example voltage) due to the tolerance:

a) manufacturers should ensure that at least the specified test value is applied;

b) test houses should ensure that no more than the specified test value is applied.

4.2 Sequence of tests

The sequence of tests is optional unless otherwise specified. The equipment under test shall be carefully inspected after each test. If the result of a test causes doubt whether any earlier tests would have been passed if the sequence had been reversed, these earlier tests shall be repeated.

4.3 Reference test conditions

4.3.1 Environmental conditions

Unless otherwise specified in this standard, the following environmental conditions shall exist in the test location:

a) a temperature of 15 °C to 35 °C;

b) a relative humidity of not more than 75 %, but not exceeding the limits of 1.4.1 d);

c) an air pressure of 75 kPa to 106 kPa;

d) no hoar-frost, dew, percolating water, rain, solar radiation, etc.

4.3.2 State of equipment

4.3.2.1 General

Unless otherwise specified, each test shall be carried out on the equipment assembled for NORMAL USE and under the least favourable combination of the conditions given in 4.3.2.2

to 4.3.2.13.

NOTE In case of doubt, tests should be performed in more than one combination of conditions.

If dimensions or mass make it unsuitable to carry out particular tests on completely assembled equipment, tests on sub-assemblies are allowed, provided it is verified that the assembled equipment will meet the requirements of this standard.

4.3.2.2 Position of equipment

The equipment shall be in any position of NORMAL USE and with any ventilation unimpeded. Equipment intended to be built into a wall, recess, cabinet, etc., shall be installed as specified in the manufacturer's instructions.

4.3.2.3 Accessories

Accessories and OPERATOR-interchangeable parts available from, or recommended by, the manufacturer for use with the equipment under test shall be either connected or not connected.

4.3.2.4 Covers and removable parts

Covers or parts which can be removed without using a TOOL shall be removed or not removed.

4.3.2.5 MAINS supply

The following requirements apply.

a) The supply voltage shall be between 90 % and 110 % of any RATED supply voltage for which the equipment can be set or, if the equipment is RATED for a greater fluctuation, at any supply voltage within the fluctuation range.
b) The frequency shall be any RATED frequency.
c) Equipment for both a.c. and d.c. shall be connected to an a.c. or d.c. supply.
d) Equipment for single-phase a.c. supply shall be connected both with normal and reverse polarity.
e) If the means of connection permits reversal, battery-operated and d.c. equipment shall be connected with both reverse and normal polarity.

4.3.2.6 Input and output voltages

Input and output voltages, including floating voltages but excluding the MAINS supply voltage, shall be set to any voltage within the RATED voltage range.

4.3.2.7 Earth TERMINALS

PROTECTIVE CONDUCTOR TERMINALS, if any, shall be connected to earth.

FUNCTIONAL EARTH TERMINALS shall be connected or not connected to earth.

4.3.2.8 Controls

Controls which an OPERATOR can adjust without the use of a TOOL shall be set to any position except that:

a) MAINS selection devices shall be set to the correct value;
b) combinations of settings shall not be made if they are prohibited by the manufacturer’s marking on the equipment.

4.3.2.9 Connections

The equipment shall be connected for NORMAL USE, or not connected.

4.3.2.10 Load on motors

Load conditions of motor-driven parts of equipment shall be in accordance with the NORMAL USE.

4.3.2.11 Output

For equipment giving an electrical output:

a) the equipment shall be operated in such a way as to provide the RATED output power to the RATED load;
b) the RATED load impedance of any output shall be connected or not connected.

4.3.2.12 Duty cycle

Equipment for short-term or intermittent operation shall be operated for the longest RATED period and shall have the shortest RATED recovery period consistent with the manufacturer's instructions.

Equipment for short-term or intermittent operation that develops significant heat during the startup phase, and that relies on continued operation to dissipate that heat, shall also be operated for the shortest RATED period followed by the shortest RATED recovery period.

4.3.2.13 Loading and filling

Equipment intended to be loaded with a specific material in NORMAL USE shall be loaded with the least favourable quantity of the materials specified in the instructions for use, including not loaded (empty) if the instructions for use permit this in NORMAL USE.

NOTE If the specified material could cause a HAZARD during test, another material may be used provided that it can be shown that the result of the test is not affected.

4.4 Testing in SINGLE FAULT CONDITION

4.4.1 General

The following requirements apply.

a) Examination of the equipment and its circuit diagram will generally show the fault conditions which are liable to result in HAZARDS and which, therefore, shall be applied.
b) Fault tests shall be made as specified for checking conformity, unless it can be demonstrated that no HAZARD could arise from a particular fault condition.
c) The equipment shall be operated under the least favourable combination of reference test conditions (see 4.3). These combinations may be different for different faults and they shall be recorded for each test. If the environmental limits of the reference test conditions (see 4.3) do not allow realistic assessment of SINGLE FAULT CONDITIONS, the test shall be conducted at the least favourable RATED environmental conditions of the equipment.

4.4.2 Application of fault conditions

4.4.2.1 General

Fault conditions shall include those specified in 4.4.2.2 to 4.4.2.14. They shall be applied only one at a time and shall be applied in turn in any convenient order. Multiple simultaneous faults shall not be applied unless they are a consequence of an applied fault.

NOTE For example, fans may be stopped one fan at a time unless they share a common power or control source. In that case, the common fans should be stopped simultaneously by interrupting the power or control source.

After each application of a fault condition, the equipment or part shall pass the applicable tests of 4.4.4.

4.4.2.2 PROTECTIVE IMPEDANCE

The following requirements apply.

a) If a PROTECTIVE IMPEDANCE is formed by a combination of components, each component shall be short-circuited or disconnected, whichever is less favourable.
b) If a PROTECTIVE IMPEDANCE is formed with a single component that meets the requirements of 6.5.4, it need not be short-circuited or disconnected.

4.4.2.3 Protective conductor

The protective conductor shall be interrupted, except for PERMANENTLY CONNECTED EQUIPMENT and equipment utilizing a connector meeting the requirements of IEC 60309.

4.4.2.4 Equipment or parts for short-term or intermittent operation

These shall be operated continuously if continuous operation could occur in a SINGLE FAULT CONDITION. Individual parts may include motors, relays, other electromagnetic devices and heaters.

4.4.2.5 Motors

Motors shall be stopped while fully energized or prevented from starting, whichever is less favourable.

One supply phase of any multi-phase motor shall be interrupted while the motor is operating at its intended full load.

4.4.2.6 Capacitors

Capacitors (except for self-healing capacitors) in the auxiliary winding circuits of motors shall be short-circuited.

4.4.2.7 MAINS transformers

4.4.2.7.1 General

The secondary windings of MAINS transformers shall be short-circuited as specified in 4.4.2.7.2, and overloaded as specified in 4.4.2.7.3.

A transformer damaged during one test may be repaired or replaced before the next test.

Tests for MAINS transformers tested as separate components are specified in 14.6.

4.4.2.7.2 Short circuit

Each untapped output winding, and each section of a tapped output winding, which is loaded in NORMAL USE, shall be tested in turn, one at a time, to simulate short circuits in the load. Overcurrent protection devices remain fitted during the test. All other windings are loaded or not loaded, whichever load condition of NORMAL USE is less favourable.

4.4.2.7.3 Overload

Each untapped output winding, and each section of a tapped output winding, is overloaded in turn one at a time. The other windings are loaded or not loaded, whichever load condition of NORMAL USE is less favourable. If any overloads arise from testing in the fault conditions of 4.4, secondary windings shall be subjected to those overloads.

Overloading is carried out by connecting a variable resistor across the winding. The resistor is adjusted as quickly as possible and readjusted, if necessary, after 1 min to maintain the applicable overload. No further readjustments are then permitted.

If overcurrent protection is provided by a current-breaking device, the overload test current is the maximum current which the overcurrent protection device is just capable of passing for 1 h. Before the test, the device is replaced by a link with negligible impedance. If this value cannot be derived from the specification, it is to be established by test.

For equipment in which the output voltage is designed to collapse when a specified overload current is reached, the overload is slowly increased to a point just before the point which causes the output voltage to collapse.

In all other cases, the loading is the maximum power output obtainable from the transformer.

Transformers with overtemperature protection which meets the requirements of 14.3 during the short-circuit test of 4.4.2.7.2 need not be subjected to overload tests.

4.4.2.8 Outputs

Outputs shall be short-circuited one at a time.

4.4.2.9 Equipment for more than one supply

Equipment which is designed to be operated from more than one type of supply shall be simultaneously connected to these supplies, unless this is prevented by the construction.

4.4.2.10 Cooling

Equipment cooling shall be restricted as follows, one fault at a time:

a) air-holes with filters shall be closed;
b) forced cooling by motor-driven fans shall be stopped;
c) cooling by circulation of water or other coolant shall be stopped;
d) loss of cooling liquid shall be simulated.

4.4.2.11 Heating devices

In equipment incorporating heating devices, the following faults shall be applied one at a time:

a) timers which limit the heating period shall be overridden to energize the heating circuit continuously;
b) temperature controllers, except for overtemperature protection devices meeting the requirements of 14.3, shall be overridden to energize the heating circuit continuously.

4.4.2.12 Insulation between circuits and parts

Insulation between circuits and parts which is below the level specified for BASIC INSULATION shall be bridged to check against the spread of fire if the method of 9.1 a) is used.

4.4.2.13 Interlocks

Each part of an interlock system for the protection of the OPERATOR shall be short-circuited or open-circuited in turn if the system prevents access to HAZARDS when a cover, etc. is removed without the use of a TOOL.

4.4.2.14 Voltage selectors

Voltage selectors which an OPERATOR can set for different RATED supply voltages shall be set for each possible setting with the equipment connected to each of its RATED supply circuits.

4.4.3 Duration of tests

4.4.3.1 General

The equipment shall be operated until further change as a result of the applied fault is unlikely. Each test is normally limited to 1 h since a secondary fault arising from a SINGLE FAULT CONDITION will usually manifest itself within that time. If there is an indication that a HAZARD of electric shock, spread of fire or injury to persons may eventually occur, the test shall be continued for 4 h unless one of these HAZARDS arises before then.

4.4.3.2 Current limiting devices

If a device which interrupts or limits the current during operation is included to limit the temperature of parts which can easily be touched, the maximum temperature attained by those parts shall be measured, whether the device operates or not.

4.4.3.3 Fuses

If a fault is terminated by the opening of a fuse and if the fuse does not operate within approximately 1 s, the current through the fuse under the relevant fault condition shall be measured. The pre-arcing time/current characteristics of the fuse shall be evaluated to find out whether the minimum operating current is reached and what is the maximum time before the fuse operates. The current through the fuse may vary as a function of time.

If the minimum operating current of the fuse is not reached in the test, the equipment shall be operated for a period corresponding to the maximum fusing time or continuously for the duration specified in 4.4.3.1, with the fuse replaced with a short-circuit.

4.4.4 Conformity after application of fault conditions

4.4.4.1 General

Conformity with requirements for protection against electric shock after the application of single faults is checked as follows:

a) *by making the measurements of 6.3.2 to check that no ACCESSIBLE conductive parts have become HAZARDOUS LIVE;*
b) *by performing a voltage test on DOUBLE INSULATION or REINFORCED INSULATION to check that the protection is still at least at the level of BASIC INSULATION. The voltage tests are made as specified in 6.7 and 6.8 (without humidity preconditioning) with the test voltage for BASIC INSULATION;*
c) *by measuring the temperature of transformer windings if the protection against electrical HAZARDS is achieved by DOUBLE INSULATION or REINFORCED INSULATION within the transformer. The temperatures of Table 20 shall not be exceeded.*

4.4.4.2 Temperature

Conformity with requirements for temperature protection is checked by determining the temperature of the outer surface of the ENCLOSURE *and of parts which can easily be touched (See Clause 10).*

4.4.4.3 Spread of fire

Conformity with requirements for protection against the spread of fire is checked by placing the equipment on white tissue-paper covering a softwood surface and covering the equipment with cheesecloth. No molten metal, burning insulation, flaming particles, etc. shall fall on the surface on which the equipment stands and there shall be no charring, glowing, or flaming of the tissue paper or cheesecloth. Melting of insulation material shall be ignored if no HAZARD *could arise.*

4.4.4.4 Other HAZARDS

Conformity with other requirements for protection against HAZARDS *is checked as specified in Clauses 7 to 16.*

5 Marking and documentation

5.1 Marking

5.1.1 General

Equipment shall bear markings as specified in 5.1.2 to 5.2. Except for marking of internal parts, these markings shall be visible from the exterior, or be visible after removing a cover or opening a door without the aid of a TOOL, if the cover or door is intended to be removed or opened by an OPERATOR. Markings applying to the equipment as a whole shall not be put on parts which can be removed by an OPERATOR without the use of a TOOL.

For rack- or panel-mounted equipment, markings are permitted to be on a surface that becomes visible after removal of the equipment from the rack or panel.

Letter symbols for quantities and units shall be as specified in IEC 60027. Graphic symbols shall be in accordance with Table 1 if applicable. There are no colour requirements for symbols. Graphic symbols shall be explained in the documentation.

NOTE 1 IEC or ISO symbols should be used if available.

NOTE 2 Markings should not be on the bottom of the equipment, except on HAND-HELD EQUIPMENT or where space is limited.

Conformity is checked by inspection.

5.1.2 Identification

The equipment shall, as a minimum, be marked with:

a) the name or trade mark of the manufacturer or supplier;

b) a model number, name or other means to identify the equipment. If equipment bearing the same distinctive designation (model number) is manufactured at more than one location, equipment from each manufacturing location shall be marked so that the location can be identified.

   NOTE The marking of factory location may be in code and need not be on the equipment exterior.

Conformity is checked by inspection.

5.1.3 MAINS supply

The equipment shall be marked with the following information.

a) Nature of supply:
   1) a.c.: RATED MAINS frequency or range of frequencies;
   2) d.c.: symbol 1 of Table 1.

   NOTE 1 For information purposes it may be useful to mark

   – equipment intended for a.c. with symbol 2 of Table 1;

   – equipment suitable for both a.c. and d.c. with symbol 3 of Table 1;

   – equipment for three-phase supply with symbol 4 of Table 1.

b) The RATED supply voltage(s) or the RATED range of supply voltages.

   NOTE 2 RATED voltage fluctuations may also be marked.

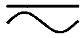
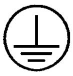
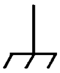
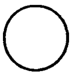
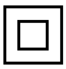
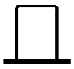
c) The maximum RATED power in watts (active power) or volt-amperes (apparent power), or the maximum RATED input current, with all accessories or plug-in modules connected. If the equipment can be used on more than one voltage range, separate values shall be marked for each voltage range unless the maximum and minimum values do not differ by more than 20 % of the mean value. The marked value shall not be less than 90 % of the maximum value.

d) Equipment which an OPERATOR can set for different RATED supply voltages shall be provided with means for the indication of the voltage for which the equipment is set. For PORTABLE EQUIPMENT the indication shall be visible from the exterior. If the equipment is so constructed that the supply voltage setting can be altered without the use of a TOOL, the action of changing the setting shall also change the indication.

e) Accessory MAINS socket-outlets accepting standard MAINS plugs shall be marked with the voltage if it is different from the MAINS supply voltage. If the outlet is for use only with specific equipment, it shall be marked to identify the equipment for which it is intended. If not, the maximum RATED current or power shall be marked, or symbol 14 of Table 1 placed beside the outlet with the full details included in the documentation.

Conformity is checked by inspection and by measurement of power or input current to check the requirements of 5.1.3 c) have been met. The measurement is made at each RATED voltage range with the equipment in the condition of maximum power or current consumption as applicable with all accessories and plug-in modules connected. If the input current varies during the normal operating cycle, the steady-state current is taken as the mean indication of the highest measured r.m.s. value during a 1 min period of the normal operation cycle. To exclude any initial inrush current, the measurement is not made until the current has stabilized (usually after 1 min). Transients are ignored.

Table 1 – Symbols

Number	Symbol	Reference	Description
1		IEC 60417-5031 (2002-10)	Direct current
2		IEC 60417-5032 (2002-10)	Alternating current
3		IEC 60417-5033 (2002-10)	Both direct and alternating current
4		IEC 60417-5032-1 (2002-10)	Three-phase alternating current
5		IEC 60417-5017 (2006-08)	Earth (ground) TERMINAL
6		IEC 60417-5019 (2006-08)	PROTECTIVE CONDUCTOR TERMINAL
7		IEC 60417-5020 (2002-10)	Frame or chassis TERMINAL
8			Not used
9		IEC 60417-5007 (2009-02)	On (Power)
10		IEC 60417-5008 (2009-02)	Off (Power)
11		IEC 60417-5172 (2003-02)	Equipment protected throughout by DOUBLE INSULATION or REINFORCED INSULATION
12			Caution, possibility of electric shock
13		IEC 60417-5041 (2002-10)	Caution, hot surface
14		ISO 7000-0434B (2004-01)	Caution [a]
15		IEC 60417-5268 (2002-10)	In position of a bi-stable push control
16		IEC 60417-5269 (2002-10)	Out position of a bi-stable push control
17		ISO 361	Ionizing radiation

[a] See 5.4.1 which requires manufacturers to state that documentation must be consulted in all cases where this symbol is marked.

5.1.4 Fuses

For any fuse which may be replaced by an OPERATOR, there shall be a marking beside the fuseholder, which will enable the OPERATOR to identify the correct replacement fuse (see 5.4.5).

Conformity is checked by inspection.

5.1.5 TERMINALS, connections and operating devices

5.1.5.1 General

If necessary for safety, an indication shall be given of the purpose of TERMINALS, connectors, controls, and indicators, including any connections for fluids such as gas, water and drainage. Where there is insufficient space, symbol 14 of Table 1 may be used.

NOTE 1 For additional information, see IEC 60445 and IEC 60447.

NOTE 2 Individual pins of multi-pin connectors need not be marked.

Push-buttons and actuators of emergency stop devices, and indicators used only to indicate a warning of danger or the need for urgent action, shall be coloured red and coded as specified in IEC 60073. If the meaning of colour relates to the safety of persons or the environment, supplementary means of coding shall be provided (see IEC 60073).

NOTE 3 National authorities may require that equipment used in certain environments meet the man-machine interface requirements pertinent to that environment.

Conformity is checked by inspection.

5.1.5.2 TERMINALS

TERMINALS for connection to the MAINS supply shall be identifiable.

The following TERMINALS shall be marked as follows:

a) FUNCTIONAL EARTH TERMINALS with symbol 5 of Table 1;
b) PROTECTIVE CONDUCTOR TERMINALS with symbol 6 of Table 1, except when the PROTECTIVE CONDUCTOR TERMINAL is part of an approved MAINS appliance inlet. The symbol shall be placed on the TERMINAL or close to it;
c) TERMINALS of circuits which are permitted by 6.6.3 to be connected to ACCESSIBLE conductive parts, with symbol 7 of Table 1 unless connection is self-evident;

   NOTE This symbol may also be considered as a warning symbol in that it indicates that a HAZARDOUS LIVE voltage must not be connected to the TERMINAL. The symbol should also be used if it is likely that an OPERATOR could make such a connection inadvertently.

d) TERMINALS supplied from the interior of the equipment and which are HAZARDOUS LIVE, with the voltage, current, charge or energy value or range, or with symbol 14 of Table 1. This requirement does not apply to MAINS supply outlets where a standard MAINS socket outlet is used.

Conformity is checked by inspection.

5.1.6 Switches and circuit-breakers

If the power supply switch or circuit-breaker is used as the disconnecting device, the off-position shall be clearly marked.

NOTE It is recommended that the on-position also be marked.

Symbols 9 and 10 of Table 1 can, in some cases, also be suitable as the device identification (see 6.11.3.1 c)). A lamp alone is not considered to be a satisfactory marking.

If a push-button switch is used as the power supply switch, symbols 9 and 15 of Table 1 may be used to indicate the on-position, or symbols 10 and 16 to indicate the off-position, with the pair of symbols (9 and 15, or 10 and 16) close together.

Conformity is checked by inspection.

5.1.7 Equipment protected by DOUBLE INSULATION or REINFORCED INSULATION

Equipment which is only partially protected by DOUBLE INSULATION or REINFORCED INSULATION shall not be marked with symbol 11 of Table 1.

NOTE Equipment protected throughout by DOUBLE INSULATION or REINFORCED INSULATION may be marked with symbol 11 of Table 1.

Conformity is checked by inspection.

5.1.8 Field-wiring TERMINAL boxes

If the temperature of the TERMINALS or the ENCLOSURE of a field-wiring TERMINAL box or compartment exceeds 60 °C in NORMAL CONDITION at an ambient temperature of 40 °C, or at the maximum RATED ambient temperature if higher, there shall be a marking to warn the installer to consult the installation instructions before determining the temperature RATING of the cable to be connected to the TERMINALS. The marking shall be visible before and during connection, or be beside the TERMINALS. Symbol 14 is an acceptable marking.

Conformity, in case of doubt, is checked by measurement as specified in 10.3 a) and, if applicable, by inspection of markings.

5.2 Warning markings

Warning markings specified in this standard shall meet the following requirements.

Warning markings shall be visible when the equipment is ready for NORMAL USE. If a warning applies to a particular part of the equipment, the marking shall be placed on or near that part.

The size of warning markings shall be as follows:

a) symbols shall be at least 2,75 mm high. Text shall be at least 1,5 mm high and contrast in colour with the background;

b) symbols or text moulded, stamped or engraved in a material shall be at least 2,0 mm high. If not contrasting in colour, they shall have a depth or raised height of at least 0,5 mm.

If it is necessary for the RESPONSIBLE BODY or OPERATOR to refer to the documentation to preserve the protection afforded by the equipment, the equipment shall be marked with symbol 14 of Table 1. Symbol 14 is not required to be used if other symbols which address the safety aspects are used and explained in the documentation.

If the instructions for use state that an OPERATOR is permitted to gain access, using a TOOL, to a part or location which in NORMAL USE may present a HAZARD, there shall be a warning marking indicating that the equipment must be placed in a safe state before access. Symbol 14 shall be used for this purpose with the warning text included in the documentation. Additional symbols may be used to indicate the nature of the HAZARD such as symbol 12, 13, or 17 as appropriate.

Symbols are the preferred marking method over text warnings. Supplemental text may be provided adjacent to the symbol.

Conformity is checked by inspection.

5.3 Durability of markings

Required markings shall remain clear and legible under conditions of NORMAL USE and shall resist the effects of the cleaning agents specified by the manufacturer.

Conformity is checked by performing the following test for durability of markings on the outside of the equipment. The markings are rubbed by hand, without undue pressure, for 30 s with a cloth soaked with each specified cleaning agent (or, if not specified, with 70 % isopropyl alcohol).

After the above treatment the markings shall be clearly legible and adhesive labels shall not have worked loose or become curled at the edges.

5.4 Documentation

5.4.1 General

The following documentation necessary for safety purposes, as needed by the OPERATOR or the RESPONSIBLE BODY, shall be provided with the equipment. Safety documentation for service personnel authorized by the manufacturer shall be made available to such personnel:

a) intended use of the equipment;

b) technical specification;

c) name and address of the manufacturer or supplier from whom technical assistance may be obtained;

d) the information specified in 5.4.2 to 5.4.6;

e) information about how to mitigate RISKS remaining after a RISK assessment has been performed (see Clause 17);

f) for equipment which for safety reasons requires specific accessories (for example probe assemblies) with specific characteristics, the documentation shall indicate that only accessories which meet the manufacturer’s specifications shall be used;

g) if a HAZARD could be caused by an incorrect reading when measuring, indicating or detecting harmful or corrosive substances, or HAZARDOUS LIVE electrical quantities, the instructions shall provide guidance on how to determine that the equipment is functioning correctly;

h) instructions for lifting and carrying (see 7.5.1).

Warning symbols and warning statements that are marked on the equipment shall be explained in the documentation. In particular, the documentation shall include a statement that it must be consulted in all cases where symbol 14 of Table 1 is marked, in order to find out the nature of the potential HAZARDS and any actions which have to be taken to avoid them.

NOTE 1 Markings and text on equipment are considered equivalent to the documentation.

NOTE 2 If NORMAL USE involves the handling of harmful or corrosive substances, instruction should be given on correct use and safety provisions. If any harmful or corrosive substance is specified or supplied by the equipment manufacturer, the necessary information on its constituents and the correct disposal procedure should also be given.

Documentation may be provided on printed or electronic media, however printed information is required for all information necessary for safety that might not be available in electronic form at the time it is needed. The documentation shall be delivered with the equipment. Consideration shall be given to the ability of the RESPONSIBLE BODY to read the media.

Conformity is checked by inspection.

5.4.2 Equipment RATINGS

Documentation shall include the following:

a) the supply voltage or voltage range, frequency or frequency range, and power or current RATING;

b) a description of all input and output connections as required by 6.6.1 a);

c) the rating of the insulation of external circuits as required by 6.6.1 b);

d) a statement of the range of environmental conditions for which the equipment is designed including:

   1) indoor or outdoor use,
   2) altitude,
   3) temperature,
   4) relative humidity,
   5) MAINS supply voltage fluctuations,
   6) OVERVOLTAGE CATEGORY, except for cord/plug-connected equipment,
   7) WET LOCATION, if applicable,
   8) POLLUTION DEGREE of the intended environment,

e) for equipment RATED for ingress protection according to IEC 60529 the information required in 11.6.1;

f) for equipment with an impact RATING less than 5 J, the information specified in 8.1 d).

Conformity is checked by inspection.

5.4.3 Equipment installation

The documentation shall include installation and specific commissioning instructions and, if necessary for safety, warnings against HAZARDS which could arise during installation or commissioning or as a result of improper installation or commissioning of the equipment. Such information includes, if applicable:

a) assembly, location and mounting requirements;

b) instructions for protective earthing;

c) connections to the supply;

d) for PERMANENTLY CONNECTED EQUIPMENT:

   1) supply wiring requirements;
   2) requirements for any external switch or circuit-breaker (see 6.11.3.1) and external overcurrent protection devices (see 9.6.2) and a recommendation that the switch or circuit-breaker be near the equipment;

e) ventilation requirements;

f) requirements and safety characteristics for special external services, for example: maximum and minimum temperature, pressure, or flow of air or cooling liquid;

g) instructions relating to sound level (see 12.5.1).

NOTE It is recommended to add a statement in the documentation for the installation that the safety of any system incorporating the equipment is the responsibility of the assembler of the system.

Conformity is checked by inspection.

5.4.4 Equipment operation

Instructions for use shall include, if applicable:

a) identification and description of operating controls and their use in all operating modes;

b) instructions not to position the equipment so that it is difficult to operate the disconnecting device;

c) instructions for interconnection to accessories and other equipment, including indication of suitable accessories, detachable parts and any special materials;

d) specifications of limits for intermittent operation;

e) explanations of symbols related to safety which are used on the equipment;

f) instructions for replacement of consumable materials;

g) instructions for cleaning and decontamination;

h) a statement listing potentially poisonous or injurious substances that can be liberated from the equipment, and possible quantities;

i) detailed instructions about RISK reduction procedures relating to flammable liquids (see 9.5 c));

j) details of methods of reducing the RISKS of burns from surfaces permitted to exceed the temperature limits of 10.1.

If equipment conforming to IEC 60950 is used with equipment conforming to this standard, and if there is a HAZARD due to moisture or liquids, the instructions for use shall specify any additional precautions necessary.

There shall be a statement in the instructions that, if the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

Conformity is checked by inspection.

5.4.5 Equipment maintenance and service

Instructions shall be provided to the RESPONSIBLE BODY in sufficient detail to permit safe maintenance, inspection and testing of the equipment, and to ensure continued safety of the equipment after the maintenance, inspection and test procedure.

If applicable, manufacturer's documentation shall instruct against replacing detachable MAINS supply cords by inadequately RATED cords.

For equipment using replaceable batteries, the specific battery type shall be stated.

The manufacturer shall specify any parts which are required to be examined or supplied only by the manufacturer or his agent.

The RATING and characteristics of replaceable fuses shall be stated.

Instructions on the following subjects shall be provided for service personnel, as necessary to permit safe servicing and continued safety of the equipment after servicing if the equipment is suitable to be serviced:

a) product-specific RISKS that may affect the service personnel;

b) protective measures for these RISKS;

c) verification of the safe state of the equipment after repair.

NOTE Instructions for service personnel need not be supplied to the RESPONSIBLE BODY, but should be made available to service personnel.

Conformity is checked by inspection.

5.4.6 Integration into systems or effects resulting from special conditions

Aspects resulting from integration into systems or effects resulting from special ambient or application conditions shall be described in the documentation.

Conformity is checked by inspection of the documentation.

6 Protection against electric shock

6.1 General

6.1.1 Requirements

Protection against electric shock shall be maintained in NORMAL CONDITION and SINGLE FAULT CONDITION (see 6.4 and 6.5). ACCESSIBLE parts (see 6.2) shall not be HAZARDOUS LIVE (see 6.3). Voltage, current, charge or energy between an ACCESSIBLE part and earth, or between any two ACCESSIBLE parts on the same piece of equipment within a distance of 1,8 m (over a surface or through air), shall not exceed the levels of 6.3.1 in NORMAL CONDITION nor of 6.3.2 in SINGLE FAULT CONDITION.

Conformity is checked by the determination of ACCESSIBLE parts as specified in 6.2 and by the measurements of 6.3 to establish that the levels of 6.3.1 and 6.3.2 are not exceeded, followed by the tests of 6.4 to 6.11.

6.1.2 Exceptions

If it is not feasible for operating reasons to prevent the following parts being both ACCESSIBLE and HAZARDOUS LIVE, they are permitted to be ACCESSIBLE to an OPERATOR during NORMAL USE while they are HAZARDOUS LIVE:

a) parts of lamps and lamp sockets after lamp removal;

b) parts intended to be replaced by an OPERATOR (for example, batteries) and which may be HAZARDOUS LIVE during the replacement or other OPERATOR action, but only if they are ACCESSIBLE only by means of a TOOL and have a warning marking (see 5.2);

If any of the parts in a) and b) receives a charge from an internal capacitor, they shall not be HAZARDOUS LIVE 10 s after interruption of the supply.

If a charge is received from an internal capacitor, conformity is checked by the measurements of 6.3 to establish that the levels of 6.3.1 c) are not exceeded.

6.2 Determination of ACCESSIBLE parts

6.2.1 General

Unless obvious, determination of whether a part is ACCESSIBLE is made as specified in 6.2.2 to 6.2.4 in all positions of NORMAL USE. Test fingers (see Annex B) and pins are applied without force unless a force is specified. Parts are considered to be ACCESSIBLE if they can be touched with any part of a test finger or test pin, or if they could be touched in the absence of a covering which is not considered to provide suitable insulation (see 6.9.2).

If, in NORMAL USE, an OPERATOR is intended to perform any actions (with or without a TOOL) that could increase the accessibility of parts, such actions are taken before performing the examinations of 6.2.2 to 6.2.4.

NOTE Examples of such actions include:

a) removing covers;

b) opening doors;

c) adjusting controls;

d) replacing consumable material;

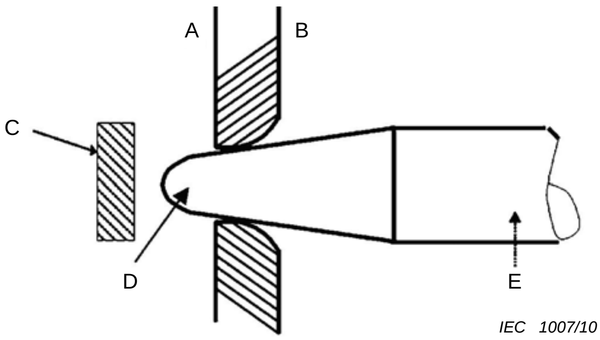
e) removing parts.

Rack-mounted and panel-mounted equipment is installed as specified in the manufacturer's instructions before making the examinations of 6.2.2 to 6.2.4. For such equipment, the OPERATOR *is assumed to be in front of the panel.*

6.2.2 Examination

The jointed test finger (see Figure B.2) is applied in every possible position. If a part could become ACCESSIBLE *by applying a force, the rigid test finger (see Figure B.1) is applied with a force of 10 N. The force is exerted by the tip of the test finger so as to avoid wedge and lever action. The test is applied to all outer surfaces, including the bottom. However, on equipment accepting plug-in modules the tip of the jointed test finger is inserted only to a depth of 180 mm from the opening in the equipment.*

The test finger is likewise applied to all openings in the ENCLOSURE*, including holes and* TERMINALS*. In these cases, the* ACCESSIBLE *parts of the* ENCLOSURE *are considered to include any part of the test finger which can be inserted into the hole or* TERMINAL *(see Figure 1).*



Key

A inside of equipment

B outside of equipment

C HAZARDOUS LIVE part

D tip of test finger is considered to be ACCESSIBLE

E test finger

Figure 1 – Measurements through openings in ENCLOSURES

6.2.3 Openings above parts that are HAZARDOUS LIVE

A metal test pin 100 mm long and 4 mm in diameter is inserted into any openings above parts which are HAZARDOUS LIVE*. The test pin is suspended freely and allowed to penetrate up to 100 mm.*

The additional safety measures of 6.5.1 for protection in SINGLE FAULT CONDITION *are not required solely because a part is* ACCESSIBLE *only by this test.*

NOTE This exception is permitted because the insertion of an object similar to this test pin is considered to be a SINGLE FAULT CONDITION and one means of protection is sufficient.

This test is not applied to TERMINALS*.*

6.2.4 Openings for pre-set controls

A metal test pin 3 mm in diameter is inserted through holes intended to give access to pre-set controls which require the use of a screwdriver or other TOOL*. The test pin is applied in every* *possible direction through the hole. Penetration shall not exceed three times the distance from the* ENCLOSURE *surface to the control shaft or 100 mm, whichever is smaller.*

6.3 Limit values for ACCESSIBLE parts

6.3.1 Levels in NORMAL CONDITION

Voltages above the levels of a) are deemed to be HAZARDOUS LIVE if any of the levels of b) or c) are exceeded at the same time.

a) The a.c. voltage levels are 30 V r.m.s., 42,4 V peak and the d.c. voltage level is 60 V. For equipment intended for use in WET LOCATIONS, the a.c. voltage levels are 16 V r.m.s., 22,6 V peak and the d.c.voltage level is 35 V.

b) The current levels are:

1) 0,5 mA r.m.s. for sinusoidal waveforms, 0,7 mA peak for non-sinusoidal waveforms or mixed frequencies, or 2 mA d.c., when measured with the measuring circuit of Figure A.1. If the frequency does not exceed 100 Hz, the measuring circuit of Figure A.2 can be used. The measuring circuit of Figure A.4 is used for equipment intended for use in WET LOCATIONS.

2) 70 mA r.m.s. when measured with the measuring circuit of Figure A.3. This relates to possible burns at higher frequencies.

c) The levels of capacitive charge or energy are:

1) 45 µC charge for voltages up to 15 kV peak or d.c.; line A of Figure 3 shows the capacitance versus voltage where the charge is 45 µC.

2) 350 mJ stored energy for voltages above 15 kV peak or d.c.

6.3.2 Levels in SINGLE FAULT CONDITION

Voltages above the levels of a) are deemed to be HAZARDOUS LIVE if any of the levels of b) or c) are exceeded at the same time.

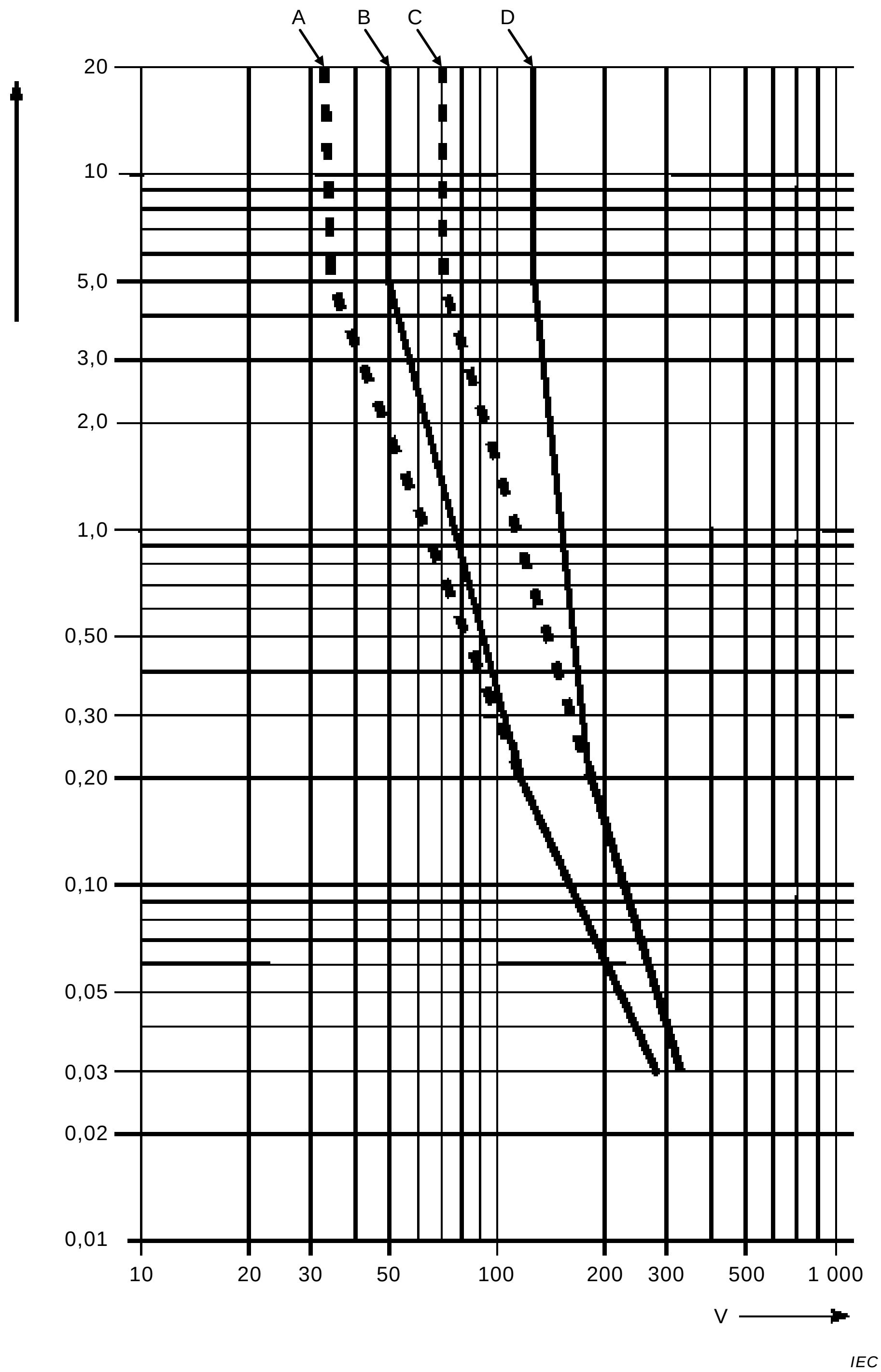
a) The a.c. voltage levels are 50 V r.m.s., 70 V peak and the d.c. voltage level is 120 V. For equipment intended for use in WET LOCATIONS, the a.c. voltage levels are 33 V r.m.s, 46,7 V peak and the d.c. voltage level is 70 V . For voltages of short duration, the duration versus voltage levels are those of Figure 2, measured across a 50 kΩ resistor.

b) The current levels are:

3) 3,5 mA r.m.s. for sinusoidal waveforms, 5 mA peak for non-sinusoidal waveforms or mixed frequencies, or 15 mA d.c., when measured with the measuring circuit of Figure A.1. If the frequency does not exceed 100 Hz, the measuring circuit of Figure A.2 can be used. The measuring circuit of Figure A.4 is used for equipment intended for use in WET LOCATIONS;

4) 500 mA r.m.s. when measured with the measuring circuit of Figure A.3. This relates to possible burns at higher frequencies.

c) The capacitance level is line B of Figure 3.



Key

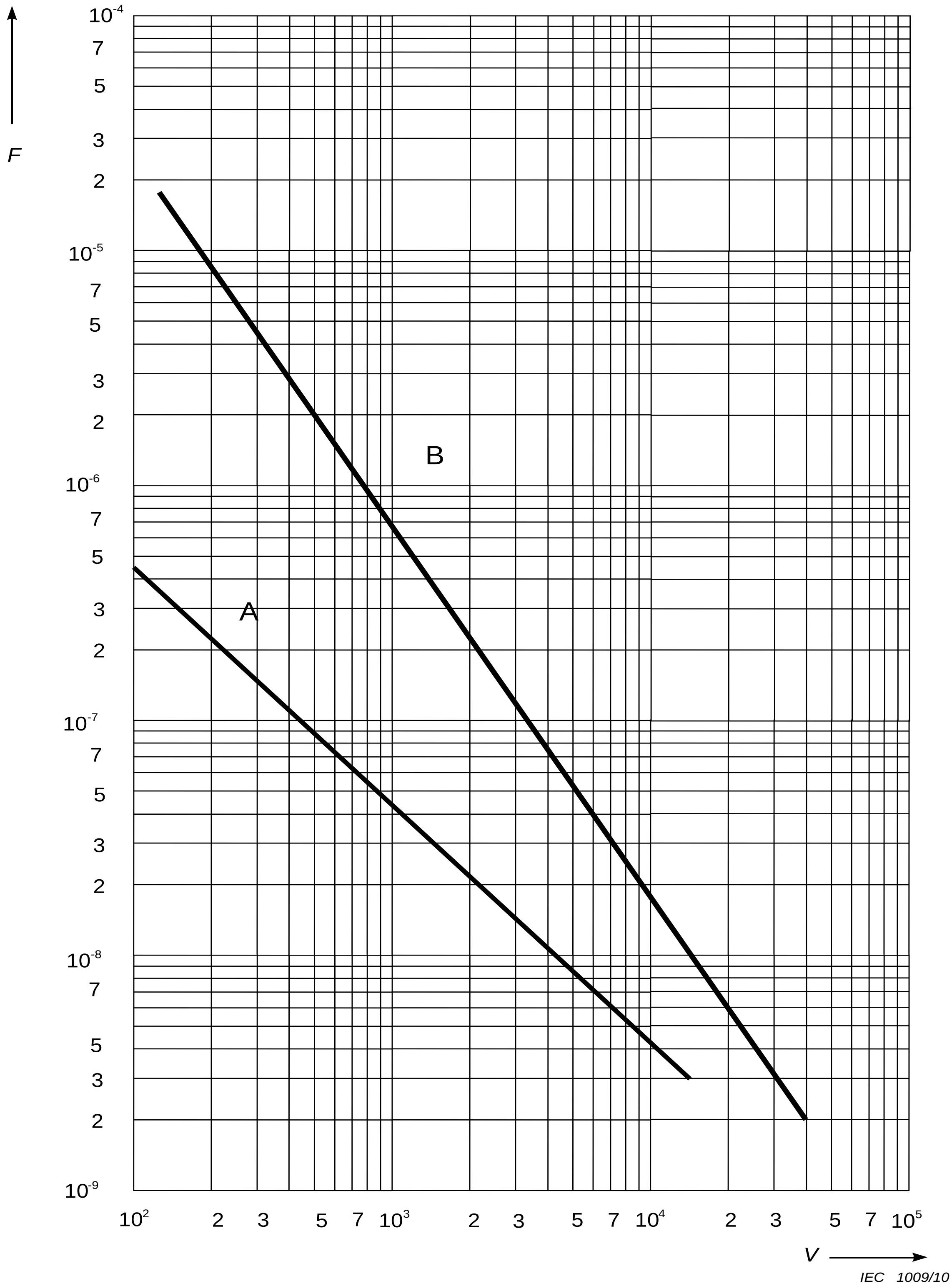
A a.c. voltage level in WET LOCATIONS

B a.c. voltage level in dry locations

C d.c. voltage level in WET LOCATIONS

D d.c. voltage level in dry locations

Figure 2 – Maximum duration of short-term ACCESSIBLE voltages in SINGLE FAULT CONDITION (see 6.3.2 a))



Key

A NORMAL CONDITION

B SINGLE FAULT CONDITION

Figure 3 – Capacitance level versus voltage in NORMAL CONDITION and SINGLE FAULT CONDITION (see 6.3.1 c) and 6.3.2 c))

6.4 Primary means of protection

6.4.1 General

ACCESSIBLE parts shall be prevented from becoming HAZARDOUS LIVE by one or more of the following means (see Annex D):

a) ENCLOSURES or PROTECTIVE BARRIERS (see 6.4.2);

b) BASIC INSULATION (see 6.4.3);

c) impedance (see 6.4.4).

Conformity is checked by inspection and as specified in 6.4.2. to 6.4.4.

6.4.2 ENCLOSURES and PROTECTIVE BARRIERS

ENCLOSURES and PROTECTIVE BARRIERS shall meet the rigidity requirements of 8.1.

If ENCLOSURES or PROTECTIVE BARRIERS provide protection by insulation, they shall meet the requirements of BASIC INSULATION.

If ENCLOSURES or PROTECTIVE BARRIERS provide protection by limiting access, CLEARANCES and CREEPAGE DISTANCES between ACCESSIBLE parts and HAZARDOUS LIVE parts shall meet the requirements of 6.7 and the applicable requirements for BASIC INSULATION.

Conformity is checked as specified in 6.7 and 8.1.

6.4.3 BASIC INSULATION

CLEARANCES, CREEPAGE DISTANCES and solid insulation forming BASIC INSULATION between ACCESSIBLE parts and HAZARDOUS LIVE parts shall meet the requirements of 6.7.

Conformity is checked as specified in 6.7.

6.4.4 Impedance

An impedance used as a primary means of protection shall meet all the following requirements:

a) it shall limit the current or voltage to not more than the applicable level of 6.3.2;

b) it shall be RATED for the maximum WORKING VOLTAGE and for the amount of power that it will dissipate;

c) CLEARANCE and CREEPAGE DISTANCE between terminations of the impedance shall meet the applicable requirements of 6.7 for BASIC INSULATION.

Conformity is checked by inspection, by measuring the voltage or current to confirm that they do not exceed the levels of 6.3.2, and by measuring CLEARANCE and CREEPAGE DISTANCE as specified in 6.7.

6.5 Additional means of protection in case of SINGLE FAULT CONDITIONS

6.5.1 General

ACCESSIBLE parts shall be prevented from becoming HAZARDOUS LIVE in SINGLE FAULT CONDITION. The primary means of protection (see 6.4) shall be supplemented by one of a), b), c) or d). Alternatively one of the single means of protection e) or f) shall be used. See Figure 4 and Annex D.

a) PROTECTIVE BONDING (see 6.5.2);

b) SUPPLEMENTARY INSULATION (see 6.5.3);

c) automatic disconnection of the supply (see 6.5.5);

d) current- or voltage-limiting device (see 6.5.6);

e) REINFORCED INSULATION (see 6.5.3);

f) PROTECTIVE IMPEDANCE (see 6.5.4).

Conformity is checked by inspection and as specified in 6.5.2 to 6.5.6.

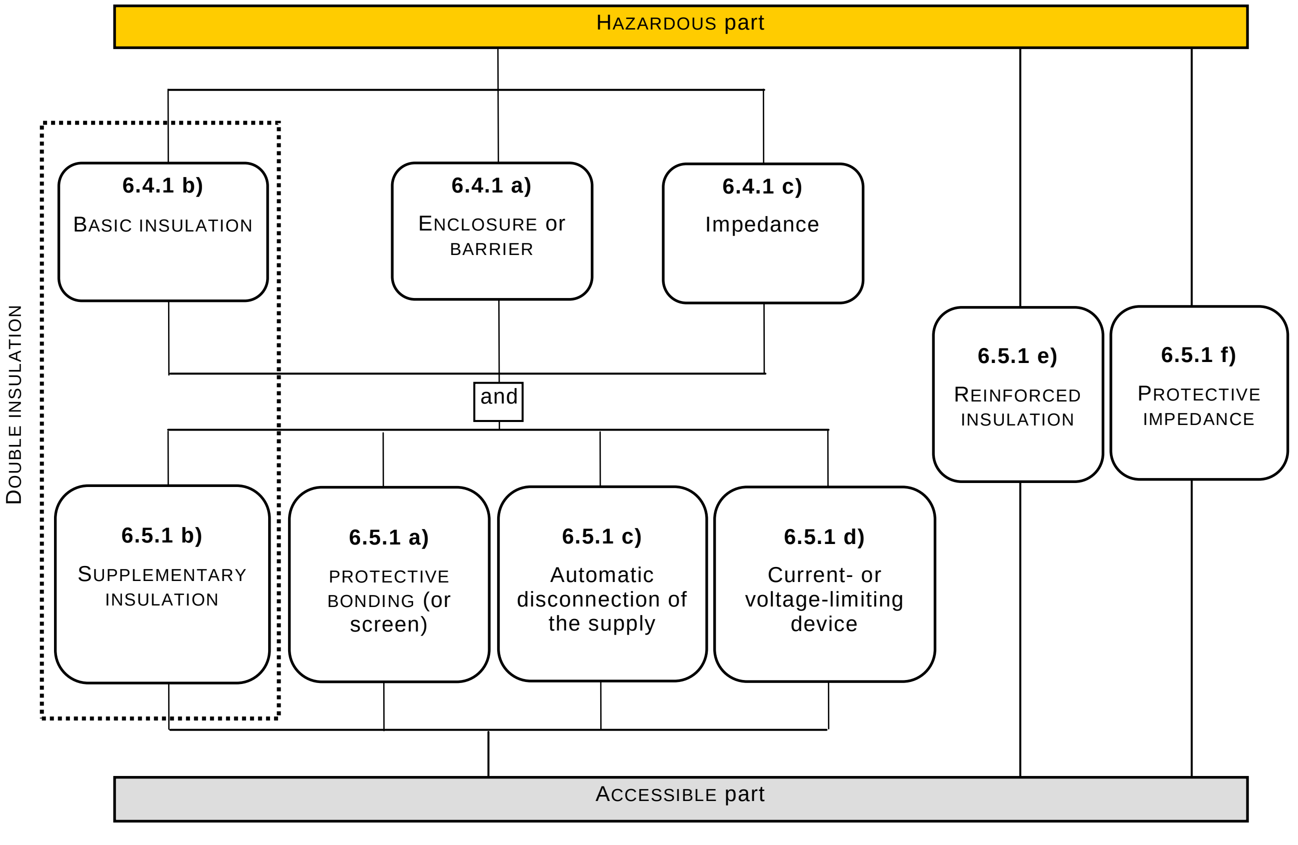


Figure 4 – Acceptable arrangement of protective means against electric shock

6.5.2 PROTECTIVE BONDING

6.5.2.1 General

ACCESSIBLE conductive parts shall be bonded to the PROTECTIVE CONDUCTOR TERMINAL if they could become HAZARDOUS LIVE in case of a single fault of the primary means of protection specified in 6.4. Alternatively, such ACCESSIBLE parts shall be separated from parts which are HAZARDOUS LIVE by a conductive protective screen bonded to the PROTECTIVE CONDUCTOR TERMINAL.

Conformity is checked as specified in 6.5.2.2 to 6.5.2.6.

6.5.2.2 Integrity of PROTECTIVE BONDING

The integrity of PROTECTIVE BONDING shall be assured as specified below.

a) PROTECTIVE BONDING shall consist of directly connected structural parts or discrete conductors, or both. It shall withstand all thermal and dynamic stresses to which it could be subjected before one of the overcurrent protective means specified in 9.6 disconnects the equipment from the supply.

b) Soldered connections subject to mechanical stress shall be mechanically secured independently from the soldering. Such connections shall not be used for other purposes such as fixing constructional parts.

c) Screw connections shall be secured against loosening.

d) If a part of the equipment is removable by an OPERATOR, the PROTECTIVE BONDING for the remainder of the equipment shall not be interrupted (except for a part that also carries the MAINS input connection to the whole equipment).

e) Unless they are specifically designed for electrical inter-connection and meet the requirements of 6.5.2.4, movable conductive connections, for example, hinges, slides, etc., shall not be the sole PROTECTIVE BONDING path.

f) The exterior metal braid of cables shall not be regarded as PROTECTIVE BONDING, even if connected to the PROTECTIVE CONDUCTOR TERMINAL.

g) If power from the MAINS supply is passed through equipment for use by other equipment, means shall also be provided for passing the protective conductor through the equipment to protect the other equipment. The impedance of the protective conductor path through the equipment shall not exceed that specified in 6.5.2.4.

h) Protective conductors may be bare or insulated. Insulation shall be green-and-yellow, except in the following cases:

   1) for earthing braids, either green-and-yellow or colourless-transparent;

   2) for internal protective conductors, and other conductors connected to the PROTECTIVE CONDUCTOR TERMINAL in assemblies such as ribbon cables, busbars, flexible printed wiring, etc., any colour may be used provided that no HAZARD is likely to arise from non-identification of the protective conductor.

Equipment using PROTECTIVE BONDING shall be provided with a TERMINAL that is suitable for connection to a protective conductor and meets the requirements of 6.5.2.3.

Conformity is checked by inspection.

6.5.2.3 PROTECTIVE CONDUCTOR TERMINAL

PROTECTIVE CONDUCTOR TERMINALS shall meet the following requirements.

a) The contact surfaces shall be metal.

NOTE 1 Materials of PROTECTIVE BONDING systems should be chosen to minimize electro-chemical corrosion between the TERMINAL and the protective conductor, or any other metal in contact with them.

b) The integral protective conductor connection of an appliance inlet shall be regarded as the PROTECTIVE CONDUCTOR TERMINAL.

c) For equipment provided with a rewirable flexible cord and for PERMANENTLY CONNECTED EQUIPMENT, the PROTECTIVE CONDUCTOR TERMINAL shall be located near the MAINS supply TERMINALS.

d) If the equipment does not require connection to a MAINS supply, but nevertheless has a circuit or part which is required to be protectively earthed, the PROTECTIVE CONDUCTOR TERMINAL shall be located near the TERMINALS of that circuit for which protective earthing is necessary. If this circuit has external TERMINALS, the PROTECTIVE CONDUCTOR TERMINAL shall also be external.

e) PROTECTIVE CONDUCTOR TERMINALS for MAINS CIRCUITS shall be at least equivalent in current-carrying capacity to the MAINS supply TERMINALS.

f) Plug-in type PROTECTIVE CONDUCTOR TERMINALS combined with other TERMINALS and intended to be connected and disconnected without the use of a TOOL, shall be designed so that the protective conductor connection makes first and breaks last with respect to the other connections. Examples include plugs and appliance couplers for MAINS cords and connector assemblies of plug-in units.

g) If the PROTECTIVE CONDUCTOR TERMINAL is also used for other bonding purposes, the protective conductor shall be applied first and secured independently of other connections.

The protective conductor shall be connected in such a way that it is unlikely to be removed during servicing that does not require disconnection of the protective conductor.

h) For equipment in which the protective conductor is required for protection against a single fault in a measuring circuit, the following shall apply:

1) the PROTECTIVE CONDUCTOR TERMINAL and protective conductor shall have at least the current RATING of the measuring TERMINALS;

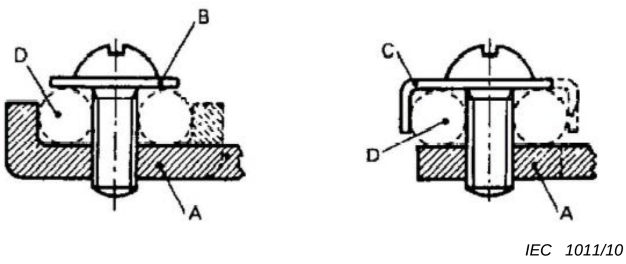
2) the PROTECTIVE BONDING shall not be interrupted by any switching or interrupting device.

i) FUNCTIONAL EARTH TERMINALS (for example, measuring earth TERMINALS) shall allow a connection which is independent from the connection of the protective conductor.

NOTE 2 Equipment may be equipped with FUNCTIONAL EARTH TERMINALS, irrespective of the protective means taken.

j) If the PROTECTIVE CONDUCTOR TERMINAL is a binding screw assembly (see Figure 5), it shall be of a suitable size for the bond wire, but with a thread size no smaller than 4,0 mm, with at least three turns of the screw engaged.

k) The contact pressure required for a bonding connection shall not be capable of being reduced by deformation of materials forming part of the connection.



Key

A fixed part

B washer or clamping plate

C anti-spread device

D conductor space

Figure 5 – Examples of binding screw assemblies

Conformity is checked by inspection. Conformity for j) is also checked by the following test.

The binding screw assembly is to be tightened and loosened three times, together with the least favourable conductor to be secured, using the tightening torques specified in Table 2. All parts of the binding screw assembly shall withstand this test without mechanical failure.

Table 2 – Tightening torque for binding screw assemblies

Thread size mm	4,0	5,0	6,0	8,0	10,0
Tightening torque N·m	1,2	2,0	3,0	6,0	10,0

6.5.2.4 Impedance of PROTECTIVE BONDING of plug-connected equipment

The impedance between the PROTECTIVE CONDUCTOR TERMINAL and each ACCESSIBLE part for which PROTECTIVE BONDING is specified shall not exceed 0,1 Ω. If the equipment has a non-detachable power cord, the impedance between the protective conductor plug pin of the MAINS cord and each ACCESSIBLE part for which PROTECTIVE BONDING is specified shall not exceed 0,2 Ω.

Conformity is checked by applying a test current for 1 min and then calculating impedance. The test current is the greater of

a) *25 A a.c. r.m.s. at RATED MAINS frequency or d.c.,*

b) *a current equal to twice the RATED current of the equipment.*

If the equipment contains overcurrent protection devices for all poles of the MAINS supply, and if the wiring on the supply side of the overcurrent protection devices cannot become connected to ACCESSIBLE conductive parts in the case of a single fault, the test current need not be more than twice the RATED current of the internal overcurrent protection devices.

6.5.2.5 Impedance of PROTECTIVE BONDING of PERMANENTLY CONNECTED EQUIPMENT

PROTECTIVE BONDING of PERMANENTLY CONNECTED EQUIPMENT shall be of low impedance.

Conformity is checked by applying a test current of twice the value of the overcurrent protection means specified in the equipment installation instructions for the building supply MAINS CIRCUIT for 1 min between the PROTECTIVE CONDUCTOR TERMINAL and each ACCESSIBLE conductive part for which PROTECTIVE BONDING is required. The voltage between them shall not exceed 10 V a.c. r.m.s. or d.c.

If the equipment contains overcurrent protection devices for all poles of the MAINS supply, and if the wiring on the supply side of the overcurrent protection devices cannot become connected to ACCESSIBLE conductive parts in the case of a single fault, the test current need not be more than twice the RATED current of the internal overcurrent protection devices.

6.5.2.6 Transformer PROTECTIVE BONDING screen

If the transformer is fitted with a screen for PROTECTIVE BONDING purposes that is separated only by BASIC INSULATION from a winding that is connected to a HAZARDOUS LIVE circuit, the screen shall satisfy the requirements of 6.5.2.2 a) and b), and be of low impedance.

Conformity is checked by inspection and by one of the following tests:

a) *a test current of twice the value of the overcurrent protection means of the winding is applied for 1 min between the screen and the PROTECTIVE CONDUCTOR TERMINAL. The voltage between them shall not exceed 10 V a.c. r.m.s. or d.c.;*

b) *the test of 6.5.2.4 using test current twice the value of the overcurrent protection means of the winding. The impedance shall not exceed 0,1 Ω.*

NOTE If test a) or b) is carried out, a specially prepared sample transformer having an extra lead-out wire from the free end of the screen is used to ensure that the current during the test passes through the screen.

6.5.3 SUPPLEMENTARY INSULATION and REINFORCED INSULATION

CLEARANCES, CREEPAGE DISTANCES and solid insulation forming SUPPLEMENTARY INSULATION or REINFORCED INSULATION shall meet the applicable requirements of 6.7.

Conformity is checked as specified in 6.7.

6.5.4 PROTECTIVE IMPEDANCE

A PROTECTIVE IMPEDANCE shall limit the current or voltage to the levels of 6.3.1 in NORMAL CONDITION and 6.3.2 in SINGLE FAULT CONDITION.

Insulation between the terminations of the PROTECTIVE IMPEDANCE shall meet the requirements of 6.7 for DOUBLE INSULATION or REINFORCED INSULATION.

A PROTECTIVE IMPEDANCE shall be one or more of the following:

a) an appropriate single component which shall be constructed, selected and tested so that safety and reliability for protection against electric shock is assured. In particular, the component shall be:
   1) RATED for twice the maximum WORKING VOLTAGE;
   2) if a resistor, RATED for twice the power dissipation for the maximum WORKING VOLTAGE.
b) a combination of components.

A PROTECTIVE IMPEDANCE shall not be a single electronic device that employs electron conduction in a vacuum, gas or semiconductor

Conformity is checked by inspection, by measuring the current or voltage to confirm that they do not exceed the applicable levels of 6.3 and by measuring CLEARANCES and CREEPAGE DISTANCES as specified in 6.7. Conformity of a single component is checked by inspection of its RATINGS.

6.5.5 Automatic disconnection of the supply

An automatic disconnection device shall meet both the following requirements.

a) It shall be RATED to disconnect the load within the time specified in Figure 2.
b) It shall be RATED for the maximum RATED load conditions of the equipment.

Conformity is checked by inspection of the device specification. In case of doubt, the device is tested to check that it disconnects the supply within the required time.

6.5.6 Current- or voltage-limiting device

A current- or voltage-limiting device shall meet all the following requirements:

a) it shall be RATED to limit the current or voltage to the levels not exceeding the values of 6.3.2;
b) it shall be RATED for the maximum WORKING VOLTAGE and, if applicable, for the maximum operational current;
c) CLEARANCE and CREEPAGE DISTANCE between the terminations of the current or voltage-limiting device shall meet the applicable requirements of 6.7 for SUPPLEMENTARY INSULATION.

Conformity is checked by inspection, by measuring the voltage or current to confirm that they do not exceed the levels of 6.3.2, and by measuring CLEARANCES and CREEPAGE DISTANCES as specified in 6.7.

6.6 Connections to external circuits

6.6.1 General

In NORMAL CONDITION and in SINGLE FAULT CONDITION of the equipment, no ACCESSIBLE parts of the equipment and no ACCESSIBLE parts of an external circuit shall become HAZARDOUS LIVE as a result of connecting the external circuit to the equipment.

NOTE 1 External circuits are all circuits connected to TERMINALS of the equipment.

NOTE 2 For connection to MAINS supply source, see 6.10.

Protection shall be achieved by separation of circuits, unless short-circuiting of the separation could not cause a HAZARD.

The manufacturer's instructions or equipment markings shall include the following information, if applicable, for each external TERMINAL:

a) RATED conditions at which the TERMINAL has been designed to operate while maintaining safety (maximum RATED input/output voltage, specific type of connector, designated use, etc.);
b) RATING of the insulation required for the external circuit to conform to the requirements for protection against electric shock, arising from the connection to the TERMINAL, in NORMAL CONDITION and SINGLE FAULT CONDITION.

Conformity is checked by:

1) *inspection;*
2) *the determinations of 6.2;*
3) *the measurements of 6.3 and 6.7;*
4) *the voltage test of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7).*

6.6.2 TERMINALS for external circuits

ACCESSIBLE conductive parts of TERMINALS that receive a charge from an internal capacitor shall not be HAZARDOUS LIVE 10 s after interruption of the supply.

Conformity is checked by inspection, and by the determination of ACCESSIBLE conductive parts as specified in 6.2 and in case of doubt by measurement of the remaining voltage or charge.

6.6.3 Circuits with TERMINALS which are HAZARDOUS LIVE

These circuits shall not be connected to ACCESSIBLE conductive parts, except for circuits which are not MAINS CIRCUITS, and which are designed to be operated with one TERMINAL contact at earth potential. In such cases, the ACCESSIBLE conductive parts shall not be HAZARDOUS LIVE.

If such a circuit is also designed to be operated with one ACCESSIBLE TERMINAL contact (signal low) floating at a voltage which is not HAZARDOUS LIVE, this TERMINAL contact is permitted to be connected to a common FUNCTIONAL EARTH TERMINAL or system (for example, a coaxial screening system). This common FUNCTIONAL EARTH TERMINAL or system is also permitted to be connected to other ACCESSIBLE conductive parts.

Conformity is checked by inspection.

6.6.4 TERMINALS for stranded conductors

TERMINALS for stranded conductors that are intended to be connected during installation, maintenance, or operation of the equipment shall be located or shielded so that there is no possibility of accidental contact between HAZARDOUS LIVE parts of different polarity or between such parts and other ACCESSIBLE parts, even if a strand of a conductor escapes from a TERMINAL. This requirement does not apply to connections that are only to be made at the manufacturing facility.

Conformity is checked by inspection after fully inserting a stranded conductor *a) with the maximum length of insulation removed as specified by the equipment manufacturer, or*

b) with an 8 mm length of insulation removed if no specification is given by the equipment manufacturer.

With one of the strands free, the free strand shall not touch parts of different polarity or other ACCESSIBLE parts, when bent in every possible direction, without tearing back the insulation or making sharp bends.

TERMINALS of circuits carrying HAZARDOUS LIVE voltage or current shall be anchored, fitted or designed so that conductors will not work loose when they are tightened, loosened or when connections are made.

Conformity is checked by manual test and inspection.

6.7 Insulation requirements

6.7.1 The nature of insulation

6.7.1.1 General

Insulation between circuits and ACCESSIBLE parts (see 6.2) or between separate circuits consists of a combination of CLEARANCES, CREEPAGE DISTANCES and solid insulation. When used to provide protection against a HAZARD, the insulation needs to withstand the electric stresses that are caused by the voltages that may appear on the MAINS supply or in the equipment.

Electric stresses originating from MAINS include:

a) WORKING VOLTAGE across the insulation. This WORKING VOLTAGE is normally the line-to-neutral voltage of the MAINS supply (also see Annex I);
b) TRANSIENT OVERVOLTAGES that may occasionally appear on the line conductors. The magnitude of the overvoltages depends on the OVERVOLTAGE CATEGORY and the line-to-neutral voltage of the MAINS supply;
c) short-term TEMPORARY OVERVOLTAGES that may occur between the line conductor and earth in electrical installations. These TEMPORARY OVERVOLTAGES may have a value of the line-to-neutral voltage of the MAINS supply plus 1 200 V, and may last up to 5 s;
d) long-term TEMPORARY OVERVOLTAGES that may occur between the line conductor and earth in electrical installations. These TEMPORARY OVERVOLTAGES may have a value of the line-to neutral voltage of the MAINS supply plus 250 V and may last longer than 5 s.

NOTE See IEC 60364-4-44, Clause 442 for additional information on these TEMPORARY OVERVOLTAGES.

The requirements for insulation depend on:

1) the required level of insulation (BASIC INSULATION, SUPPLEMENTARY INSULATION, or REINFORCED INSULATION);
2) the maximum TRANSIENT OVERVOLTAGE that may appear on the circuit, either as a result of an external event (such as a lightning strike or a switching transient), or as the result of the operation of the equipment;
3) the maximum WORKING VOLTAGE (including steady-state and recurring peak voltages);
4) the POLLUTION DEGREE of the micro-environment;
5) the maximum TEMPORARY OVERVOLTAGE that may occur in a MAINS CIRCUIT because of a fault in the MAINS distribution system.

6.7.1.2 CLEARANCES

Required CLEARANCES depend on the factors in 6.7.1.1 a) to d) as well as the RATED altitude for operation. If the equipment is RATED to operate at an altitude greater than 2 000 m, all CLEARANCES shall be multiplied by the applicable factor of Table 3.

Table 3 – Multiplication factors for CLEARANCES of equipment RATED for operation at altitudes up to 5 000 m

RATED operating altitude m	Multiplication factor
Up to 2 000	1,00
2 001 to 3 000	1,14
3 001 to 4 000	1,29
4 001 to 5 000	1,48

See Annex C for details of how to measure CLEARANCES.

6.7.1.3 CREEPAGE DISTANCES

Required CREEPAGE DISTANCES depend on the factors in 6.7.1.1 a) to d) as well as the Comparative Tracking Index (CTI) of the insulating material.

Materials are separated into four groups according to their 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

These CTI values refer to values obtained, in accordance with IEC 60112, on samples of the relevant material specifically made for the purpose and tested with solution A. For materials where the CTI value is not known, material group IIIb is assumed.

For glass, ceramics, or other inorganic insulating materials which do not track, there are no requirements for CREEPAGE DISTANCES.

A CREEPAGE DISTANCE may be split in several portions of different materials and/or have different POLLUTION DEGREES if one of the CREEPAGE DISTANCES is dimensioned to withstand the total voltage or if the total distance is dimensioned according to the material having the lowest CTI and the highest POLLUTION DEGREE.

See Annex C for details of how to measure CREEPAGE DISTANCES.

6.7.1.4 Solid insulation

The requirements for solid insulation depend on the factors in 6.7.1.1 a) to d).

The term “solid insulation” is used to describe many different types of construction, including monolithic blocks of insulating material and insulation subsystems composed of multiple insulating materials, organized in layers or otherwise.

The electric strength of a thickness of solid insulation is considerably greater than that of the same thickness of air. The insulating distances through solid insulation are therefore typically smaller than the distances through air. As a result, electric fields in solid insulation are typically higher, and often are less homogeneous.

Solid insulation material may contain gaps or voids. When a solid insulation system is constructed from layers of solid materials, there are also likely to be gaps or voids between layers. These voids will perturb the electric field so that a disproportionately large part of the electric field is located in the void, potentially causing ionization within the void, resulting in partial discharge. These partial discharges will influence the adjacent solid insulation and may reduce its service life.

Solid insulation is not a renewable medium: damage is cumulative over the life of the equipment. Solid insulation is also subject to ageing and to degradation from repeated high voltage testing.

6.7.1.5 Requirements for insulation according to type of circuit

Requirements for insulation in particular types of circuits are specified as follows:

a) in 6.7.2 for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II with a nominal supply voltage up to 300 V;

NOTE 1 See Annex I for nominal voltages of MAINS supplies.

b) in 6.7.3 for secondary circuits separated from the circuits in a) only by means of a transformer;

c) in K.1 for MAINS CIRCUITS of OVERVOLTAGE CATEGORY III or IV or for OVERVOLTAGE CATEGORY II over 300 V;

d) in K.2 for secondary circuits separated from the circuits in c) only by means of a transformer

e) in K.3 for circuits that have one or more of the following characteristics:

  1) the maximum possible TRANSIENT OVERVOLTAGE is limited by the supply source or within the equipment to a known level below the level assumed for the MAINS CIRCUIT;

  2) the maximum possible TRANSIENT OVERVOLTAGE is above the level assumed for the MAINS CIRCUIT;

  3) the WORKING VOLTAGE is the sum of voltages from more than one circuit, or is a mixed voltage;

  4) the WORKING VOLTAGE includes a recurring peak voltage that may include a periodic non-sinusoidal waveform or a non-periodic waveform that occurs with some regularity;

  5) the WORKING VOLTAGE has a frequency above 30 kHz.

NOTE 2 Requirements for insulation of measuring circuits are specified in IEC 61010-2-030.

NOTE 3 See K.3 for requirements for switching circuits such as a switching power supply.

NOTE 4 The assumed transient overvoltage level for mains is equal to the required rated impulse voltage of equipment in Table 443.2 of IEC 60364-4-44:2007/AMD1:2015.

6.7.2 Insulation for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II with a nominal supply voltage up to 300 V

6.7.2.1 CLEARANCES and CREEPAGE DISTANCES

CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS shall meet the values of Table 4 taking the following into account.

a) The values in Table 4 are for BASIC INSULATION and SUPPLEMENTARY INSULATION. Values for REINFORCED INSULATION shall be twice the values for BASIC INSULATION.

b) Minimum CLEARANCE for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION for POLLUTION DEGREE 3 is 0,8 mm.

c) If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCES shall be multiplied by the applicable factor of Table 3.

Conformity is checked by inspection and measurement.

TABLE 4 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V

Voltage line-to-neutral a.c. r.m.s. or d.c.	Values for CLEARANCE	Values for CREEPAGE DISTANCE								
		Printed wiring board material		Other insulating material						
		POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
		All material groups	Material groups I, II, IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
≤150	0,5	0,5	0,5	0,5	0,8	1,1	1,6	2,0	2,2	2,5
>150 ≤ 300	1,5	1,5	1,5	1,5	1,5	2,1	3,0	3,8	4,1	4,7

Linear interpolation of the CREEPAGE DISTANCES is allowed.

Coatings that meet the requirements of Annex H when applied to the outer surfaces of printed wiring boards reduce the POLLUTION DEGREE of the coated area to POLLUTION DEGREE 1.

Conformity of coatings is checked as specified in Annex H.

6.7.2.2 Solid insulation

6.7.2.2.1 General

Solid insulation of MAINS CIRCUITS shall withstand the electric and mechanical stresses that may occur in NORMAL USE, in all RATED environmental conditions (see 1.4), during the intended life of the equipment.

NOTE The manufacturer should take the expected life of the equipment into account when selecting insulating materials.

Conformity is checked by inspection, and by the a.c. test of 6.8.3.1 or the d.c. test of 6.8.3.2, using the applicable voltage from Table 5 for 1 min.

Table 5 – Test voltages for solid insulation in MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V

Voltage line-to-neutral a.c. r.m.s. or d.c.	1 min a.c. test voltage		1 min d.c. test voltage	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION
V	V	V	V	V
≤ 150	1 350	2 700	1 900	3 800
>150 ≤ 300	1 500	3 000	2 100	4 200

Solid insulation shall also meet the following requirements, as applicable:

a) for solid insulation used as an ENCLOSURE or PROTECTIVE BARRIER, the requirements of Clause 8;

b) for moulded and potted parts, the requirements of 6.7.2.2.2;

c) for inner layers of printed wiring boards, the requirements of 6.7.2.2.3;

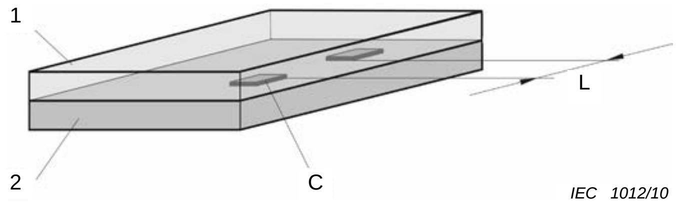
d) for thin-film insulation, the requirements of 6.7.2.2.4.

Conformity is checked as specified in 6.7.2.2.2 to 6.7.2.2.4, and in Clause 8, as applicable.

6.7.2.2.2 Moulded and potted parts

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located on an interface between the same two layers moulded together shall be separated by at least 0,4 mm (see Figure 6, item L) after the moulding is completed.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key

1 Layer 1

2 Layer 2

C Conductor

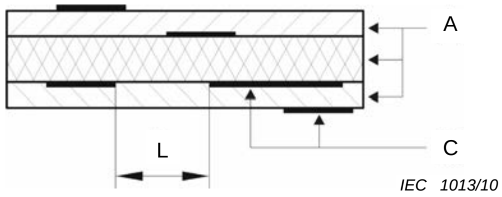
L Distance between conductors

Figure 6 – Distance between conductors on an interface between two layers

6.7.2.2.3 Inner insulating layers of printed wiring boards

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers shall be separated by at least 0,4 mm (see Figure 7, item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key

L Distance between adjacent conductors

A Layers

C Conductors

Figure 7 – Distance between adjacent conductors along an interface of two inner layers

REINFORCED INSULATION of inner insulating layers of printed wiring boards shall also have adequate electric strength through the respective layers. One of the following methods shall be used:

a) the thickness of the insulation is at least 0,4 mm;

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation is assembled from at least two separate layers of printed wiring board materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of Table 5 for BASIC INSULATION;

Conformity is checked by inspection of the manufacturer's specifications.

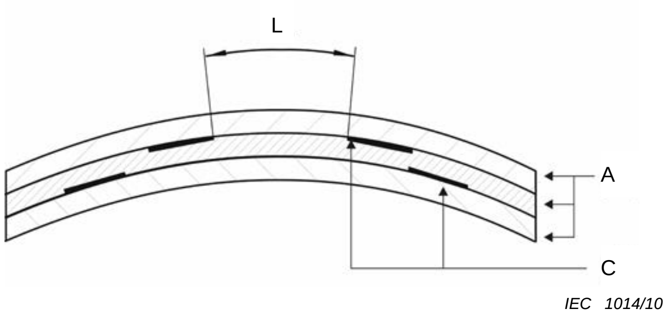
c) the insulation is assembled from at least two separate layers of printed wiring board materials, and the combination of layers is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of Table 5 for REINFORCED INSULATION.

Conformity is checked by inspection of the manufacturer's specifications.

6.7.2.2.4 Thin-film insulation

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers (see Figure 8, item L).shall be separated by the applicable CLEARANCE and CREEPAGE DISTANCE of 6.7.2.1.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key

L Distance between adjacent conductors

A Layers of thin-film material such as tape and polyester film

C Conductors

NOTE There may be air present between the layers

Figure 8 – Distance between adjacent conductors located between the same two layers

REINFORCED INSULATION through the layers of thin-film insulation shall also have adequate electric strength. One of the following methods shall be used:

a) the thickness through the insulation is at least 0,4 mm;

Conformity is checked by inspection and either by measurement of the part or by inspection of the manufacturer's specifications.

b) the insulation consists of at least two separate layers of thin-film materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of Table 5 for BASIC INSULATION;

Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation consists of at least three separate layers of thin-film materials, any two of which have been tested to exhibit adequate electric strength.

Conformity is checked by the a.c. test of 6.8.3.1 or the d.c. test of 6.8.3.2 applied to two of the three layers using the applicable voltage for REINFORCED INSULATION of Table 5 for 1 min.

NOTE For the purposes of this test a special sample may be assembled with only two layers of the material.

6.7.3 Insulation for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V

6.7.3.1 General

In this standard, secondary circuits are circuits where separation from MAINS CIRCUITS is achieved by a transformer in which the primary windings are separated from the secondary windings by REINFORCED INSULATION, DOUBLE INSULATION, or a screen connected to the PROTECTIVE CONDUCTOR TERMINAL.

NOTE These circuits are assumed to be subjected to lower TRANSIENT OVERVOLTAGE levels than the MAINS CIRCUIT.

6.7.3.2 CLEARANCES

CLEARANCES for secondary circuits shall meet a) or b):

a) for BASIC INSULATION and SUPPLEMENTARY INSULATION, meet the values of Table 6, or for REINFORCED INSULATION meet twice the values of Table 6;

b) pass the voltage test of 6.8 using the applicable test voltage from Table 6.

The following adjustments apply:

1) values for test voltages for REINFORCED INSULATION are 1,6 times the values for BASIC INSULATION;

2) if the equipment is RATED to operate at an altitude greater than 2 000 m, the values for CLEARANCES are multiplied by the applicable factor of Table 3;

3) minimum CLEARANCE is 0,2 mm for POLLUTION DEGREE 2 and 0,8 mm for POLLUTION DEGREE 3.

Conformity is checked by inspection and measurement and for b) by the a.c. test of 6.8.3.1 with a duration of at least 5 s, or by the 1 min d.c. test of 6.8.3.2, using the applicable test voltage from Table 6. The value of the d.c. test voltage is √2 times the a.c. r.m.s. test voltage.

Table 6 – CLEARANCES and test voltages for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY II up to 300 V

Secondary WORKING VOLTAGE		MAINS voltage, line-to-neutral, OVERVOLTAGE CATEGORY II			
		≤ 150 V a.c. r.m.s.		> 150 V ≤ 300 V a.c. r.m.s.	
a.c. r.m.s. V	**d.c. or a.c. peak** V	**CLEARANCE** mm	**Test voltage** V a.c. r.m.s.	**CLEARANCE** mm	**Test voltage** V a.c. r.m.s.
16	22,6	0,10	500	0,48	830
3050	42,4	0,11	510	0,50	840
100	70	0,12	520	0,53	860
150	140	0,13	540	0,61	900
300	210	0,16	580	0,69	940
600	420	0,39	770	0,94	1 040
1 000	840	1,01	1 070	1,61	1 450
1 250	1 400	1,92	1 630	2,52	1 970
1 600	1 750	2,50	1 960	3,16	2 280
2 000	2 240	3,39	2 390	4,11	2 730
2 500	2 800	4,49	2 890	5,30	3 230
3 200	3 500	6,02	3 520	6,91	3 850
4 000	4 480	8,37	4 390	9,16	4 660
5 000	5 600	10,9	5 320	11,6	5 610
6 300	7 000	14,0	6 590	14,9	6 960
8 000	8 820	18,2	8 270	19,1	8 620
10 000	11 200	23,9	10 400	24,7	10 700
12 500	14 000	30,7	12 900	31,6	13 300
16 000	17 500	39,6	16 100	40,5	16 400
20 000	22 400	52,5	20 400	53,5	20 700
25 000	28 000	67,9	25 300	68,9	25 600
32 000	35 000	87,9	31 600	89,0	32 000
40 000	44 800	117	40 400	118	40 700
50 000	56 000	151	50 300	153	50 800
63 000	70 000	196	62 800	198	63 400
	88 200	258	79 400	260	80 000
Linear interpolation is allowed.					

6.7.3.3 CREEPAGE DISTANCES

CREEPAGE DISTANCES for BASIC INSULATION or SUPPLEMENTARY INSULATION for secondary circuits shall meet the applicable values of Table 7, based on the WORKING VOLTAGE which stresses the insulation. Values for REINFORCED INSULATION are twice the values for BASIC INSULATION.

Conformity is checked by inspection and measurement.

Coatings that meet the requirements of Annex H when applied to the outer surfaces of printed wiring boards reduce the POLLUTION DEGREE of the coated area to POLLUTION DEGREE 1.

Conformity of coatings is checked as specified in Annex H.

Table 7 – CREEPAGE DISTANCES for secondary circuits

Secondary WORKING VOLTAGE a.c. r.m.s. or d.c.	Printed wiring board material		Other insulating material						
	POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
	All material groups	Material groups I, II or IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III[b]
V	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	0,025	0,04	0,08	0,40	0,40	0,40	1,00	1,00	1,00
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05
16	0,025	0,04	0,10	0,45	0,45	0,45	1,10	1,10	1,10
20	0,025	0,04	0,11	0,48	0,48	0,48	1,20	1,20	1,20
25	0,025	0,04	0,125	0,50	0,50	0,50	1,25	1,25	1,25
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3
40	0,025	0,04	0,16	0,56	0,80	1,10	1,4	1,6	1,8
50	0,025	0,04	0,18	0,60	0,85	1,20	1,5	1,7	1,9
63	0,040	0,063	0,20	0,63	0,90	1,25	1,6	1,8	2,0
80	0,063	0,10	0,22	0,67	0,95	1,3	1,7	1,9	2,1
100	0,10	0,16	0,25	0,71	1,00	1,4	1,8	2,0	2,2
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4
160	0,25	0,40	0,32	0,80	1,1	1,6	2,0	2,2	2,5
200	0,40	0,63	0,42	1,00	1,4	2,0	2,5	2,8	3,2
250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0
320	0,75	1,6	0,75	1,60	2,2	3,2	4,0	4,5	5,0
400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0
630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0
800	2,4	4,0	2,4	4,0	5,6	8,0	10,0	11	12,5
1 000	3,2 [a]	5,0 [a]	3,2	5,0	7,1	10,0	12,5	14	16
1 250			4,2	6,3	9,0	12,5	16	18	20
1 600			5,6	8,0	11	16	20	22	25
2 000			7,5	10,0	14	20	25	28	32
2 500			10,0	12,5	18	25	32	36	40
3 200			12,5	16	22	32	40	45	50
4 000			16	20	28	40	50	56	63
5 000			20	25	36	50	63	71	80
6 300			25	32	45	63	80	90	100
8 000			32	40	56	80	100	110	125
10 000			40	50	71	100	125	140	160
12 500			50	63	90	125			
16 000			63	80	110	160			
20 000			80	100	140	200			
25 000			100	125	180	250			
32 000			125	160	220	320			
40 000			160	200	280	400			
50 000			200	250	360	500			
63 000			250	320	450	600			

[a] For voltages above 1 000 V, CREEPAGE DISTANCES on printed wiring board material are the same as for other insulators of the same Material Group.

[b] Material group IIIb is not recommended for application in POLLUTION DEGREE 3 above 630 V.

Linear interpolation is allowed.

6.7.3.4 Solid insulation

6.7.3.4.1 General

Solid insulation in secondary circuits shall withstand the electrical and mechanical stresses that may occur in NORMAL USE, in all RATED environmental conditions (see 1.4), during the intended life of the equipment.

NOTE The manufacturer should take the expected life of the equipment into account when selecting insulating materials.

Conformity is checked by both of the following tests:

a) by the voltage test of 6.8.3.1 for 5 s using the applicable test voltage of Table 6 for BASIC INSULATION or SUPPLEMENTARY INSULATION. For REINFORCED INSULATION the values are multiplied by 1,6;

b) additionally, if the WORKING VOLTAGE exceeds 300 V, by the voltage test of 6.8.3.1 for 1 min with a test voltage of 1,5 times the WORKING VOLTAGE for BASIC INSULATION or SUPPLEMENTARY INSULATION and twice the WORKING VOLTAGE for REINFORCED INSULATION.

Solid insulation shall also meet the following requirements, as applicable:

1) for solid insulation used as an ENCLOSURE or PROTECTIVE BARRIER, the requirements of Clause 8;
2) for moulded and potted parts, the requirements of 6.7.3.4.2;
3) for inner insulating layers of printed wiring boards, the requirements of 6.7.3.4.3;
4) for thin-film insulation, the requirements of 6.7.3.4.4.

Conformity is checked as specified in 6.7.3.4.2 to 6.7.3.4.4 and Clause 8, as applicable.

6.7.3.4.2 Moulded and potted parts

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers shall be separated by the applicable minimum distance of Table 8 (see Figure 6 item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

Table 8 – Minimum values for distance or thickness (see 6.7.3.4.2 to 6.7.3.4.4)

Peak value of the a.c. or d.c. WORKING VOLTAGE or recurring peak voltage	Minimum value	Peak value of the a.c. or d.c. WORKING VOLTAGE or recurring peak voltage	Minimum value
kV	mm	kV	mm
>0,046 7 ≤ 0,33	0,05	>8,0 ≤ 10	3,5
>0,33 ≤ 0,8	0,1	>10 ≤ 12	4,5
>0,8 ≤ 1,0	0,15	>12 ≤15	5,5
>1,0 ≤ 1,2	0,2	>15 ≤ 20	8
>1,2 ≤ 1,5	0,3	>20 ≤ 25	10
>1,5 ≤ 2,0	0,45	>25 ≤ 30	12,5
>2,0 ≤ 2,5	0,6	>30 ≤ 40	17
>2,5 ≤ 3,0	0,8	>40 ≤ 50	22
>3,0 ≤ 4,0	1,2	>50 ≤ 60	27
>4,0 ≤ 5,0	1,5	>60 ≤ 80	35
>5,0 ≤ 6,0	2	>80 ≤ 100	45
>6,0 ≤ 8,0	3		

6.7.3.4.3 Inner insulating layers of printed wiring boards

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers shall be separated by the applicable minimum distance of Table 8 (see Figure 7, item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

REINFORCED INSULATION of inner insulating layers of printed wiring boards shall also have adequate electric strength through the respective layers. One of the following methods shall be used:

a) the thickness of the insulation is at least the applicable minimum distance of Table 8;

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation is assembled from at least two separate layers of printed wiring board materials, each of which is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of Table 6 for BASIC INSULATION;

   Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation is assembled from at least two separate layers of printed wiring board materials, and the combination of layers is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of Table 6 multiplied by 1,6.

   Conformity is checked by inspection of the manufacturer's specifications.

6.7.3.4.4 Thin-film insulation

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers (see Figure 8, item L) shall be separated by at least the applicable CLEARANCE and CREEPAGE DISTANCE of 6.7.3.2 and 6.7.3.3.

Conformity is checked by measurement or by inspection of the part or the manufacturer's specifications.

REINFORCED INSULATION through the layers of thin-film insulation shall also have adequate electric strength. One of the following methods shall be used:

a) the thickness of the insulation is at least the applicable value of Table 8;

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation consists of at least two separate layers of thin-film materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of Table 6 for BASIC INSULATION;

   Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation consists of at least three separate layers of thin-film materials, any two of which have been tested to exhibit adequate electric strength.

   Conformity is checked by the a.c. test of 6.8.3.1 with a duration of at least 1 min, or, for circuits stressed only by d.c., the 1 min d.c. test of 6.8.3.2, using the applicable test voltage from Table 6 multiplied by 1,6, applied to two of the three layers.

   NOTE For the purposes of this test a special sample may be assembled with only two layers of the material.

6.8 Procedure for voltage tests

6.8.1 General

The following test procedures apply to type testing, and deterioration of the test specimen may occur. Further use of the test specimen may not be appropriate.

Test equipment for the voltage tests is specified in IEC 61180-1 and IEC 61180-2.

ACCESSIBLE insulating parts of the ENCLOSURE are covered with metal foil everywhere except around TERMINALS. For test voltages up to 10 kV a.c. peak or d.c., the distance from foil to TERMINAL is not more than 20 mm. For higher voltages it is the minimum to prevent flashover. For guidance to these minimum distances, see Table 9.

NOTE The distances of Table 9 will prevent flashover between foil and TERMINALS.

Table 9 – Distances between TERMINALS and foil

Test voltage	Distance
kV	mm
10	20
20	45
30	70
50	130
70	195
100	290

ACCESSIBLE parts of controls with parts made of insulating material are wrapped in metal foil or have soft conductive material pressed against them.

The foil is applied after the humidity preconditioning (if applicable) and connected to the low TERMINAL of the test voltage generator.

When verifying a CLEARANCE within equipment, it is necessary to ensure that the specified voltage appears at the CLEARANCE. PROTECTIVE IMPEDANCE, impedances and voltage-limiting devices in parallel with the insulation to be tested may be disconnected.

The equipment is not energized during the tests.

When verifying CLEARANCES, the values for test voltages given in 6.7 apply to tests performed at 2 000 m. For other test site altitudes, the corrections of Table 10 are applied for CLEARANCES but not for tests of solid insulation.

NOTE 1 The electric testing of CLEARANCES will also stress the associated solid insulation.

NOTE 2 Where two or more protective means are used in combination (see 6.5.1), the voltages specified for REINFORCED INSULATION might be applied to parts of circuits which are not required to withstand these voltages. To test the complete equipment appropriately it may be necessary to test subassemblies separately.

Table 10 – Correction factors according to test site altitude for test voltages for CLEARANCES

	Correction factors			
Test voltage peak	**≥327 V < 600 V**	**≥600 V < 3 500 V**	**≥3 500 V < 25 kV**	**≥25 kV**
Test voltage r.m.s.	**≥231 V < 424 V**	**≥424 V < 2 475 V**	**≥2 475 V < 17,7 kV**	**≥17,7 kV**
Test site altitude m				
0	1,08	1,16	1,22	1,24
500	1,06	1,12	1,16	1,17
1 000	1,04	1,08	1,11	1,12
2 000	1,00	1,00	1,00	1,00
3 000	0,96	0,92	0,89	0,88
4 000	0,92	0,85	0,80	0,79
5 000	0,88	0,78	0,71	0,70
Linear interpolation is allowed.				

6.8.2 Humidity preconditioning

Unless otherwise specified in this standard, the equipment is subjected to humidity preconditioning before the voltage tests. The equipment is not energized during preconditioning.

This treatment need not be applied to parts that are clearly unlikely to be influenced by humidity and temperature.

Parts which can be removed without the use of a TOOL are removed and subjected to humidity preconditioning together with the main part.

Preconditioning is carried out in a humidity chamber containing air with a humidity of 93 % RH ± 3 % RH. The temperature of the air in the chamber is maintained at 40 °C ± 2 °C.

Before applying humidity, the equipment is brought to a temperature of 42 °C ± 2 °C, normally by keeping it at this temperature for at least 4 h before the humidity preconditioning.

The air in the chamber is stirred and the chamber is designed so that condensation will not precipitate on the equipment.

The equipment remains in the chamber for 48 h, after which it is removed and allowed a recovery period of 2 h under the environmental conditions of 4.3.1, with the covers of non-ventilated equipment removed.

The tests are performed and completed within 1 h of the end of the recovery period after humidity preconditioning. Parts that have been removed are re-assembled or not, whichever is less favourable.

6.8.3 Test procedures

6.8.3.1 The a.c. voltage test

The voltage tester shall have a regulated output capable of maintaining the test voltage throughout the test. The waveform of the test voltage shall be substantially sinusoidal. This requirement is fulfilled if the ratio between the peak value and the r.m.s. value is $\sqrt{2} \pm 3$ *%.*

The a.c. voltage test is performed at the RATED MAINS frequency, but for equipment RATED for MAINS frequencies including 50 Hz and 60 Hz, a test at either 50 Hz or at 60 Hz is sufficient.

The test voltage is raised uniformly from 0 V to the specified value within 5 s and held at that value for at least the specified time.

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test.

6.8.3.2 The d.c. voltage test

The d.c. test voltage shall be substantially free of ripple. This requirement is fulfilled if the ratio between the peak value of the voltage and the average value is 1,0 $\pm$ *3 %.*

The d.c. test voltage is raised uniformly from 0 V to the specified value within 5 s and held at that value for at least the specified time.

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test.

6.8.3.3 The impulse voltage test

The test shall be conducted for five impulses of each polarity with an interval of at least 1 s between impulses. The impulse voltage test is carried out with a 1,2/50 μ*s waveform (see Figure 1 of IEC 61180-1). The wave shape of each impulse shall be observed (see Note 1).*

When verifying CLEARANCES within equipment by an impulse voltage test, it is necessary to ensure that the specified impulse voltage appears at the CLEARANCE. PROTECTIVE IMPEDANCE and voltage-limiting devices in parallel with the insulation to be tested shall be disconnected.

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test, but partial discharges are allowed. Partial discharge will be indicated by a step in the resulting wave shape which will occur earlier in successive impulses. Breakdown on the first impulse may either indicate a complete failure of the insulation system or the operation of overvoltage limiting devices in the equipment.

NOTE 1 If there are overvoltage limiting devices in the equipment, care must be taken to examine the waveshape to ensure that their operation is not taken to indicate insulation failure. Distortions of the impulse voltage which do not change from impulse to impulse may be caused by operation of an overvoltage limiting device and do not indicate a (partial) breakdown of solid insulation.

NOTE 2 Partial discharges in voids can lead to partial notches of extremely short durations in the waveform which may be repeated in the course of an impulse.

6.9 Constructional requirements for protection against electric shock

6.9.1 General

If a failure could cause a HAZARD:

a) the security of wiring connections subject to mechanical stresses shall not depend on soldering;

b) screws securing removable covers shall be captive if their length determines a CLEARANCE or CREEPAGE DISTANCE between ACCESSIBLE conductive parts and HAZARDOUS LIVE parts;

c) accidental loosening or freeing of the wiring, screws, etc., shall not cause ACCESSIBLE parts to become HAZARDOUS LIVE;

d) CLEARANCES and CREEPAGE DISTANCES between the ENCLOSURE and HAZARDOUS LIVE parts shall not be reduced below the values for BASIC INSULATION by loosening of parts or wires.

NOTE Screws or nuts with lock washers are not regarded as likely to become loose, nor are wires which are mechanically secured by more than soldering alone.

Conformity is checked by inspection and by measurement of CLEARANCES and CREEPAGE DISTANCES.

6.9.2 Insulating materials

The following shall not be used as insulation for safety purposes:

a) materials which can easily be damaged (for example, lacquer, enamel, oxides, anodic films);

b) non-impregnated hygroscopic materials (for example, paper, fibres, fibrous materials).

Conformity is checked by inspection.

6.9.3 Colour coding

Green-and-yellow insulation shall not be used except for:

a) protective earth conductors;

b) PROTECTIVE BONDING conductors;

c) potential equalization conductors for safety purposes;

d) functional earth conductors.

Conformity is checked by inspection.

6.10 Connection to the MAINS supply source and connections between parts of equipment

6.10.1 MAINS supply cords

The following requirements apply to non-detachable MAINS supply cords and to detachable MAINS supply cords supplied with the equipment.

Cords shall be RATED for the maximum current for the equipment and the cable used shall meet the requirements of IEC 60227 or IEC 60245. Cords certified or approved by a recognized testing authority are regarded as meeting this requirement.

If a cord is likely to contact hot external parts of the equipment, it shall be made of suitably heat-resistant material.

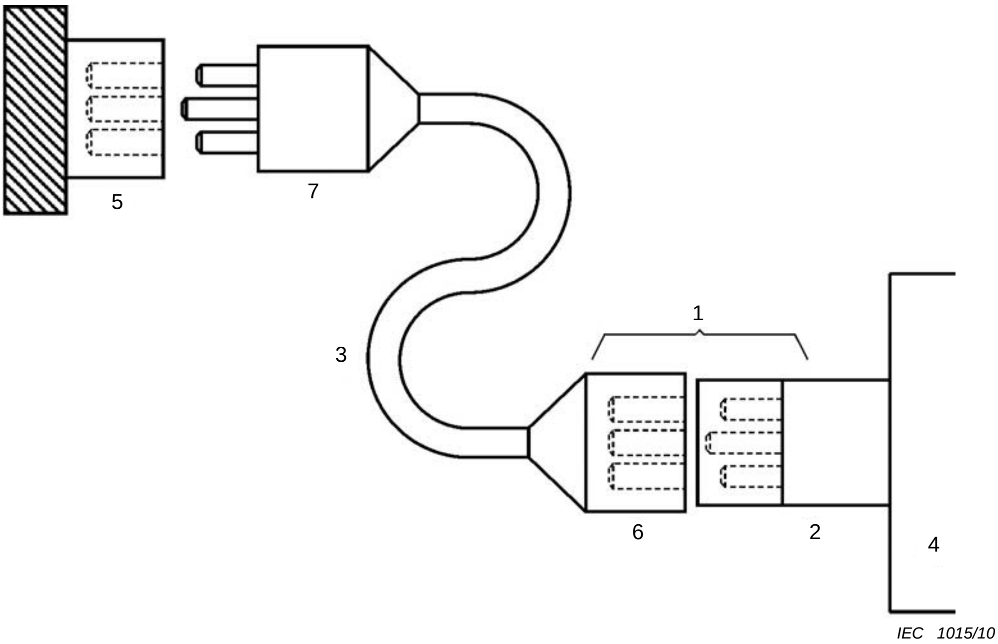
If the cord is detachable, both the cord and the appliance inlet shall have adequate temperature RATINGS.

Conductors coloured green-and–yellow shall be used only for connection to PROTECTIVE CONDUCTOR TERMINALS.

Detachable MAINS supply cords with MAINS connectors according to IEC 60320 shall either meet the requirements of IEC 60799, or shall be RATED at least for the current RATING of the MAINS connector fitted to the cord.

Figure 9 explains the terminology for MAINS supply cords.

Conformity is checked by inspection and, where necessary, by measurement.



Key

1	Appliance coupler	5	Fixed mains socket-outlet
2	Appliance inlet	6	Mains connector
3	Cable	7	Mains plug
4	Equipment		

Figure 9 – Detachable MAINS supply cords and connections

6.10.2 Fitting of non-detachable MAINS supply cords

6.10.2.1 Cord entry

MAINS supply cords shall be protected against abrasion and sharp bends at the point where the cord enters the equipment, by one of the following means:

a) an inlet or bushing with a smoothly rounded opening;

b) a reliably fixed flexible cord guard made of insulating material protruding beyond the inlet opening by at least five times the overall diameter of a cord with the largest cross-sectional area which can be fitted. For flat cords, the larger cross-sectional dimension is taken as the overall diameter.

Conformity is by inspection, and if needed by measurement of dimensions.

6.10.2.2 Cord anchorage

The cord anchorage shall relieve the conductors of the cord from strain, including twisting, where they are connected within the equipment, and shall protect the insulation of the conductors from abrasion. The protective earth conductor, if any, shall be the last to take the strain if the cord slips in its anchorage.

Cord anchorages shall meet the following requirements:

a) the cord shall not be clamped by a screw which bears directly on the cord;
b) knots in the cord shall not be used;
c) it shall not be possible to push the cord into the equipment to an extent which could cause a HAZARD;
d) failure of the cord insulation in a cord anchorage which has metal parts shall not cause ACCESSIBLE conductive parts to become HAZARDOUS LIVE.
e) it shall not be possible to loosen the cord anchorage without the use of a TOOL.
f) it shall be designed so that cord replacement does not cause a HAZARD, and it shall be clear how the relief from strain is provided.

A compression bushing shall not be used as a cord anchorage unless it is suitable for use with the MAINS supply cord supplied with it or specified for it by the manufacturer.

Conformity is checked by inspection and by the following push-pull test:

For each combination of cord and bushing, the cord is pushed into the equipment manually, as far as possible. It is then subjected 25 times to a steady pull of the value shown in Table 11, applied for 1 s each time in the least favourable direction. Immediately afterwards it is subjected for 1 min to a torque of the value shown in Table 11. The torque shall be applied as close as possible to the external end of the cord anchorage or bushing.

Table 11 – Values for physical tests on cord anchorages

Mass of equipment kg	Force for pull test N	Torque for torque test N·m
≤1	30	0,10
>1 ≤ 4	60	0,25
>4	100	0,35

After the tests:

1) *the cord shall not have been damaged;*
2) *the cord shall not have been displaced longitudinally by more than 2 mm;*
3) *there shall be no signs of strain at the point where the anchorage clamps the cord;*
4) *CLEARANCES and CREEPAGE DISTANCES shall not have been reduced below the applicable values;*
5) *the cord shall pass the a.c. voltage test of 6.8.3.1 (without humidity preconditioning) with a duration of at least 1 min as follows:*
   i) *for equipment with a protective earth conductor, the test is made between the protective conductor and the line and neutral conductors joined together, with the test voltage from Table 5 or Table K.8 for BASIC INSULATION for the appropriate line-to-neutral voltage;*

ii) *for equipment without a protective earth conductor, the test is made between* ACCESSIBLE *conductive parts of the equipment and the line and neutral conductors joined together, with the test voltage from Table 5 or Table K.8 for* REINFORCED INSULATION *for the appropriate line-to-neutral voltage.*

6.10.3 Plugs and connectors

Plugs and connectors for connecting equipment to the MAINS supply, including appliance couplers used to connect detachable MAINS supply cords, shall conform to the relevant specifications for plugs, socket-outlets and connectors.

If the equipment is designed to be supplied only at voltages below the level of 6.3.2 a) in NORMAL CONDITION or SINGLE FAULT CONDITION, or from a source used solely to supply that equipment, the plugs of the power supply cord shall not fit into the socket-outlets of MAINS supply systems at voltages above the RATED supply voltage of the equipment. MAINS-type plugs and sockets shall not be used for purposes other than connection of a MAINS supply.

If plug pins of cord-connected equipment receive a charge from an internal capacitor, the pins shall not be HAZARDOUS LIVE 5 s after disconnection of the supply.

On equipment with accessory MAINS socket-outlets:

a) if the outlet can accept a standard MAINS supply plug, there shall be a marking as specified in 5.1.3 e);
b) if the outlet has a TERMINAL contact for a protective earth conductor, the input MAINS supply connection to the equipment shall include a protective earth conductor connected to a PROTECTIVE CONDUCTOR TERMINAL.

Conformity is checked by inspection. For plugs receiving a charge from an internal capacitor, the measurements of 6.3 are made to establish that the levels of 6.3.1 c) are not exceeded.

6.11 Disconnection from supply source

6.11.1 General

Except as specified in 6.11.2, equipment shall be provided with a means for disconnecting it from each electrical supply source, whether external or internal to the equipment. The disconnecting means shall disconnect all current-carrying conductors.

NOTE Equipment may also be provided with a switch or other disconnecting device for functional purposes.

Conformity is checked as specified in 6.11.3.1 to 6.11.4.3.

6.11.2 Exceptions

A disconnecting device is not required if a short circuit or overload cannot cause a HAZARD.

NOTE Examples include:

a) equipment intended for supply only from a low energy source such as a small battery or signal powered equipment;

b) equipment intended only for connection to an impedance protected supply. Such a supply is one having an impedance of such value that, if the equipment is subjected to an overload or short circuit, the RATED supply conditions are not exceeded and no HAZARD can arise;

c) equipment which constitutes an impedance protected load. Such a load is a component without discrete overcurrent or thermal protection, and of such impedance that the RATING is not exceeded if the circuit of which the component is a part is subjected to an overload or short circuit.

Conformity is checked by inspection. In case of doubt, a short circuit or overload is applied to check that no HAZARD *can arise.*

6.11.3 Requirements according to type of equipment

6.11.3.1 PERMANENTLY CONNECTED EQUIPMENT and multi-phase equipment

PERMANENTLY CONNECTED EQUIPMENT and multi-phase equipment shall employ a switch or circuit-breaker as the means for disconnection.

If a switch is not part of the equipment, documentation for equipment installation shall specify that:

a) a switch or circuit-breaker must be included in the installation;

b) it must be suitably located and easily reached;

c) it must be marked as the disconnecting device for the equipment.

Conformity is checked by inspection.

6.11.3.2 Single-phase cord-connected equipment

Single-phase cord-connected equipment shall have one of the following as a disconnecting device:

a) a switch or circuit-breaker;

b) an appliance coupler which can be disconnected without the use of a TOOL;

c) a separable plug, without a locking device, to mate with a socket-outlet in the building.

Conformity is checked by inspection.

6.11.4 Disconnecting devices

6.11.4.1 General

If a disconnecting device is part of the equipment, it shall be located electrically as close as practicable to the supply. Power-consuming components shall not be electrically located between the supply source and the disconnecting device, except that electromagnetic interference suppression circuits are permitted to be located on the supply side of the disconnecting device.

Conformity is checked by inspection.

6.11.4.2 Switches and circuit-breakers

An equipment circuit-breaker employed as a disconnecting device shall meet the relevant requirements of IEC 60947-2 and be suitable for the application.

An equipment switch employed as a disconnecting device shall meet the relevant requirements of IEC 60947-3, and be suitable for the application.

If a switch or a circuit-breaker is used as a disconnecting device, it shall be marked to indicate this function. If there is only one device – one switch or one circuit-breaker – symbols 9 and 10 of Table 1 are sufficient if the symbols are marked on or adjacent to the switch or circuit-breaker.

A switch shall not be incorporated in a MAINS supply cord.

A switch or circuit-breaker shall not interrupt a protective earth conductor.

Conformity is checked by inspection.

6.11.4.3 Appliance couplers and plugs

If an appliance coupler or separable plug is used as the disconnecting device, it shall be readily identifiable and easily reached by the OPERATOR. For single-phase PORTABLE EQUIPMENT, a plug on a cord of length not greater than 3 m is considered to be easily reached. The protective earth conductor of an appliance coupler shall be connected before the supply conductors and disconnected after them.

Conformity is checked by inspection.

7 Protection against mechanical HAZARDS

7.1 General

The equipment shall not cause a mechanical HAZARD in NORMAL USE, or cause a HAZARD in a SINGLE-FAULT CONDITION that might not be easily noticed. Mechanical HAZARDS include, but are not limited to, the following:

a) sharp edges which could cause cuts (see 7.2);
b) moving parts that could crush body parts or penetrate the skin (see 7.3);
c) unstable equipment that could fall on a person while in use or while being moved (see 7.4);
d) falling equipment, resulting from breakage of the carrying device (see 7.5), wall mounting bracket (see 7.6) or other support part (see 7.5); and
e) expelled parts from the equipment (see 7.7).

NOTE If the equipment consists of two or more units, the value of the mass refers to the mass of each individual unit. However, if one or more units are intended to be attached to and supported by another unit, these units are treated as a single unit.

Conformity is checked as specified in 7.2 to 7.7.

7.2 Sharp edges

All easily-touched parts of the equipment shall be smooth and rounded so as not to cause injury during NORMAL USE of the equipment.

Unless the fault presents an obvious HAZARD, easily-touched parts of the equipment shall not cause an injury in SINGLE FAULT CONDITION.

Conformity is checked by inspection and, if necessary, by application of an object that represents a finger in size, shape and hardness, to check for abrasions or cuts.

NOTE An acceptable procedure is outlined in UL 1439.

7.3 Moving parts

7.3.1 General

HAZARDS from moving parts shall not exceed a tolerable level except as specified in 7.3.2. The conditions specified in 7.3.4 and 7.3.5 are considered to represent a tolerable level. If these conditions are not met, a RISK assessment shall be carried out according to 7.3.3 or Clause 17.

NOTE In this context moving parts mean parts that are driven by an energy source other than directly applied human or animal effort.

Conformity is checked as specified in 7.3.2, 7.3.3, 7.3.4, 7.3.5 and Clause 17 as applicable.

7.3.2 Exceptions

If it is not feasible for operating reasons to prevent certain moving parts from causing a potential HAZARD, access is permitted in the following circumstances.

a) Equipment with easily-touched moving parts which are obviously intended to operate on parts or materials external to the equipment, for example drilling and mixing equipment, shall be designed to minimize inadvertent touching of these moving parts (for example, by guards or handles).

b) If, during routine maintenance outside NORMAL USE, it is unavoidable for technical reasons for an OPERATOR to perform a function which requires access to moving parts that could cause a HAZARD, access is permitted if all of the following precautions have been taken:

   1) access is not possible without the use of a TOOL;

   2) the instructions for the RESPONSIBLE BODY include a statement that OPERATORS must be trained before being allowed to perform the hazardous operation;

   3) there are warning markings on covers or parts which have to be removed to obtain access, prohibiting access by untrained OPERATORS. As an alternative, symbol 14 of Table 1 shall be placed on the covers or parts, with the warnings included in the documentation.

Conformity is checked by inspection.

7.3.3 RISK assessment for mechanical HAZARDS to body parts

RISKS shall be reduced to a tolerable level by at least the applicable minimum protective measure of Table 12, taking into account the severity, probability of exposure and possibility of avoiding the HAZARD.

Conformity is checked by evaluation of the RISK assessment documentation to ensure that the RISKS have been eliminated or that only TOLERABLE RISKS remain.

Table 12 – Protective measures against mechanical HAZARDS to body parts

Mechanical HAZARD conditions			Minimum protective measures [d]
Severity [a]	**Probability of exposure** [b]	**Possibility of avoiding the HAZARD** [c]	
S	E_2	P_2	C
S	E_2	P_1	C
S	E_1	P_2	C
S	E_1	P_1	B
M	E_2	P_2	B
M	E_2	P_1	A
M	E_1	P_2	A
M	E_1	P_1	No action

[a] **Severity:**

M = Moderate HAZARDS, sufficient to bruise or scratch a body part.

S = Serious HAZARDS, sufficient to break bones or dismember a body part.

[b] **Probability of exposure:**

E_1 = Exposure is not intended during NORMAL USE

E_2 = Exposure is intended during NORMAL USE

[c] **Possibility of avoiding the HAZARD:**

P_1 = Possibility of avoidance:

- The motion is visible and velocity is low enough for body parts to be removed without being trapped, or
- an audible or visible alarm is activated before body parts can be trapped.

P_2 = No possibility of avoidance:

Conditions other than P1.

[d] **Minimum protective measures:**

A = Low level measures; warning markings, audible or visual signals or instructions for use.

B = Moderate measures; emergency switches, PROTECTIVE BARRIERS or covers removable only with a TOOL, distances (see ISO 13857), or separations (see ISO 13854 or EN 349).

C = Stringent measures; interlocks, PROTECTIVE BARRIERS or covers removable only with a TOOL and with instructions to disconnect from the power source.

7.3.4 Limitation of force and pressure

The physical levels specified below are not considered to be hazardous. They are based on a combination of contact force, duration and contact area. The levels below shall be met in NORMAL CONDITION and SINGLE-FAULT CONDITION.

The maximum tolerable continuous contact pressure is 50 N/cm^2, with a maximum force of 150 N.

The maximum tolerable temporary force for body contact areas of at least 3 cm^2 is 250 N for a maximum duration of 0,75 s.

Conformity is checked by inspection and, in case of doubt, by measurement. For the purposes of this subclause, the width of a finger is considered to be 1,2 cm and the width of any other body part is considered to be 5,0 cm. The contact area will be determined to be the width of the body part multiplied by the width of the moving part, or the cross-sectional contact area of the moving part, if smaller.

EXAMPLE In a particular case, a finger might be able to touch a moving part that is 0,9 mm wide. If the part can exert a continuous force of 40 N, then the contact pressure would be calculated as:

Area = 1,2 cm × 0,09 cm = 0,108 cm²

Pressure = 40 N / 0,108 cm² = 370 N/cm²

In this case, the pressure exceeds the permissible limit even though the force is less than the permissible limit. In this case, the moving part would be considered to be hazardous.

7.3.5 Gap limitations between moving parts

7.3.5.1 Gap limitations between moving parts – Access normally allowed

If the force and pressure of the moving parts exceed the limits of 7.3.4 and if a body part could be inserted between moving parts, the width of the gap shall not decrease from a value larger than the minimum gap of Table 13 for that body part to a value smaller than the minimum gap in NORMAL CONDITION and SINGLE-FAULT CONDITION.

Conformity is checked by inspection and, in case of doubt, by measurement.

7.3.5.2 Gap limitations between moving parts – Access normally prevented

While parts are moving, gaps between moving parts into which body parts could be inserted shall not increase to more than the acceptable gap of Table 14, in NORMAL CONDITION and SINGLE-FAULT CONDITION.

Conformity is checked by inspection and, in case of doubt, by measurement.

Table 13 – Minimum maintained gaps to prevent crushing for different body parts

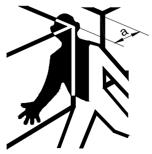
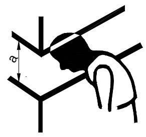
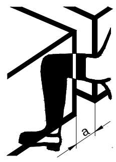
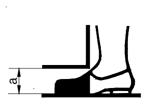
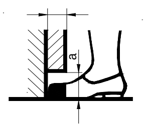
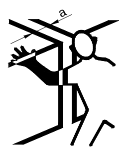
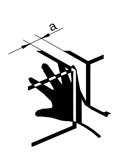
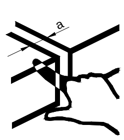
Part of body	Minimum gap (a) to avoid crushing mm	Illustration
Torso	500	
Head	300	
Leg	180	
Foot	120	
Toes	50	
Arm	120	
Hand, wrist, fist	100	
Finger	25	
The values in this table are for adults. For equipment that may be operated by children or youths, consideration should be given to smaller dimensions.		

Table 14 – Maximum gaps to prevent access for different body parts

Part of body	Maximum Gap (a) [a] to prevent access mm
Head	120
Foot	35
Finger	4
The values in this table are for adults. For equipment that may be operated by children or youths, consideration should be given to smaller dimensions.	
[a] See Table 13 for examples of gap (a).	

7.4 Stability

Equipment and assemblies of equipment not secured to the building structure before operation shall be physically stable.

If means are provided to ensure that stability is maintained after the opening of drawers, etc. by an OPERATOR, either these means shall be automatic or there shall be a warning marking to apply the means.

Each castor and support foot shall be RATED to support a load not less than its normal load, or the castors and support feet shall be tested according to d) or e), below.

Conformity is checked by inspection and by carrying out each of the following tests, if applicable, to ensure that the equipment will not overbalance. Containers contain the RATED amount of substance which provides the least favourable conditions of NORMAL USE. Castors are in their least favourable position of NORMAL USE. Doors, drawers, etc. are closed unless otherwise specified below.

a) Equipment other than HAND-HELD EQUIPMENT is tilted in each direction to an angle of 10° from its normal position.

b) Equipment which has both a height of 1 m or more and a mass of 25 kg or more, and all floor-standing equipment, has a force applied at its top, or at a height of 2 m if the equipment has a height of more than 2 m. The force is 250 N, or 20 % of the weight of the equipment, whichever is less, and is applied to all surfaces in directions which could cause the equipment to topple. Stabilizers used in NORMAL USE, and doors, drawers, etc., intended to be opened by an OPERATOR, are in their least favourable positions.

c) Floor-standing equipment has a force of 800 N applied downwards at the point of maximum moment to:

1) all horizontal working surfaces;

2) other surfaces providing an obvious ledge and which are not more than 1 m above floor level.

Doors, drawers, etc. are closed, except that those intended to be opened by an OPERATOR are in their least favourable positions.

d) The castor or support foot that supports the greatest load (M) is loaded with 4 times that load (4M).

e) The castor or support foot that supports the greatest load is removed from the equipment and the equipment is placed on a flat surface.

NOTE During this test, the unit should be secured so that complete overturning is not possible if this could present a HAZARD to those conducting the test. However, this restraint must not interfere with the determination of whether the unit would overbalance.

7.5 Provisions for lifting and carrying

7.5.1 General

Equipment or parts having a mass of 18 kg or more shall be provided with a means for lifting and carrying, or directions shall be given in the documentation.

Conformity is checked as specified in 7.5.2 and 7.5.3.

7.5.2 Handles and grips

If carrying handles or grips are fitted to the equipment, or supplied with it, they shall be capable of withstanding a force of four times the weight of the equipment.

Conformity is checked by inspection and by the following test.

A single handle or grip is subjected to a force corresponding to four times the weight of the equipment. Unless the handle mounting screws (if any) are secured against loosening, one screw is removed before performing these tests. The force is applied uniformly over a 70 mm width at the centre of the handle or grip, without clamping. The force is steadily increased so that the test value is attained after 10 s and maintained for a period of 1 min.

If more than one handle or grip is fitted, the force is distributed between the handles or grips in the same proportion as in NORMAL USE. If the equipment is fitted with more than one handle or grip but is so designed that it may readily be carried by only one handle or grip, the total force is applied to each handle or grip.

After the tests the handles or grips shall not have broken loose from the equipment and there shall not be any permanent distortion, cracking or other evidence of failure which could cause a HAZARD.

7.5.3 Lifting devices and supporting parts

Parts of lifting devices and parts that support heavy loads shall be RATED for the maximum load or shall be tested to withstand four times the maximum static load.

Conformity is checked by inspection of the RATINGS of the parts, or by the following test:

A total load equal to four times the maximum load is placed at the least favourable position of a RATED load in NORMAL USE.

During the test, no part of a lifting device or a load support shall break or deform to an extent that could cause a HAZARD.

7.6 Wall mounting

Mounting brackets on equipment intended to be mounted on a wall or ceiling shall withstand a force of four times the weight of the equipment.

Conformity is checked after mounting the equipment in accordance with the manufacturer's instructions, using the fasteners and wall construction specified. Adjustable brackets are adjusted to the position that will give the maximum projection from the wall.

If no wall construction is specified, a 12 mm ± 2 mm thick plasterboard (drywall) on nominal 50 mm × 100 mm ± 10 mm studs at 400 mm ± 10 mm centres is used as the support surface. Fasteners are applied as specified in the installation documentation or, if not specified, are positioned in the plasterboard between the studs.

The mounting brackets are then subjected to a weight equal to four times the weight of the equipment, acting vertically through the centre of gravity. The test weight is applied gradually and is increased from zero to full load in 5 s to 10 s, then maintained for 1 min.

If more than one fastener is specified for mounting a bracket, then one fastener is removed and the test is repeated with a weight equal to two times the weight of the equipment.

After the tests, there shall be no damage to the bracket or the mounting surface which could cause a HAZARD.

7.7 Expelled parts

Equipment shall contain or limit the energy of parts which could cause a HAZARD if expelled in the event of a fault.

The means of protection against expelled parts shall not be removable without the aid of a TOOL.

NOTE Clause 8 does not address HAZARDS from parts that could be expelled from inside the equipment.

Conformity is checked by inspection after application of the relevant fault conditions of 4.4.

8 Resistance to mechanical stresses

8.1 General

Equipment shall not cause a HAZARD when subjected to mechanical stresses likely to occur in NORMAL USE.

The normal energy protection level required is 5 J. Levels below 5 J but not less than 1 J are permitted provided that all the following criteria are met:

a) the lower level is justified by a RISK assessment carried out by the manufacturer (see Clause 17);
b) when the equipment is installed in its intended application it cannot easily be touched by unauthorized persons or the general public;
c) in NORMAL USE, the equipment is only accessed for occasional operations such as adjustment, programming or maintenance;
d) the equipment is marked with an IK code in accordance with IEC 62262 or with symbol 14 of Table 1, and the RATED energy level and test method are stated in the accompanying documentation. For non-metallic ENCLOSURES with a minimum RATED ambient temperature below 2 °C, the stated value shall be that applicable to the lowest RATED ambient temperature. If impact energies used are between IK values of IEC 62262, any IK marking shall be for the nearest lower value.

Conformity is checked by inspection and by performing each of the following tests on the ENCLOSURE *as applicable:*

1) the static test of 8.2.1;

2) for equipment other than HAND-HELD EQUIPMENT and DIRECT PLUG-IN EQUIPMENT, the impact test of 8.2.2 at the energy level specified above. If the specified energy level is not 5 J the test of IEC 62262 is an alternative to the impact test of 8.2.2, using test Eha (pendulum test) or test Ehc (vertical hammer) described in IEC 60068-2-75;

3) except for FIXED EQUIPMENT and equipment with a mass over 100 kg, the test of 8.3.1 or 8.3.2, as applicable. The equipment is not operated during the tests.

An ENCLOSURE with an impact RATING of at least IK08 by the ENCLOSURE manufacturer, and that would clearly have met the criteria of 8.1 i) to 8.1 vii) after that test, need not be subjected to the test of 8.2.2.

Parts which do not form part of an ENCLOSURE are not subjected to the tests of 8.2.1 and 8.2.2.

After the tests, visibly damaged windows and displays shall be inspected to check that HAZARDOUS LIVE parts exceeding the values of 6.3.2 have not become ACCESSIBLE, and insulation of all other parts of the ENCLOSURE which could have been affected by the tests shall pass the voltage tests of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7). In addition the equipment is inspected to check that:

i) *there have been no leaks of corrosive or harmful substances;*

ii) *ENCLOSURES show no cracks which could cause a HAZARD;*

iii) *CLEARANCES are not less than their permitted values;*

iv) *the insulation of internal wiring remains undamaged;*

v) *PROTECTIVE BARRIERS necessary for safety have not been damaged or loosened;*

vi) *no moving parts are exposed, except as permitted by 7.3;*

vii) *there has been no damage which could cause spread of fire.*

8.2 ENCLOSURE rigidity tests

8.2.1 Static test

The equipment is held firmly against a rigid support and subjected to a force of 30 N applied by the hemispherical end of a hard rod of 12 mm diameter. The rod is applied to each part of the ENCLOSURE which could easily be touched when the equipment is ready for use, including any part of the bottom of PORTABLE EQUIPMENT, and which could cause a HAZARD if distorted.

In case of doubt whether a non-metallic ENCLOSURE will pass this test at an elevated temperature, this test is performed after the equipment is operated at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher, until a steady-state condition is reached. The equipment is disconnected from the supply source before the test is performed.

8.2.2 Impact test

Bases, covers, etc., intended to be removed and replaced by an OPERATOR have their fixing screws tightened using a torque likely to be applied in NORMAL USE. With the equipment held firmly against a rigid support, the impact is applied to any point on surfaces which are easily touched in NORMAL USE and which would be likely to cause a HAZARD if damaged.

NOTE A support is considered to be sufficiently rigid if its displacement is less than or equal to 0,1 mm under the effect of an impact directly applied and whose energy corresponds to the degree of protection.

Non-metallic ENCLOSURES of equipment with a minimum RATED ambient temperature below 2 °C are cooled to the minimum RATED ambient temperature, then tested within 10 min.

Impacts may be applied to empty ENCLOSURES if it is clear that the equipment would have passed the test if it had been tested in complete condition.

If an ENCLOSURE is damaged by an impact but meets the pass criteria, a new ENCLOSURE may be used for the next impact.

FIXED EQUIPMENT is mounted as specified in the installation instructions. Other equipment is held firmly against a rigid support and each test point is subjected to one impact by a smooth steel sphere with a mass 500 g ± 25 g and with a diameter of approximately 50 mm.

The impact test can be performed with the equipment mounted at 90° to its normal position to allow both the method of Figure 10 a) and Figure 10 b).

Figure 10 a) shows the impact applied to a horizontal surface, with the sphere allowed to fall freely from a height of X.

Figure 10 b) shows the impact applied to a vertical surface, with the sphere suspended by a cord and allowed to fall as a pendulum through a vertical distance of X.

In both cases the dimension X is determined from Table 15 according to the energy level to be applied.

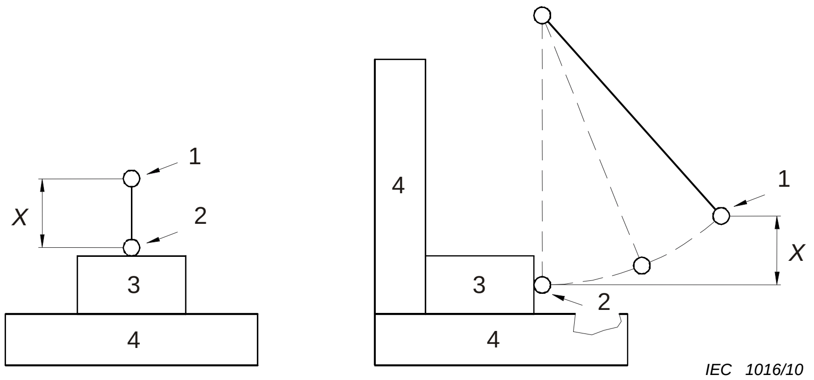


Figure 10a – Impact applied to a horizontal surface **Figure 10b – Impact applied to a vertical surface**

Key

1	Sphere start position	2	Sphere impact position
3	Test sample	4	Rigid supporting surface

X Vertical fall distance. See Table 15 for values of *X*

Figure 10 – Impact test using a sphere

Table 15 – Impact energy levels, test height and corresponding IK codes

	Impact energy level J **and IK Code**		
	1 (IK06)	**2 (IK07)**	**5 (IK08)**
Vertical fall distance (X) mm	200	400	1 000

8.3 Drop test

8.3.1 Equipment other than HAND-HELD EQUIPMENT and DIRECT PLUG-IN EQUIPMENT

The equipment is placed in its position of NORMAL USE on a smooth, hard rigid surface of concrete or steel. It is then tilted about each bottom edge in turn so that the distance between *the opposite edge and the test surface is 100 mm for equipment up to 20 kg, 25 mm for equipment between 20 kg and 100 kg, or so that the angle made by the bottom and test surface is 30°, whichever is less severe. It is then allowed to fall freely onto the test surface.*

If the number of bottom edges exceeds four, the number of drops shall be limited to four edges.

NOTE If the equipment consists of two or more units, the value for the mass refers to the mass of each individual unit. However, if one or more units are intended to be attached to, or supported by, another unit, these units are treated as a single unit.

The method of test shall not allow the equipment to topple onto any other face instead of falling back onto the test face as intended.

8.3.2 HAND-HELD EQUIPMENT and DIRECT PLUG-IN EQUIPMENT

The equipment is dropped once through a distance of 1 m onto a 50 mm thick hardwood board having a density of more than 700 kg/m^3 lying flat on a rigid base such as concrete. The equipment is dropped so that it lands in the position expected to present the most severe condition.

Non-metallic ENCLOSURES of equipment with a minimum RATED ambient temperature below 2 °C are cooled to the minimum RATED ambient temperature, then tested within 10 min.

9 Protection against the spread of fire

9.1 General

There shall be no spread of fire outside the equipment in NORMAL CONDITION or in SINGLE FAULT CONDITION. Figure 11 is a flow chart showing methods of conformity verification.

Equipment energized from a MAINS supply shall also meet the requirements of 9.6.

Conformity is checked by at least one of the following methods.

a) Testing in the SINGLE FAULT CONDITIONS (see 4.4) that could cause the spread of fire outside the equipment. The conformity criteria of 4.4.4.3 shall be met.

b) Verifying elimination or reduction of the sources of ignition within the equipment as specified in 9.2.

c) Verifying, as specified in 9.3, that if a fire occurs it will be contained within the equipment.

These alternative methods can be applied throughout the equipment or individually for different sources of HAZARDS or for different areas of the equipment.

NOTE 1 Methods b) and c) are based on fulfilling specified design criteria, in contrast to method a) which relies entirely on testing in specified SINGLE FAULT CONDITIONS.

NOTE 2 See 13.2.2 concerning protection against fire caused by batteries.

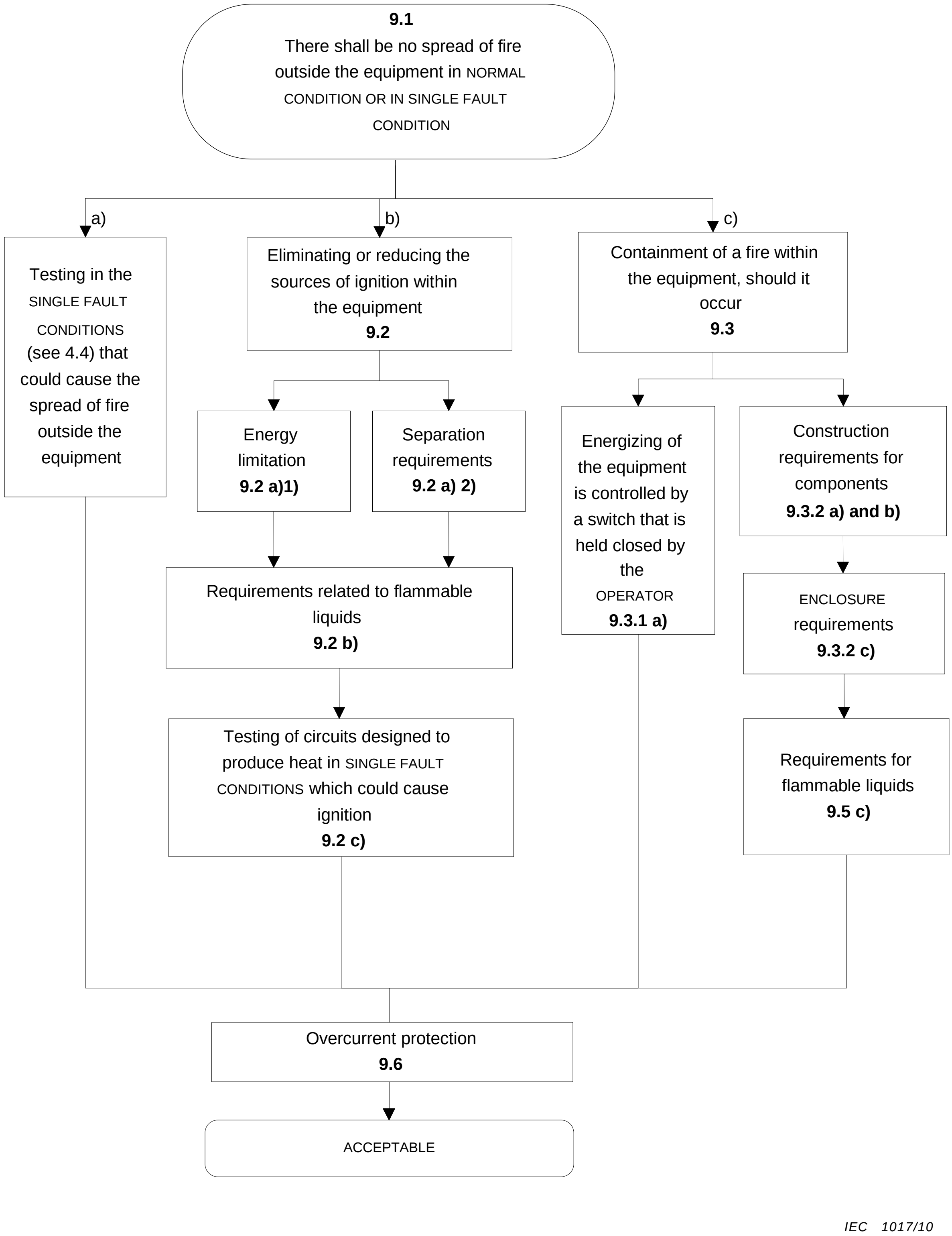


Figure 11 – Flow chart to explain the requirements for protection against the spread of fire

9.2 Eliminating or reducing the sources of ignition within the equipment

The possibility of ignition and occurrence of fire is considered to be reduced to a tolerable level if all the following requirements a), b) and c), if applicable, are met.

a) Either 1) or 2):

   1) the voltage, current and power available to the circuit or part of equipment are limited as specified in 9.4;

      Conformity is checked by measurement of limited-energy values as specified in 9.4.

   2) insulation between parts at different potentials meets the requirements for BASIC INSULATION, or it can be demonstrated that bridging the insulation will not cause ignition.

      Conformity is checked by inspection and in case of doubt by test.

b) Any ignition HAZARD related to flammable liquids is reduced to a tolerable level as specified in 9.5.

   Conformity is checked as specified in 9.5.

c) In circuits designed to produce heat, no ignition occurs when tested in SINGLE FAULT CONDITION (see 4.4).

   Conformity is checked by the relevant tests of 4.4, applying the criteria of 4.4.4.3.

9.3 Containment of fire within the equipment, should it occur

9.3.1 General

The possibility of the spread of fire outside the equipment is considered to be reduced to a tolerable level if the equipment meets one of the following constructional requirements:

a) energizing of the equipment is controlled by a switch that needs to be continuously held in the energized state by the OPERATOR;
b) the equipment and the equipment ENCLOSURE conform to the constructional requirements of 9.3.2 and the applicable requirements of 9.5 are met.

Conformity is checked by inspection and as specified in 9.3.2 and 9.5.

9.3.2 Constructional requirements

The following constructional requirements shall be met.

a) Connectors and insulating material on which components are mounted shall have a flammability classification V-2, or better, of IEC 60695-11-10. See also 14.7 for requirements for printed wiring boards.

   NOTE 1 V-0 is better than V-1, which is better than V-2.

   Conformity is checked by inspection of data on materials, and, in case of doubt, by performing the vertical burning test of IEC 60695-11-10 on samples of the material used in the relevant parts.

b) Insulated wires and cables shall retard flame propagation.

   NOTE 2 Wire with a flammability RATING of UL 2556 VW-1 or equivalent is considered to meet this requirement.

   Conformity is checked by inspection of data on materials, and, in case of doubt, by performing whichever of the following tests is applicable:

1) *for wires and cables with overall cross-sectional area of the conductors exceeding 0,5 mm^2, the test of IEC 60332-1-2;*

2) *for wires and cables with overall cross-sectional area of the conductors of 0,5 mm^2 or less, the test of IEC 60332-2-2.*

c) The ENCLOSURE shall meet the following requirements:

1) The bottom and sides of the ENCLOSURE within the 5° arc of Figure 13 of circuits that are not limited circuits according to 9.4 shall comply with one of the following requirements:

   i) have no openings;

   ii) be made of metal with perforations as specified in Table 16;

   iii) be a metal screen with a mesh not exceeding 2 mm × 2 mm centre to centre and a wire diameter of at least 0,45 mm;

   iv) have openings with baffles according to Figure 12.

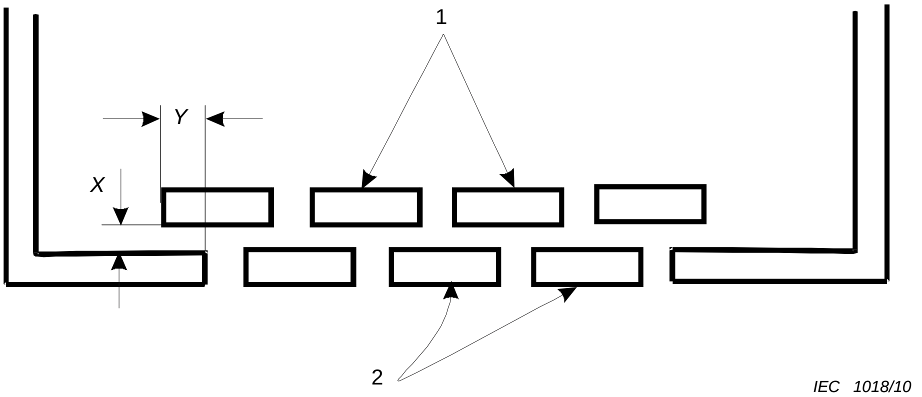
2) The ENCLOSURE, and any baffle or flame barrier, shall be made of metal (except magnesium) or of non-metallic materials having a flammability classification of V-1 or better, of IEC 60695-11-10.

3) The ENCLOSURE, and any baffle or flame barrier, shall have adequate rigidity.

Conformity is checked by inspection. In case of doubt, the flammability classification of requirement c) 2) is checked by performing the vertical burning test of IEC 60695-11-10 on samples of the material used in the relevant parts.

Table 16 – Acceptable perforation of the bottom of an ENCLOSURE

Minimum thickness mm	Maximum diameter of holes mm	Minimum spacing of holes centre to centre mm
0,66	1,14	1,70 (233 holes/645 mm^2)
0,66	1,19	2,36
0,76	1.15	1,70
0,76	1,19	2,36
0,81	1,91	3,18 (72 holes/645 mm^2)
0,89	1,90	3,18
0,91	1,60	2,77
0,91	1,98	3,18
1,00	1,60	2,77
1,00	2,00	3,00



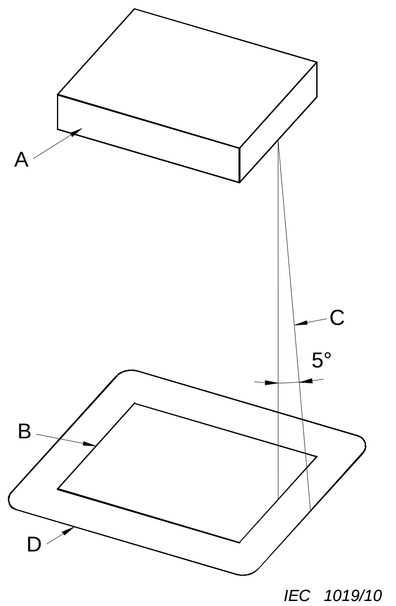
Y ≥ twice *X* but never less than 25 mm

Key

1 Baffle plates (may be below the bottom of the ENCLOSURE)

2 Bottom of ENCLOSURE

Figure 12 – Baffle



Key

A Part or component of the equipment that is considered to be a source of fire HAZARD. This consists of an entire component or part of the equipment if it is not otherwise shielded, or the unshielded portion of a component that is partially shielded by its casing.

B Projection of the outline of A on the horizontal plane.

C Inclined line that traces out the minimum area of the bottom and sides to be constructed as specified in 9.3.2 c) 1) and 9.3.2 c) 2). This line projects at a 5° angle from the vertical at every point around the perimeter of A and is oriented so as to trace out the maximum area.

D Minimum area of the bottom to be constructed as specified in 9.3.2 c) 1).

Figure 13 – Area of the bottom of an ENCLOSURE to be constructed as specified in 9.3.2 c) 1)

9.4 Limited-energy circuit

A limited-energy circuit is a circuit that meets all the following criteria.

a) The voltage appearing in the circuit is not more than 30 V r.m.s., 42,4 V peak, or 60 V d.c.

b) The current that can appear in the circuit is limited by one of the following means:

1) the maximum available current is limited inherently or by impedance so that it cannot exceed the applicable value of Table 17;
2) current is limited by an overcurrent protection device so that it cannot exceed the applicable values of Table 18;
3) a regulating network limits the maximum available current so that it cannot exceed the relevant value of Table 17 in NORMAL CONDITION or as a result of a fault in the regulating network.

c) It is separated by at least BASIC INSULATION from other circuits having energy values exceeding criteria a) or b) above.

If an overcurrent protection device is used, it shall be a fuse or a non-adjustable non-self-resetting electromechanical device.

Conformity is checked by inspection and by measuring the potentials appearing in the circuit and the maximum available current, under the following conditions:

i) the potentials appearing in the circuit are measured in the load condition that maximizes the voltage;

ii) output current is measured after 60 s of operation, with the resistive load (including short circuit) which produces the highest value of current.

Table 17 – Limits of maximum available current

Open-circuit output voltage (*U or Û*) V			**Maximum available current** A
a.c. r.m.s.	**d.c.**	**Peak**[a]	**a.c. r.m.s. or d.c.**
$U \leq 2$	$U \leq 2$	$\hat{U} \leq 2{,}8$	50
$2 < U \leq 12{,}5$	$2 < U \leq 12{,}5$	$2{,}8 < \hat{U} \leq 17{,}6$	$100 / U$
$12{,}5 < U \leq 18{,}7$	$12{,}5 < U \leq 18{,}7$	$17{,}6 < \hat{U} \leq 26{,}4$	8
$18{,}7 < U \leq 30$	$18{,}7 < U \leq 60$	$26{,}4 < \hat{U} \leq 42{,}4$	$150 / U$

[a] The peak value (*Û*) applies to non-sinusoidal a.c. and to d.c. with ripple exceeding 10 %, and is provided for convenience. The r.m.s. value of the maximum available current shall be determined as that value is related to heating.

Table 18 – Values for overcurrent protection devices

Potential appearing in the circuit (*U or Û*) V			**Current that the device breaks after not more than 120 s**[b c] A
a.c. r.m.s.	**d.c.**	**Peak** [a]	**a.c. r.m.s. or d.c.**
$U \leq 2$	$U \leq 2$	$\hat{U} \leq 2{,}8$	62,5
$2 < U \leq 12{,}5$	$2 < U \leq 12{,}5$	$2{,}8 < \hat{U} \leq 17{,}6$	125 / U
$12{,}5 < U \leq 18{,}7$	$12{,}5 < U \leq 18{,}7$	$17{,}6 < \hat{U} \leq 26{,}4$	10
$18{,}7 < U \leq 30$	$18{,}7 < U \leq 60$	$26{,}4 < \hat{U} \leq 42{,}4$	200 / U

a The peak value (*Û*) applies to non-sinusoidal a.c. and to d.c. with ripple exceeding 10 %, and is provided for convenience. The r.m.s. value of the maximum available current shall be determined as that value is related to heating.

b The evaluation is based on the specified time-current breaking characteristic of the device, which is different from the RATED breaking current. (For example, an ANSI/UL 248-14 5 A fuse is specified to break 10 A at 120 s or less and an IEC 60127 T-type 4 A fuse is specified to break at 8,4 A at 120 s or less.)

c The breaking current of fuses is dependent on temperature, and this has to be taken into account if the temperature immediately around the fuse is significantly higher than the room temperature.

9.5 Requirements for equipment containing or using flammable liquids

Flammable liquids contained in, or specified for use with, the equipment shall not cause the spread of fire in NORMAL CONDITION or in SINGLE FAULT CONDITION.

The HAZARDS arising from flammable liquids are considered to be reduced to a tolerable level if one of the following requirements is met.

a) The temperature of the surface of the liquid and parts in contact with the surface, in NORMAL CONDITION and SINGLE FAULT CONDITION, is limited to a temperature not exceeding *t* – 25 °C, where *t* is the fire point of the liquid (see 10.3 b)).

   NOTE 1 Fire point is the temperature to which a liquid must be heated (under specified conditions) so that the vapour/air mixture at the surface will support a flame for at least 5 s when an external flame is applied and withdrawn.

b) The quantity of liquid is limited to an amount that could not cause the spread of fire.

c) If the liquid can be ignited, the flames are contained to prevent the spread of fire outside the equipment. Detailed instructions for use shall be provided to establish adequate RISK reduction procedures.

Conformity with a) and b) is checked by inspection and by temperature measurement as specified in 10.4.

Conformity with c) is checked as specified in 4.4.4.3.

NOTE 2 For liquids with toxic combustion by-products, it may be convenient to use a different liquid with similar burn characteristics for testing purposes.

9.6 Overcurrent protection

9.6.1 General

Equipment intended to be energized from a MAINS supply shall be protected by fuses, circuit-breakers, thermal cut-outs, impedance limiting circuits or similar means, to provide protection against excessive current being drawn from the MAINS in case of a fault in the equipment.

NOTE 1 Overcurrent protection devices supplied with the equipment are intended to provide protection against faults which result in increased current flow, and therefore, increased heating and the probability of the start and spread of fire. These devices are not intended to provide protection against short-circuits between MAINS conductors and protective earth conductors. The building installation contains overcurrent protection devices in each unearthed MAINS conductor which are intended to protect against short-circuits between the MAINS conductor and protective earth. The breaking capacity of the overcurrent protection device should be compatible with the current RATING of the installation.

A minimum of BASIC INSULATION is required between MAINS-connected parts of opposite polarity on the supply side of the overcurrent protection device.

Overcurrent protection devices shall not be fitted in the protective conductor. Fuses or single pole circuit-breakers shall not be fitted in the neutral conductor of multi-phase equipment.

NOTE 2 Overcurrent protection devices (for example, fuses) should preferably be fitted in all supply conductors. If fuses are used as overcurrent protection devices, the fuse holders should be mounted adjacent to each other. The fuses should be of the same RATING and characteristic. Overcurrent protection devices should preferably be located on the supply side of the MAINS CIRCUITS in the equipment, including any MAINS switch. It is recognized that, in equipment generating high frequencies, it is essential for the interference suppression components to be located between the MAINS supply and the overcurrent protection devices.

Conformity is checked by inspection and by measurement, and for solid insulation by the a.c. voltage test of 6.8.3.1 or the d.c. voltage test of 6.8.3.2 (without humidity preconditioning) using the test voltage from Table 5 for BASIC INSULATION for the appropriate line-to-neutral voltage for 1 min. EMC capacitors meeting the requirements of Clause 14 may be disconnected during the voltage test.

9.6.2 PERMANENTLY CONNECTED EQUIPMENT

Overcurrent protection devices are optional in PERMANENTLY CONNECTED EQUIPMENT. If none are fitted, the installation instructions shall specify the characteristics of the overcurrent protection devices required in the building installation.

Conformity is checked by inspection.

9.6.3 Other equipment

If an overcurrent protection device is provided, it shall be within the equipment.

Conformity is checked by inspection.

10 Equipment temperature limits and resistance to heat

10.1 Surface temperature limits for protection against burns

The temperature of easily touched surfaces shall not exceed the values of Table 19 in NORMAL CONDITION, and 105 °C in SINGLE FAULT CONDITION, at an ambient temperature of 40 °C.

Easily touched surfaces of equipment RATED for a maximum ambient temperature above 40 °C are permitted to exceed the values of Table 19 in NORMAL CONDITION, and to exceed 105 °C in SINGLE FAULT CONDITION, by not more than the amount by which the maximum RATED temperature exceeds 40 °C.

If easily touched heated surfaces are necessary for the processing or heating of materials, or where otherwise not avoidable, they are permitted to exceed the values of Table 19 in NORMAL CONDITION and to exceed 105 °C in SINGLE FAULT CONDITION, provided that they are recognizable as such by appearance or function or are marked with symbol 13 of Table 1. Equipment heated by its environment to temperature values exceeding the values in Table 19 in NORMAL CONDITION and 105 °C in SINGLE FAULT CONDITION need not to be marked with symbol 13.

Surfaces protected by barriers that prevent them from being touched accidentally are not considered to be easily touched surfaces, provided that the barriers cannot be removed without the use of a TOOL.

Table 19 – Surface temperature limits in NORMAL CONDITION

Part	Limit °C
1 Outer surface of ENCLOSURE (unintentional contact)	
a) metal, uncoated or anodized	65
b) metal, coated (paint, non metallic)	80
c) plastics	85
d) glass and ceramics	80
e) small areas (<2 cm^2) that are not likely to be touched in NORMAL USE	100
2 Knobs and handles (NORMAL USE contact)	
a) metal	55
b) plastics	70
c) glass and ceramics	65
d) non-metallic parts that in NORMAL USE are held only for short periods (1 s – 4 s)	70
NOTE ISO 13732-1 gives information about the effect of the duration of contact.	

Conformity is checked by measurement as specified in 10.4, and by inspection of barriers to check that they protect against accidentally touching surfaces that are at temperatures above the values of Table 19, and that they cannot be removed without a TOOL.

10.2 Temperatures of windings

If a HAZARD could be caused by excessive temperature, the temperature of the insulating material of windings shall not exceed the values of Table 20 in NORMAL CONDITION and SINGLE FAULT CONDITION.

Conformity is checked by measurement as specified in 10.4, in NORMAL CONDITION and in the applicable SINGLE FAULT CONDITIONS of 4.4.2.5, 4.4.2.10 and 4.4.2.11, and also in any other SINGLE FAULT CONDITIONS that could cause a HAZARD as a result of excessive temperature.

Table 20 – Maximum temperatures for insulation material of windings

Class of insulation (see IEC 60085)	NORMAL CONDITION °C	SINGLE FAULT CONDITION °C
Class A	105	150
Class B	130	175
Class E	120	165
Class F	155	190
Class H	180	210

10.3 Other temperature measurements

The following other measurements are made, if applicable, for the purposes of other sub-clauses. Tests are made in NORMAL CONDITION unless stated.

a) The temperature of a field-wiring TERMINAL box or compartment is measured if there is a possibility that it could exceed 60 °C at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher (in connection with the marking requirement of 5.1.8).

b) The temperature of the surface of flammable liquids, and parts in contact with the surface, is measured in the SINGLE FAULT CONDITIONS of 4.4.2.10 and 4.4.2.11 (in connection with 9.5 a)).

c) The temperature of non-metallic ENCLOSURES is measured during the test of 10.5.1 (to establish a base temperature for the test of 10.5.2).

d) The temperature of parts made of insulating material which are used to support parts connected to the MAINS supply (to establish a temperature for test 1) of 10.5.3).

e) The temperature of TERMINALS carrying a current exceeding 0,5 A if substantial heat could be dissipated in case of poor contact (to establish a temperature for test 1) of 10.5.3).

10.4 Conduct of temperature tests

10.4.1 General

Equipment shall be tested under reference test conditions. Unless a particular SINGLE FAULT CONDITION specifies otherwise, the manufacturer's instructions concerning ventilation, cooling liquid, limits for intermittent use, etc. are followed. Any cooling liquid shall be at the highest RATED temperature.

Maximum temperature is determined by measuring the temperature rise under reference test conditions and adding this rise to 40 °C, or to the maximum RATED ambient temperature if higher.

Alternatively, temperature measurements are made at the least favourable ambient temperature within the RATED ambient temperature range of the equipment if this represents a less favourable condition. Measures are taken to eliminate errors caused by the method of achieving the test ambient temperature (e.g. suitable baffling or enclosure if the test is conducted in an environmental chamber and the forced air movements would cool the exterior of the equipment).

The temperature of insulating material of windings is measured as the temperature of winding wire and of core lamination in contact with the insulating material. It can be determined by the resistance method or by using temperature sensors selected and positioned so that they have a negligible effect on the temperature of the winding. The latter method may be used if the windings are non-uniform or if it is difficult to measure resistance.

Temperatures are measured when steady state has been reached.

10.4.2 Temperature measurement of heating equipment

Equipment intended to produce heat for functional purposes is tested in a test corner.

The test corner consists of two walls at right angles, a floor and, if necessary, a ceiling, all of plywood approximately 20 mm thick and painted matt black. The linear dimensions of the test corner should be at least 15 % greater than those of the equipment under test. Equipment is positioned at the distances from the walls, ceiling, or floor specified by the manufacturer. If no distances are specified then:

a) equipment normally used on a floor or a table is placed as near to the walls as possible;

b) equipment normally fixed to a wall is mounted on one of the walls, as near to the other wall and to the floor or ceiling as is likely to occur in NORMAL USE;

c) equipment normally fixed to a ceiling is fixed to the ceiling as near to the walls as is likely to occur in NORMAL USE.

10.4.3 Equipment intended for installation in a cabinet or a wall

Such equipment is built in as specified in the installation instructions, using walls of plywood painted matt black, approximately 10 mm thick when representing the walls of a cabinet, approximately 20 mm thick when representing the walls of a building.

10.5 Resistance to heat

10.5.1 Integrity of CLEARANCES and CREEPAGE DISTANCES

CLEARANCES and CREEPAGE DISTANCES shall meet the requirements of 6.7 when the equipment is operated at an ambient temperature of 40 °C, or the maximum RATED ambient temperature if higher.

Conformity, in cases of doubt if the equipment produces an appreciable amount of heat, is checked by operating the equipment under the reference test conditions of 4.3, except that the ambient temperature is 40 °C, or the maximum RATED ambient temperature if higher. After this test, CLEARANCES and CREEPAGE DISTANCES shall not have been reduced below the requirements of 6.7.

If the ENCLOSURE is non-metallic, the temperature of parts of the ENCLOSURE is measured during the above test for the purposes of 10.5.2.

10.5.2 Non-metallic ENCLOSURES

ENCLOSURES of non-metallic material shall be resistant to elevated temperatures.

Conformity is checked by test, after one of the following treatments.

a) *A non-operative treatment, in which the equipment, not energized, is stored for 7 h at 70 °C ± 2 °C, or at 10 °C ± 2 °C above the temperature measured during the test of 10.5.1, whichever is higher. If the equipment contains components that might be damaged by this treatment, an empty ENCLOSURE may be treated, followed by assembly of the equipment at the end of the treatment.*
b) *An operative treatment, in which the equipment is operated under the reference test conditions of 4.3, except that the ambient temperature is 20 °C ± 2 °C above 40 °C, or above the maximum RATED ambient temperature if higher than 40 °C.*

Within 10 minutes of the end of treatment the equipment shall be subjected to the suitable stresses of 8.2 and 8.3, and meet the pass criteria of 8.1.

10.5.3 Insulating material

Insulating material shall have adequate resistance to heat.

a) Parts that are made of insulating material, and which are used to support other parts that are connected to the MAINS supply, shall be made of insulating materials that will not cause a HAZARD if short circuits occur inside the equipment.
b) If in NORMAL USE, TERMINALS carry a current exceeding 0,5 A and if substantial heat could be dissipated in case of poor contact, the insulation which supports the TERMINALS shall be made of material that will not soften to an extent that could cause a HAZARD or further short circuits.

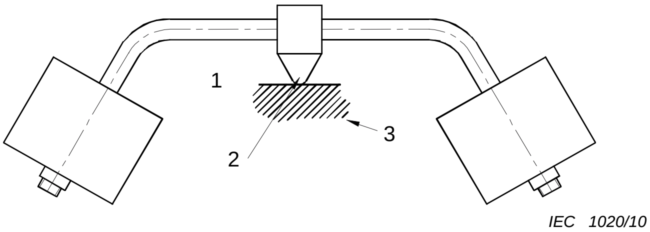
In case of doubt, conformity is checked by examination of material data. If the material data is not conclusive, one of the following tests is performed.

1) *A sample of the insulating material, at least 2,5 mm thick, is subjected to a ball-pressure test using the test apparatus Figure 14. The test is made in a heating cabinet at the temperature measured as specified in 10.3 d) or 10.3 e) ± 2 °C, or at 125 °C ± 2 °C, whichever is higher. The part to be tested is supported so that its upper surface is horizontal, and the spherical part of the apparatus is pressed against this surface with a force of 20 N. After 1 h the apparatus is removed and the sample is cooled within 10 s to approximately room temperature by immersion in cold water. The diameter of the impression caused by the ball shall not exceed 2 mm.*

   NOTE 1 If necessary, the required thickness may be obtained by using two or more sections of the part.

NOTE 2 For bobbins, only those parts that support or retain TERMINALS in position are subjected to the test.

NOTE 3 See IEC 60695-10-2 for more information about this test.



Key

1 Part to be tested

2 Spherical part of the apparatus (diameter 5 mm)

3 Support

Figure 14 – Ball-pressure test apparatus

2) The Vicat softening test of ISO 306, method A120. The Vicat softening temperature shall be at least 130 °C.

11 Protection against HAZARDS from fluids and solid foreign objects

11.1 General

Equipment shall be designed to give protection to OPERATORS and the surrounding area against HAZARDS from fluids and solid foreign objects encountered in NORMAL USE.

NOTE 1 Fluids likely to be encountered fall into three categories:

a) those having continuous contact, for example, in vessels intended to contain them;

b) those having occasional contact, for example, cleaning fluids;

c) those having accidental (unexpected) contact. The manufacturer cannot safeguard against such cases.

Fluids specified by the manufacturer, including cleaning and decontaminating fluids, are considered. Other fluids are not considered.

NOTE 2 The term “fluids” includes both liquids and gases.

NOTE 3 All pressures in Clause 11 are gauge pressures.

Conformity is checked by the treatment and tests of 11.2 to 11.7 as applicable.

11.2 Cleaning

If a cleaning or decontamination process is specified by the manufacturer, this shall not cause a direct HAZARD, nor an electrical HAZARD, nor a HAZARD resulting from corrosion or other weakening of structural parts relied upon for safety.

Conformity is checked by cleaning the equipment three times if a cleaning process is specified and decontaminating the equipment once if a decontamination process is specified, in accordance with the manufacturer’s instructions. If, immediately after this treatment, there are any signs of wetting of parts likely to cause a HAZARD, the equipment shall pass the voltage tests of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7) and ACCESSIBLE parts shall not exceed the limits of 6.3.1.

11.3 Spillage

If, in NORMAL USE, liquid is likely to be spilt into the equipment, the equipment shall be designed so that no HAZARD will occur, for example as a result of the wetting of insulation or of internal uninsulated parts, or as a result of the contact of potentially aggressive substances (such as corrosive, toxic or flammable liquids) with parts of the equipment.

If in NORMAL USE potentially aggressive substances (such as corrosive, toxic or flammable liquids) are likely to be spilt on parts of the equipment, the wetted material should be analyzed to determine compatibility with the aggressive substance.

Conformity is checked by inspection. In case of doubt, 0,2 l of water is poured steadily from a height of 0,1 m over a period of 15 s onto each point in turn where liquid might gain access to electrical parts. Immediately after this treatment, the CLEARANCES *and solid insulation shall pass the voltage tests of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7) and* ACCESSIBLE *parts shall not exceed the limits of 6.3.1.*

11.4 Overflow

Liquid overflowing from any container in the equipment which can be overfilled shall not cause a HAZARD during NORMAL USE, for example as a result of the wetting of insulation or of internal uninsulated parts that are HAZARDOUS LIVE.

Equipment likely to be moved while a container is full of liquid shall be protected against liquid surging out of the container.

Conformity is checked by the following treatment and tests. The liquid container is completely filled. A further quantity of liquid equal to 15 % of the capacity of the container or 0,25 l, whichever is the greater, is then poured in steadily over a period of 60 s. If equipment is likely to be moved while a container is full of liquid, it is then tilted 15° in the least favourable direction from the position of NORMAL USE*. Immediately after this treatment, the* CLEARANCES *and solid insulation shall pass the voltage tests of 6.8 (without humidity preconditioning) applicable to the type of insulation (see 6.7) and* ACCESSIBLE *parts shall not exceed the limits 6.3.1.*

11.5 Battery electrolyte

Batteries shall be so mounted that safety cannot be impaired by leakage of their electrolyte.

NOTE Also see 13.2.2.

Conformity is checked by inspection.

11.6 Equipment RATED with a degree of ingress protection (IP code)

11.6.1 General

Equipment RATED by the manufacturer as conforming to one of the degrees of protection as defined in IEC 60529 shall adequately resist the ingress of solid foreign objects and water which could lead to a HAZARD.

Equipment may have different degrees of protection depending on the mounting arrangements, or the assembly or operating conditions. The degrees of protection shall be specified in the documentation for each mounting arrangement. If the degree of protection depends on particular positions, covers, seals, or operating conditions, these conditions shall be specified in the documentation.

If the RATING is marked on the equipment, it shall be marked on the equipment in a manner to avoid misunderstanding and misuse. The designations of IEC 60529 shall be used (IP code).

The IP code and related operating or non-operating conditions shall be explained in the documentation together with other warnings.

For IPx8 testing, the water level above the equipment and the test duration shall be applied as specified in the documentation. The aforementioned conditions shall be more severe than those for IPx7 according to IEC 60529.

Conformity is checked by inspection and as specified in 11.6.2 to 11.6.4 as applicable.

11.6.2 Conditions for testing

The equipment shall be in a clean and new condition with all parts in place and mounted in the manner defined by the manufacturer. If it is impracticable to test the complete equipment, representative parts or smaller equipment having the same full-scale design details shall be tested.

HAND-HELD EQUIPMENT is placed in the least favourable position. Portable equipment is placed in the least favourable position of normal use. Other equipment is positioned or installed as specified in the installation instructions.

TERMINALS are considered to be part of the equipment. However, TERMINALS provided with a protective cap or cover necessary to maintain the rated degree of protection are installed as specified by the manufacturer.

The equipment is operating (energized) during the treatment except

a) if the manufacturer specifies degrees of protection for non-operating (de-energized) equipment, or
b) if, whether the equipment is operating or not operating during the treatment does not affect the test results.

EXAMPLE 1 A field housing contains electronics. Generally in this case it has no influence on the test results whether the electronics inside is operated or not. So the testing of the equipment can also be conducted without the electronics built in.

EXAMPLE 2 An equipment enclosure has a rotating shaft protruding from it using an appropriate seal for the relevant ingress protection rating. In this case the rotation of the shaft is considered as affecting the test results.

11.6.3 Protection against solid foreign objects (including dust)

The applicable test of IEC 60529 for protection against solid foreign objects is performed.

After the test, conformity is checked by inspection of the sample according to the acceptance criteria of IEC 60529.

Additionally, the equipment is inspected for ingress of foreign objects. In particular, they shall not:

a) deposit on insulation parts where it could lead to a HAZARD;
b) create accumulations that have the potential to cause the spread of fire.

NOTE A HAZARD could be caused by the bridging of conductive parts by conductive dust, or by non-conductive dust made wet by humidity.

11.6.4 Protection against water

The applicable test of IEC 60529 for protection against water is performed.

The equipment is inspected for ingress of water. If any water has entered, it shall not impair safety. In particular, it shall not:

a) deposit on insulation parts where it could lead to a hazard;

b) reach hazardous live parts or windings not designed to operate when wet;

c) accumulate near the end of a cable or enter the cable where it could cause a hazard;

d) accumulate where it could lead to a HAZARD *taking in consideration movement of the equipment.*

11.7 Fluid pressure and leakage

11.7.1 Maximum pressure

The maximum pressure to which a part of the equipment can be subjected in NORMAL USE or SINGLE FAULT CONDITION shall not exceed the RATED maximum working pressure for the part.

The maximum pressure shall be considered to be the highest of the following:

a) the RATED maximum supply pressure specified for an external source;

b) the pressure setting of an overpressure safety device provided as part of the assembly;

c) the maximum pressure that can be developed by a pressure generating device that is part of the assembly, unless the pressure is limited by an overpressure safety device.

Conformity is checked by inspection of the RATINGS *of the parts and, if necessary, by measuring pressures.*

NOTE Equipment meeting the requirements of 11.7 may not be accepted as conforming to national requirements relating to high pressures. Annex G describes requirements and tests which are accepted as evidence of conformity with national regulations in the USA, in Canada, and in some other countries.

11.7.2 Leakage and rupture at high pressure

Fluid-containing parts which in NORMAL USE have both of the following characteristics shall not cause a HAZARD through rupture or leakage:

a) a product of pressure and volume greater than 200 kPa·l;

b) a pressure greater than 50 kPa.

National authorities may allow safety to be established by calculation, for example according to the Pressure Equipment Directive (2014/68/EU).

Conformity is checked by inspection and, if a HAZARD *could arise, by the following hydraulic test.*

The test pressure (P_{test}) is the maximum pressure (P_{max}) multiplied by the applicable factor of Figure 16. Any overpressure safety device which could limit the test pressure is deactivated during the test.

The test pressure is raised gradually to P_{test} and is held at that value for 1 min. The sample shall not burst, suffer from permanent (plastic) deformation, or leak. Provided that the test pressure is maintained, leakage at a gasket during these tests is not considered a failure unless it occurs at a pressure of below 75 % of P_{test}, or below P_{max}, whichever is greater.

No leakage is allowed from fluid-containing parts intended for toxic, flammable, or otherwise hazardous substances if it could be a HAZARD.

If fluid-containing parts cannot be hydraulically tested, integrity may be verified by other suitable tests, for example, pneumatic tests using suitable media, at the same test pressure as for the hydraulic test.

As an exception to the above requirements, fluid-containing parts of refrigeration systems shall meet the relevant pressure-related requirements of EN 378-2 or IEC 60335-2-89 as applicable.

Conformity is checked as specified in EN 378-2 or IEC 60335-2-89 as applicable.

Pneumatic overpressure tests should only be conducted if no other option is available. This test can be extremely hazardous. The sudden release of stored energy due to a rupture of the test specimen can lead to severe injury or death. The stored energy in the pressurized system should be understood and appropriate safeguards put in place. These tests should only be conducted behind an explosion shield or within a suitable enclosure to protect laboratory personnel from flying debris, audible hazards, and in extreme cases the blast wave.

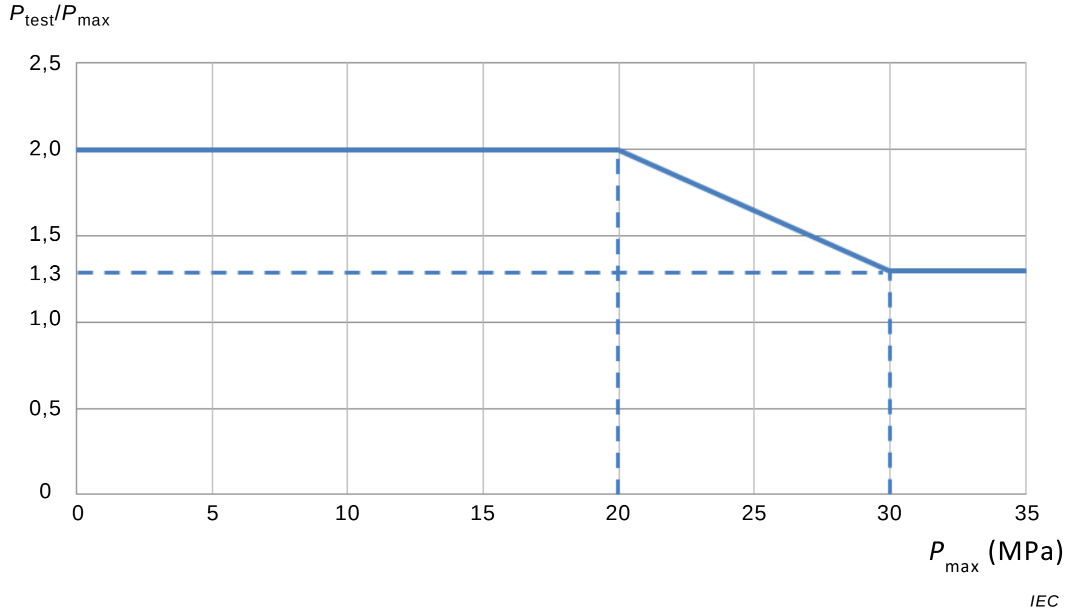


Figure 16 – Ratio between test pressure and maximum working pressure

11.7.3 Leakage from low-pressure parts

Leakage from fluid-containing parts at pressures lower than the levels of 11.7.2 shall not cause a HAZARD.

Conformity is checked by inspection of the RATINGS of parts and, if necessary, by subjecting the parts to a fluid pressure of twice the maximum pressure in NORMAL USE. No leakage shall occur which could cause a HAZARD.

11.7.4 Overpressure safety device

An overpressure safety device shall not operate in NORMAL USE. It shall conform to the following requirements.

a) It shall be connected as close as possible to the fluid-containing parts of the system that it is intended to protect.
b) It shall be installed so as to provide easy access for inspection, maintenance and repair.
c) It shall not be capable of being adjusted without the use of a TOOL.
d) It shall have its discharge opening so located and directed that the released material is not directed towards any person.
e) It shall have its discharge opening so located and directed that operation of the device will not deposit material on parts if that could cause a HAZARD.

f) It shall have adequate discharge capacity to ensure that the pressure cannot exceed the RATED maximum working pressure of the system.

There shall be no shut-off valve between an overpressure safety device and the parts that it is intended to protect.

Conformity is checked by inspection and test.

12 Protection against radiation, including laser sources, and against sonic and ultrasonic pressure

12.1 General

The equipment shall provide protection against the effects of internally generated ultraviolet, ionizing and microwave radiation; laser sources, and sonic and ultrasonic pressure.

Conformity tests are carried out if the equipment is likely to cause such HAZARDS.

12.2 Equipment producing ionizing radiation

12.2.1 Ionizing radiation

12.2.1.1 General

Equipment containing or generating ionizing radiation (from either radioactive sources or X-radiation) shall meet the following requirements.

a) If it is intended to emit radiation, it shall meet the requirements of 12.2.1.2. Alternatively, if it is within the scope of IEC 62598, it shall be tested, classified, and marked according to IEC 62598.

b) If it uses or generates radiation but only emits stray radiation, it shall meet the requirements of 12.2.1.3.

NOTE 1 See IEC 62598, for further information on the requirements for equipment which utilizes ionizing radiation.

NOTE 2 Equipment that emits ionizing radiation is regulated by health authorities in most countries. These regulations often address both the emissions of radiation from the equipment and the cumulative dose of radiation received by the workers and others in the vicinity of the equipment. See the Ionizing Radiation Directive (96/29/EURATOM) or USA 29 CFR 1910.1096 as examples of these regulations.

Conformity is checked by inspection of the IEC 62598 compliance documentation or as specified in 12.2.1.2 or 12.2.1.3, as applicable.

12.2.1.2 Equipment intended to emit radiation

Equipment which contains radioactive substances or that generates x-rays, and is intended to emit ionizing radiation outside the equipment, shall be tested and marked as follows:

The effective dose rate of radiation shall be measured at a constant distance of 50 mm to 1 m from all surfaces of the equipment. The measuring distance shall be between 50 mm and 1 m. If measurements are performed at any distance other than 50 mm, the equivalent effective dose rate at a distance of 50 mm shall be calculated. If the effective dose rate at any easily reached point 50 mm from the outer surface exceeds 5 μSv/h, the equipment shall be marked with all the following markings, if applicable:

a) with symbol 17 of Table 1;

b) for equipment containing one or more radioactive substances, with the abbreviations of the radionuclides;

c) either with the maximum dose rate value at 1 m, or with a dose rate value between 1 μSv/h and 5 μSv/h at the appropriate distance in m.

NOTE Examples of suitable markings are: "2,5 μSv/h at 1 m"; "3 μSv/h at 0,3 m".

Conformity is checked by measuring the amount of radiation in the conditions that will produce maximum radiation. The method of determining the amount of radiation shall be effective over the range of possible radiation energies. Equipment containing X-ray sources is set to produce the maximum possible level of radiation.

12.2.1.3 Equipment not intended to emit radiation

The effective dose rate of unintended stray radiation at any easily reached point 100 mm from the outer surface of the equipment shall not exceed 1 μSv/h.

NOTE Such equipment includes radioactive substances, cathode-ray tubes, X-ray sources, or electron accelerators with voltages exceeding 5 kV.

Conformity is checked by measuring the amount of radiation in the conditions that will produce maximum radiation. The method of determining the amount of radiation shall be effective over the range of possible radiation energies. Equipment containing cathode-ray tubes is tested while displaying a pattern from each beam not exceeding 30 mm × 30 mm or the smallest possible display, whichever is larger. Equipment containing X-ray sources is set to produce the maximum possible level of radiation. Displays are positioned so as to produce maximum radiation.

12.2.2 Accelerated electrons

The equipment shall be so constructed that compartments in which electrons are accelerated by voltages exceeding 5 kV cannot be opened without the use of a TOOL.

Conformity is checked by inspection.

12.3 Optical radiation

Equipment with lamps and lamp systems emitting ultraviolet, visible, or infrared radiation, including light emitting diodes, shall not permit unintentional escape of radiation that could cause a HAZARD.

The radiation sources shall be assessed in accordance with IEC 62471 except for sources considered to be safe (Table 22) or conditionally safe (Table 23). Lamp and lamp systems assessed to be in Risk Groups 1, 2 or 3 of IEC 62471 shall be labelled in accordance with IEC TR 62471-2. If the size or design of the lamp or lamp systems makes labelling impractical, symbol 14 shall be marked on the equipment and the label shall be included in the documentation.

Information on protective measures, restrictions on use, and operating instructions that may be necessary shall be provided, including the applicable conditions of use of Table 23.

NOTE Attention is drawn to the possible existence of additional guidelines or requirements which may be specified by national authorities.

Conformity is checked by inspection and if necessary, by measurement of the optical radiation to determine no hazard exists.

Table 22 – Lamp or lamp systems considered photobiologically safe

Lamp or lamp system
Indicator LEDs
Personal digital device screens
LCD screens
Computer displays
Photographic flash lamps
Interactive whiteboard presentation equipment
Task lighting with tungsten filament lamps, LED lamps, compact fluorescent tubes, or fluorescent tubes with diffusers
Any ‘Exempt Group’ (according to IEC 62471)

Table 23 – Lamp or lamp systems considered photobiologically safe under certain conditions

Lamp or lamp system	Conditions of use
Fluorescent lighting without diffusers over the lamps	Safe at normal illumination levels (~600 lux)
Metal halide/high-pressure mercury flood lights	Safe if the front cover glass is intact and if the lamp is not in line of sight
Desktop projectors	Safe if the beam is not looked into
Low-pressure UVA black-lights	Safe if not in line of sight and hands are not irradiated while holding the black-light

12.4 Microwave radiation

In NORMAL CONDITION and in SINGLE FAULT CONDITION, at any point 50 mm from the equipment, the power density of spurious microwave radiation at frequencies between 1 GHz and 100 GHz shall not exceed 10 W/m^2. This requirement does not apply to parts of the equipment where microwave radiation is propagated intentionally, for example, at waveguide output ports.

Conformity is checked by test under reference test conditions.

12.5 Sonic and ultrasonic pressure

12.5.1 Sound level

If equipment produces noise at a level which could cause a HAZARD, the manufacturer shall measure the maximum sound pressure level which the equipment can produce (except for sound from alarms and sound from parts remote from the equipment) and shall calculate the maximum sound power level as specified in ISO 3746 or ISO 9614-1.

Installation instructions shall specify how the RESPONSIBLE BODY can ensure that the sound pressure level from equipment, at its point of use after installation, will not reach a value which could cause a HAZARD. These instructions shall identify readily available and practicable protective materials or measures which may be used, including the fitting of noise-reducing baffles or hoods.

NOTE 1 A sound pressure level of 80 dBA above a reference sound pressure of 20 μPa is at present regarded by many authorities as the threshold at which a HAZARD may be caused. Special means, such as the use of protective earpieces, can make a higher level non-hazardous to an OPERATOR.

NOTE 2 The instructions for use should recommend that the sound pressure level be measured or calculated by the RESPONSIBLE BODY both at the OPERATOR'S position in NORMAL USE and at whatever point 1 m from the ENCLOSURE of the equipment has the highest sound pressure level.

Conformity is checked by measuring the maximum A-weighted sound pressure level at the OPERATOR'S position and at bystander positions, and if necessary, calculating the maximum A-weighted sound power level produced by the equipment, as specified in either ISO 3746 or ISO 9614-1. The following conditions apply.

a) During measurement, any part necessary for the correct operation of the equipment and supplied by the manufacturer as an integral part of such equipment, for example, a pump, is fitted and operated as in NORMAL USE.

b) Sound level meters used in the measurement conform either to type 1 of IEC 61672-1 or, if an integrating sound level meter, to type 1 of IEC 61672-2.

c) The test room is semi-reverberant, with a hard reflecting floor. The distance between any wall or any other object and the surface of the equipment is not less than 3 m.

d) The equipment is tested with the combination of load and other operating conditions (for example, pressure, flow, temperature) which creates the maximum sound pressure level.

12.5.2 Ultrasonic pressure

If equipment not intended to emit ultrasound produces ultrasound at a level which could cause a HAZARD, the manufacturer shall measure the maximum ultrasonic pressure level which the equipment can produce. When measured both at the OPERATOR's normal position and at 1 m from the position on the equipment with the highest pressure level, the ultrasonic pressure shall not exceed 110 dB above the reference pressure value of 20 μPa, for frequencies between 20 kHz and 100 kHz.

Conformity is checked by measuring the pressure under reference test conditions.

If equipment intended to emit ultrasound produces ultrasonic pressure at a level which could cause a HAZARD, the manufacturer shall measure the maximum ultrasonic pressure level which the equipment can produce.

The sound pressure shall be measured at the OPERATOR'S normal position and at 1 m from the position on the equipment with the highest pressure level both outside and inside the useful beam.

Outside the useful beam the ultrasonic pressure shall not exceed 110 dB above the reference pressure value of 20 μPa, for frequencies between 20 kHz and 100 kHz.

If inside the useful beam the ultrasonic pressure exceeds 110 dB for frequencies between 20 kHz and 100 kHz, the equipment shall be marked with symbol 14 of Table 1 and the following information shall be in the documentation:

a) the dimensions of the useful beam;

b) the area of the useful beam in which the ultrasonic pressure exceeds 110 dB;

c) the maximum sound pressure value inside the beam area.

Conformity is checked by inspection and measurement of the pressure under reference test conditions.

12.6 Laser sources

Equipment employing laser sources shall meet the requirements of IEC 60825-1.

Conformity is checked as specified in IEC 60825-1.

13 Protection against liberated gases and substances, explosion and implosion

13.1 Poisonous and injurious gases and substances

Equipment shall not liberate dangerous amounts of hazardous substances in NORMAL CONDITION and in SINGLE FAULT CONDITION.

If potentially-hazardous substances are liberated, the OPERATOR shall not be directly exposed to a quantity of the substance that could cause harm.

If NORMAL operation of the equipment requires the discharge of hazardous substances, and if that discharge is intended to be managed by the RESPONSIBLE BODY in accordance with the manufacturer’s instructions, then such discharge is not considered to be liberation of hazardous substances.

NOTE Chemical exposure limits and handling and disposal regulations can be found in Occupational Safety and Health (OSHA) publications or national regulatory documentation. Local, national or regional regulations may apply.

Conformity is checked by inspection of the manufacturer's documentation. The wide variety of gases and substances makes it impossible to specify conformity tests based on limit values, so reference should be made to tables of occupational threshold limit values.

13.2 Explosion and implosion

13.2.1 Components

If components liable to explode if overheated or overcharged are not provided with a pressure release device, protection for OPERATORS shall be incorporated in the equipment (see 7.7 concerning expelled parts).

Pressure release devices shall be located so that a discharge will not cause danger to OPERATORS. The construction shall be such that no pressure release device is obstructed.

Conformity is checked by inspection.

13.2.2 Batteries and battery charging

Batteries shall not cause explosion or produce a fire HAZARD as a result of excessive charge or discharge, or if a battery is installed with incorrect polarity. If necessary, protection shall be incorporated in the equipment, unless the manufacturer's instructions specify that it is for use only with batteries which have built-in protection.

If an explosion or fire HAZARD could occur through fitting a battery of the wrong type (for example, if a battery with built-in protection is specified) there shall be a warning marking on or near the battery compartment or mounting, and a warning in the manufacturer's instructions. An acceptable marking is symbol 14 of Table 1.

If equipment has means for charging rechargeable batteries, and if non-rechargeable cells could be fitted and connected in the battery compartment, there shall be a warning marking in or near the compartment. The marking shall warn against the charging of non-rechargeable batteries and indicate the type of rechargeable battery that can be used with the recharging circuit. An acceptable marking is symbol 14 of Table 1.

The battery compartment shall be designed so that there is no possibility of explosion or fire caused by build-up of flammable gases.

NOTE Also see 11.5.

Conformity is checked by inspection, including inspection of battery data, to establish that failure of a single component cannot lead to an explosion or fire HAZARD*. If necessary, a short circuit and an open circuit is made on any single component (except the battery itself) whose failure could lead to such a* HAZARD*.*

For batteries intended to be replaced by an OPERATOR*, an attempt is made to install a battery with its polarity reversed. No* HAZARD *shall arise.*

13.2.3 Implosion of cathode ray tubes

Cathode-ray tubes with a maximum face dimension exceeding 160 mm shall be intrinsically protected against the effects of implosion and against mechanical impact, unless an ENCLOSURE provides adequate protection.

A non-intrinsically protected tube shall be provided with an effective protective screen which cannot be removed without the use of a TOOL. If a separate screen of glass is used, it shall not be in contact with the surface of the tube.

A cathode-ray tube is considered to be intrinsically protected with respect to the effects of implosion if no additional protection is necessary when it is correctly mounted.

Conformity for cathode-ray tubes is checked as specified in IEC 60065.

14 Components and subassemblies

14.1 General

If safety is involved, components and subassemblies, such as power supplies and built-in information technology equipment, shall be used in accordance with their specified RATINGS unless a specific exception is made. They shall conform to one of the following:

a) applicable safety requirements of a relevant IEC standard. Conformity with other requirements of the component standard is not required. If necessary for the application, components shall be subjected to the tests of this standard, except that it is not necessary to carry out identical or equivalent tests already performed to check conformity with the component standard;

   NOTE 1 For example if components meet the safety requirements of IEC 60950-1 but are RATED for a less severe environment than the applicable environment of 1.4, they also need to meet relevant additional requirements of this standard.

b) the requirements of this standard and, where necessary for the application, any additional applicable safety requirements of the relevant IEC component standard, except that there are no additional requirements for motors and transformers which have passed the applicable tests of 4.4.2.5, 4.4.2.7, 14.2 and 14.6;

c) if there is no relevant IEC standard, the requirements of this standard;

d) applicable safety requirements of a non-IEC standard which are at least as high as those of the relevant IEC standard, provided that the component has been approved to the non-IEC standard by a recognized testing authority.

   NOTE 2 Tests performed by a recognized testing authority which confirm conformity with applicable safety requirements need not be repeated, even if the tests were performed using a non-IEC standard.

Figure 15 is a flow chart showing methods of conformity verification.

Conformity is checked by inspection and, if necessary, by test.

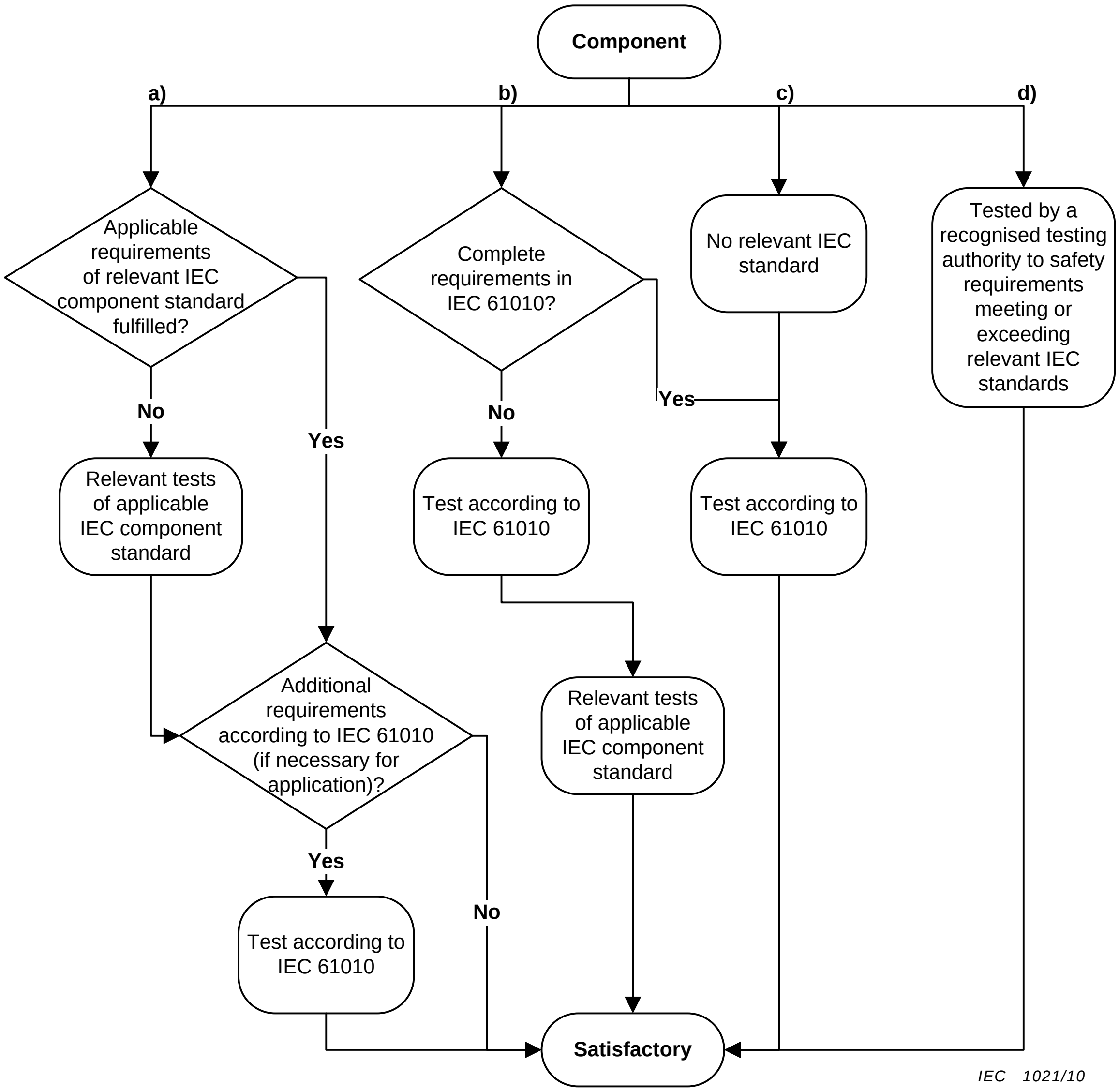


Figure 15 – Flow chart for conformity options 14.1 a), b), c) and d)

14.2 Motors

14.2.1 Motor temperatures

Motors which, when stopped or prevented from starting (see 4.4.2.5), would present an electric shock HAZARD, a temperature HAZARD, or a fire HAZARD shall be protected by an overtemperature or thermal protection device meeting the requirements of 14.3.

Conformity is checked by measurement of the temperature in the SINGLE FAULT CONDITION of 4.4.2.5.

14.2.2 Series excitation motors

If an overspeeding series excitation motor could cause a HAZARD, it shall be connected directly to the devices driven by it.

Conformity is checked by inspection.

14.3 Overtemperature protection devices

Overtemperature protection devices are devices operating in SINGLE FAULT CONDITION. They shall meet all of the following requirements:

a) be constructed so that reliable function is ensured;

b) be RATED to interrupt the maximum voltage and current of the circuit in which they are employed;

c) not operate in NORMAL USE.

If a self-resetting overtemperature protection device is used to prevent a HAZARD in case of failure of a temperature control system (for example a thermostat), the protected part of the equipment shall require intervention before becoming operational again.

Conformity is checked by inspection of the circuit diagram, the data sheet for the overtemperature protection device, and the method in which it is installed in the equipment, and by the following tests, with the equipment operated in SINGLE FAULT CONDITION (see 4.4). The number of operations is as follows:

1) self-resetting overtemperature protection devices are caused to operate 200 times;

2) non-self-resetting overtemperature protection devices, except thermal fuses, are reset after each operation and thus caused to operate 10 times;

3) non-resetting overtemperature protection devices are caused to operate once.

NOTE Forced cooling and resting periods may be introduced to prevent damage to the equipment.

During the test, resetting overtemperature protection devices shall operate each time the SINGLE FAULT CONDITION is applied and non-resetting overtemperature protection devices shall operate once. After the test, resetting overtemperature protection devices shall show no sign of damage which could prevent their operation in a further SINGLE FAULT CONDITION.

14.4 Fuse holders

If a fuse is intended to be replaced by an OPERATOR the fuse holder shall not permit HAZARDOUS LIVE parts to be ACCESSIBLE during fuse replacement.

Conformity is checked by testing with the jointed test finger (see Figure B.2) applied without force.

14.5 MAINS voltage selection devices

Devices shall be constructed so that a change from one voltage or one type of supply to another cannot occur accidentally. See 5.1.3 d) for marking requirements.

Conformity is checked by inspection and manual test.

14.6 MAINS transformers tested outside equipment

If environmental conditions could affect the test results, MAINS transformers tested outside the equipment (see 4.4.2.7) shall be tested in the same conditions as exist inside the equipment.

Conformity is checked by the short-circuit and overload tests specified in 4.4.2.7, followed by the test of 4.4.4.1 b) and c). If there is any doubt whether a transformer would pass the other tests specified in 4.4.4 and 10.2 when installed in the equipment, the tests are repeated with the transformer installed in the equipment.

14.7 Printed wiring boards

Printed wiring boards shall be made of material with a flammability classification of V-1 or better of IEC 60695-11-10.

This requirement does not apply to printed wiring boards which contain only limited-energy circuits meeting the requirements of 9.4.

Conformity of the flammability RATING is checked by inspection of data on the materials. Alternatively, conformity is checked by performing the vertical burn tests of IEC 60695-11-10 on three samples of the relevant parts. The samples may be complete boards, sections of the boards or specimens as specified in IEC 60695-11-10.

14.8 Circuits used to limit TRANSIENT OVERVOLTAGES

Any overvoltage limiting circuit that forms part of the equipment shall have adequate strength to limit likely TRANSIENT OVERVOLTAGES.

Table 21 – Impulse voltages for OVERVOLTAGECATEGORY II

Line-to-neutral MAINS voltage V r.m.s. or d.c.	**Impulse voltage** V
≤50	500
>50 ≤ 100	800
>100 ≤ 150	1 500
>150 ≤ 300	2 500
>300 ≤ 600	4 000
>600 ≤ 1 000	6 000

Conformity is checked by the following test: 5 positive and 5 negative impulses are applied with the applicable impulse voltage of Table 21, spaced up to 1 min apart, from a hybrid impulse generator (see IEC 61180-1). The generator produces an open-circuit voltage waveform of 1,2/50 μs, a short-circuit current waveform of 8/20 μs, with an output impedance (peak open-circuit voltage divided by peak short-circuit current) of 12 Ω (resistance may be added in series if needed to raise the impedance). The impulse is applied while the circuit is operating under conditions of NORMAL USE, in combination with the MAINS supply. The MAINS voltage is the maximum RATED MAINS voltage.

The test voltage is applied between each pair of MAINS supply TERMINALS of the equipment where overvoltage limiting circuits are present.

The overvoltage limiting circuit components shall not ignite or heat other materials to their self-ignition points. The overvoltage limiting circuit shall safely suppress the impulse and continue to function properly after the test.

NOTE The impulse voltage and generator output impedance specified above apply to equipment with a RATING for OVERVOLTAGE CATEGORY II. Conformity for equipment with a rating for OVERVOLTAGE CATEGORIES III and IV is specified in Clause K.4.

15 Protection by interlocks

15.1 General

Interlocks used to protect OPERATORS from HAZARDS shall prevent an OPERATOR from being exposed to the HAZARD before the HAZARD is removed and shall meet the requirements of 15.2 and 15.3.

Conformity is checked by inspection and by performing all relevant tests of this standard.

15.2 Prevention of reactivating

Until the action which caused the interlock to operate has been reversed or cancelled, an interlock for the protection of an OPERATOR shall prevent the HAZARD being re-established by reactivating without the use of a TOOL.

Conformity is checked by inspection and, if necessary, by attempting to operate by hand any interlock part which can be touched by the jointed test finger (see Figure B.2).

15.3 Reliability

An interlock system for the protection of OPERATORS shall ensure that a single fault in the interlock system is either unlikely to occur during the expected life of the equipment, or cannot cause a HAZARD.

Conformity is checked by assessment of the interlock system. In case of doubt, the interlock system or relevant parts of the system are cycled to switch the least favourable load in NORMAL USE. The number of cycles is twice the maximum number likely to occur during the expected life of the equipment or 10 000 cycles of operation whichever is higher. After the test the protection shall not be impaired.

16 HAZARDS resulting from application

16.1 REASONABLY FORESEEABLE MISUSE

No HAZARDS shall arise if adjustments, knobs, or other software-based or hardware-based controls are set in a way not intended, and not described in the instructions. Other possible cases of REASONABLY FORESEEABLE MISUSE that are not addressed by specific requirements in this standard shall be addressed by RISK assessment (see Clause 17).

Conformity is checked by inspection and by evaluation of the RISK assessment documentation.

16.2 Ergonomic aspects

If the following factors could give rise to a HAZARD, a RISK assessment shall be documented, taking into account at least the following aspects:

a) limitation of body dimensions;

b) displays and indicators;

c) accessibility and conventions of controls;

d) arrangements of TERMINALS.

Conformity is checked by inspection and by evaluation of the RISK assessment documentation.

NOTE RISK assessment procedures for ergonomics may be found in EN 894-2, EN 894-3, ISO 9241, SEMI S8, and other documents. Not all of the requirements in these documents will be applicable to equipment within the scope of this standard.

17 RISK assessment

If examination of the equipment shows that HAZARDS not fully addressed in Clauses 6 to 16 (see 1.2.1) might arise, then RISK assessment is required. It shall be carried out and documented to achieve at least a TOLERABLE RISK by an iterative process covering the following.

a) RISK analysis

RISK analysis is the process to identify HAZARDS and to estimate the RISKS based on the use of available information.

b) RISK evaluation

Each RISK analysis requires a plan to evaluate the estimated severity and likelihood of a RISK, and to judge the acceptability of the resulting RISK level.

c) RISK reduction

If the initial RISK level is not acceptable, steps shall be taken to reduce the RISK. The process of RISK analysis and RISK evaluation shall then be repeated, including checking that no new RISKS have been introduced.

RISKS remaining after a RISK assessment shall be identified in the instructions for the RESPONSIBLE BODY. Adequate information about how to mitigate these RISKS shall be given (see 5.4.1 e)).

In selecting the most appropriate methods of RISK reduction, the manufacturer shall apply the following principles, in the order given:

1) eliminate or reduce RISKS as far as possible (an inherently safe design and construction);
2) take the necessary protective measures in relation to RISKS that cannot be eliminated;
3) inform users of the residual RISKS due to any shortcomings of the protective measures adopted, indicate whether any particular training is required, and specify any need to provide personal protective equipment.

NOTE One RISK assessment procedure is outlined in Annex J. Other RISK assessment procedures are contained in ISO 14971, SEMI S10-1296, IEC 61508, ISO 14121-1, and ANSI B11.TR3. Other established procedures which implement similar steps can also be used.

Conformity is checked by evaluation of the RISK assessment documentation to ensure that the RISKS have been eliminated or that only TOLERABLE RISKS remain.

Annex A
(normative)

Measuring circuits for touch current
(see 6.3)

NOTE This annex is based on IEC 60990, which specifies procedures for measuring touch-current, and also specifies the characteristics for test voltmeters.

A.1 Measuring circuit for a.c. with frequencies up to 1 MHz and for d.c.

The current is measured using the circuit of Figure A.1. The current is calculated from:

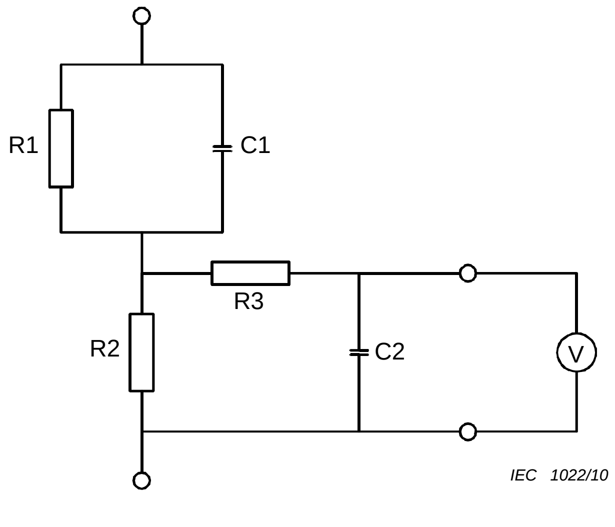
$$I = \frac{U}{500}$$

where

I is the current, in amperes;

U is the voltage, in volts, indicated by the voltmeter.

This circuit represents the impedance of the body and compensates for the change of physiological response of the body with frequency.



R1 = 1 500 Ω with a relative tolerance of ±5 %

R2 = 500 Ω with a relative tolerance of ±5 %

R3 = 10 kΩ with a relative tolerance of ±5 %

C1 = 0,22 µF with a relative tolerance of ±10 %

C2 = 0,022 µF with a relative tolerance of ±10 %

Figure A.1 – Measuring circuit for a.c. with frequencies up to 1 MHz and for d.c.

A.2 Measuring circuits for sinusoidal a.c. with frequencies up to 100 Hz and for d.c.

If the frequency does not exceed 100 Hz, the current may be measured using either of the circuits of Figure A.2. When using the voltmeter, the current is calculated from:

$$I = \frac{U}{2\ 000}$$

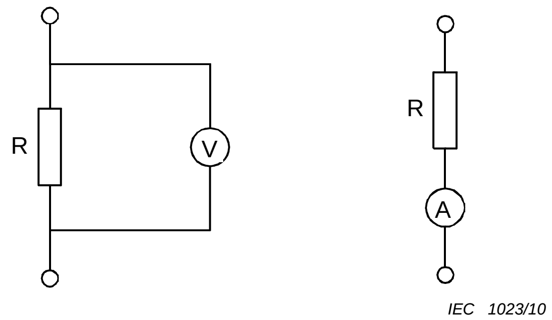
where

I is the current in amperes;

U is the voltage, in volts, indicated by the voltmeter.

The circuit represents the impedance of the body for frequencies not exceeding 100 Hz.

NOTE The value 2 000 Ω includes the impedance of the measuring instrument.



R = 2 000 Ω with a relative tolerance of ±5 %

Figure A.2 – Measuring circuits for sinusoidal a.c. with frequencies up to 100 Hz and for d.c.

A.3 Current measuring circuit for electrical burns at high frequencies

The current is measured using the circuit of Figure A.3. The current is calculated from:

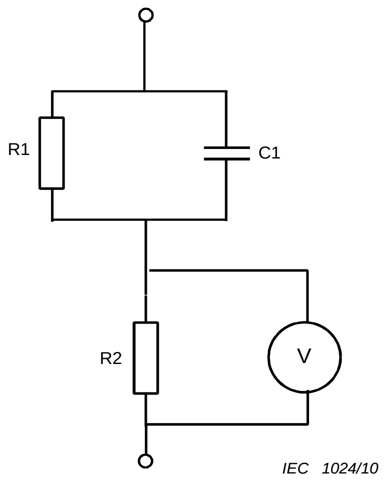
$$I = \frac{U}{500}$$

where

I is the current in amperes;

U is the voltage, in volts, indicated by the voltmeter.

This circuit compensates for the effects of high frequency on the physiological response of the body.



R1 = 1 500 Ω with a relative tolerance of ±5 %

R2 = 500 Ω with a relative tolerance of ±5 %

C1 = 0,22 μF with a relative tolerance of ±10 %

Figure A.3 – Current measuring circuit for electrical burns

A.4 Current measuring circuit for WET LOCATION

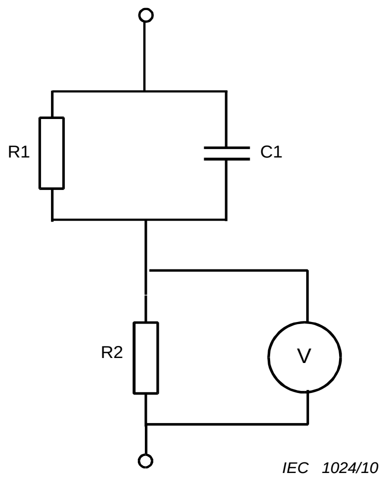
For WET LOCATION the current is measured using the circuit of Figure A.4. The current is calculated from:

$$I = \frac{U}{500}$$

where

I is the current in amperes;

U is the voltage, in volts, indicated by the voltmeter.



R1 = 375 Ω with a relative tolerance of ±5 %

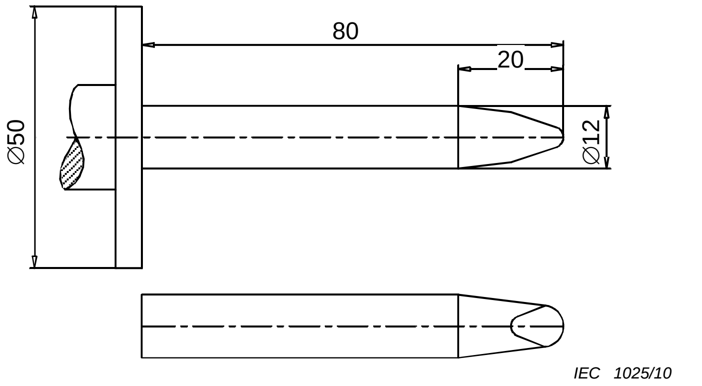
R2 = 500 Ω with a relative tolerance of ±5 %

C1 = 0,22 μF with a relative tolerance of ±10 %

Figure A.4 – Current measuring circuit for wet contact

Annex B
(normative)

Standard test fingers
(see 6.2)

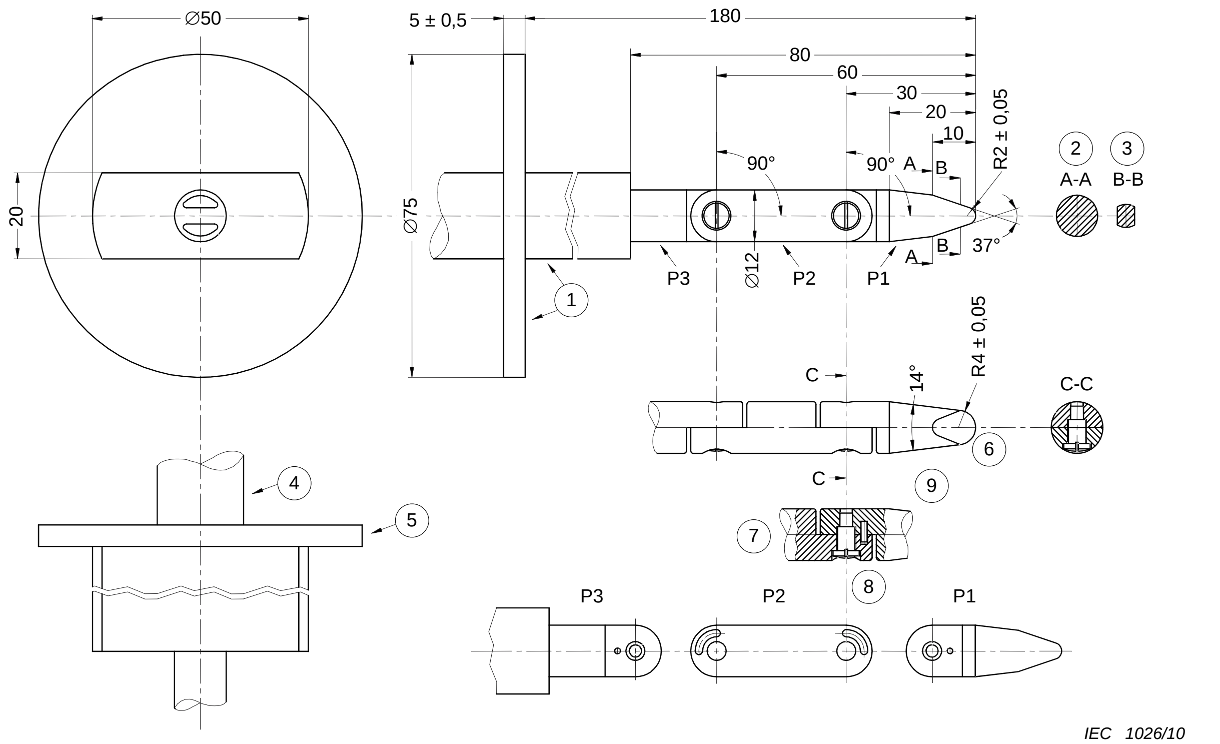


For tolerances and dimensions of the fingertip, see Figure B.2.

Dimensions in millimetres

NOTE This test finger is the same as test probe 11 of IEC 61032, Figure 7

Figure B.1 – Rigid test finger



Key

1	insulating material		
2	section AA	6	spherical
3	section BB	7	detail x (example)
4	handle	8	side view
5	stop plate	9	chamfer all edges

Dimensions in millimetres

Tolerances on dimensions without specific tolerance:

– on angles: $^{0}_{-10'}$

– on linear dimensions:

up to 25 mm: $^{0}_{-0,05}$ mm

over 25 mm: ±0,2 mm

Material of finger: heat-treated steel, etc.

Both joints of this finger may be bent through an angle of $(90\,^{+10}_{0})°$, but in one plane only.

Using the pin and groove solution is only one of the possible approaches in order to limit the bending angle to 90°. For this reason, dimensions and tolerances of these details are not given in the drawing. The actual design shall ensure a $(90\,^{+10}_{0})°$ bending angle.

NOTE This test finger is the same as test probe B of IEC 61032, Figure 2

Figure B.2 – Jointed test finger

Annex C
(normative)

Measurement of CLEARANCES and CREEPAGE DISTANCES

The methods of measuring CLEARANCES and CREEPAGE DISTANCES are indicated in the following examples 1 to 11 (see Figure C.1). These cases do not differentiate between gaps and grooves or between types of insulation.

The following assumptions are made:

a) where the distance across a groove is equal to or larger than *X* (see Table C.1), the CREEPAGE DISTANCE is measured along the contours of the groove (see example 2);

b) any recess is assumed to be bridged with an insulating link having a length equal to *X* and being placed in the least favourable position (see example 3);

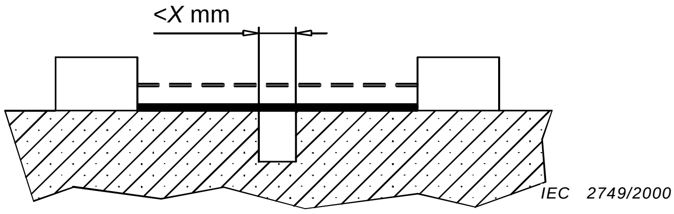
c) CLEARANCES and CREEPAGE DISTANCES measured between parts which can assume different positions in relation to each other are measured when these parts are in their least favourable position.

In the following examples dimension *X* has the value given in Table C.1 depending on the POLLUTION DEGREE.

Table C.1 – Dimensions of X

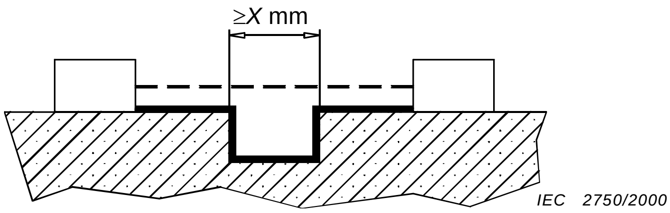
POLLUTION DEGREE	Dimension *X* mm
1	0,25
2	1,0
3	1,5

If the associated CLEARANCE is less than 3 mm, the dimension *X* in Table C.1 may be reduced to one-third of this CLEARANCE.



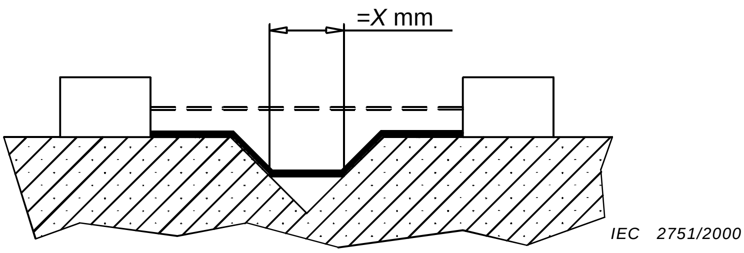
EXAMPLE 1 The path includes a parallel- or converging-sided groove of any depth with a width less than *X*.

The CLEARANCE and the CREEPAGE DISTANCE are measured directly across the groove as shown.



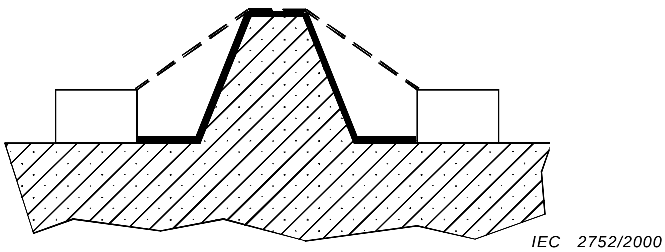
EXAMPLE 2 The path includes a parallel-sided groove of any depth and equal to or more than *X*.

The CLEARANCE is the "line-of-sight" distance. The CREEPAGE DISTANCE follows the contour of the groove.



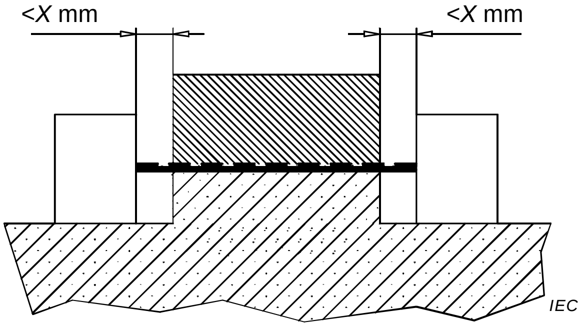
EXAMPLE 3 The path includes a V-shaped groove with a width greater than *X*.

The CLEARANCE is the "line-of-sight" distance. The CREEPAGE DISTANCE follows the contour of the groove but "short-circuits" the bottom of the groove by *X* link.



EXAMPLE 4 The path includes a rib.

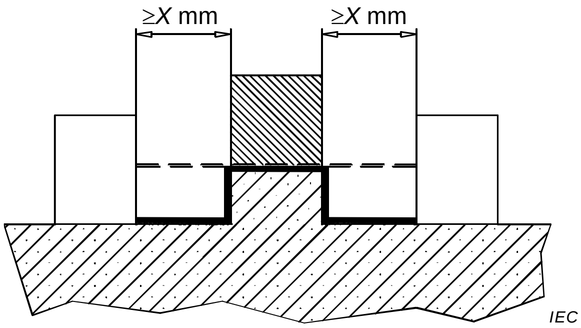
The CLEARANCE is the shortest direct air path over the top of the rib. The CREEPAGE DISTANCE follows the contour of the rib.



IEC 2753/2000

EXAMPLE 5 The path includes an uncemented joint with grooves less than *X* wide on each side.

The CLEARANCE and the CREEPAGE DISTANCE path is the “line-of-sight” distance shown.

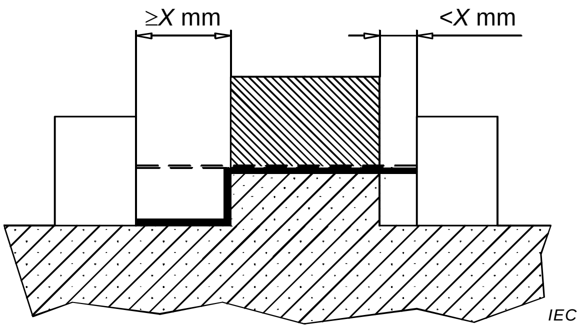


IEC 2754/2000

EXAMPLE 6 The path includes an uncemented joint with grooves equal to, or more than, *X*.

The CLEARANCE is the “line-of-sight” distance.

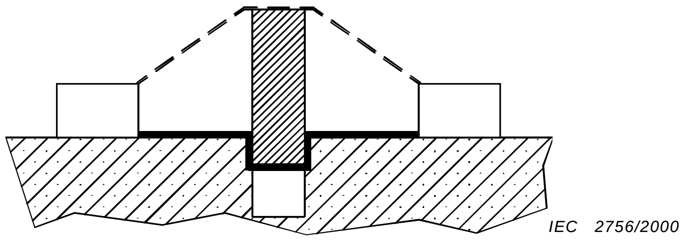
The CREEPAGE DISTANCE follows the contour of the grooves.



IEC 2755/2000

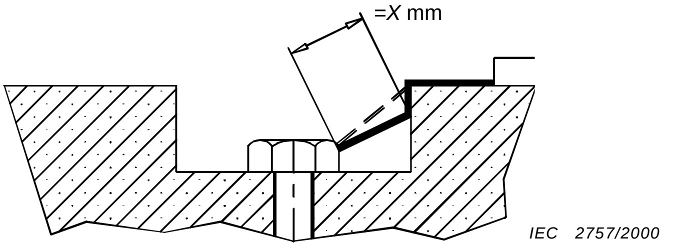
EXAMPLE 7 The path includes an uncemented joint with a groove on one side less than *X* wide and the groove on the other side equal to, or more than, *X* wide.

The CLEARANCE and the CREEPAGE DISTANCE are as shown.

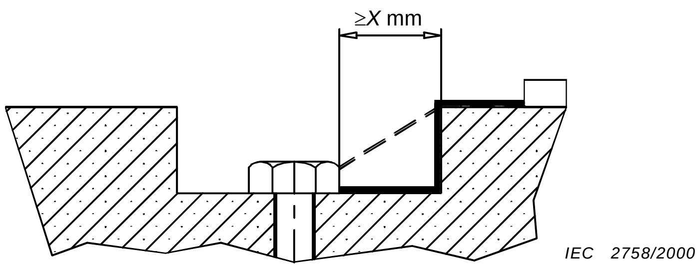


EXAMPLE 8 The CREEPAGE DISTANCE through the uncemented joint is less than the CREEPAGE DISTANCE over the barrier.

The CLEARANCE is the shortest direct air path over the top of the barrier.

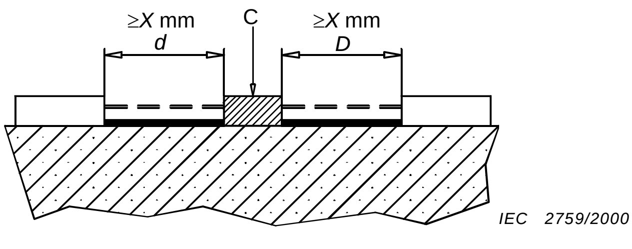


EXAMPLE 9 The gap between the head of the screw and the wall of the recess too narrow to be taken into account.



EXAMPLE 10 The gap between the head of the screw and the wall of the recess wide enough to be taken into account.

Measurement of the CREEPAGE DISTANCE is from screw to wall when the distance is equal to *X*.



EXAMPLE 11 C = floating part

The CLEARANCE is the distance $d + D$. The CREEPAGE DISTANCE is also $d + D$.

CREEPAGE DISTANCE (solid line)

CLEARANCE (dashed line)

Figure C.1 – Examples of methods of measuring CLEARANCES and CREEPAGE DISTANCES

Annex D
(normative)

Parts between which insulation requirements are specified
(see 6.4 and 6.5.3)

The following symbols are used in Figures D.1 to D.3 to indicate:

a) Requirements:

B BASIC INSULATION is required

D DOUBLE INSULATION or REINFORCED INSULATION is required

b) Circuits and parts:

A ACCESSIBLE part, not bonded to the PROTECTIVE CONDUCTOR TERMINAL

H circuit that is HAZARDOUS LIVE in NORMAL CONDITION

R impedance meeting the requirements of 6.4.4

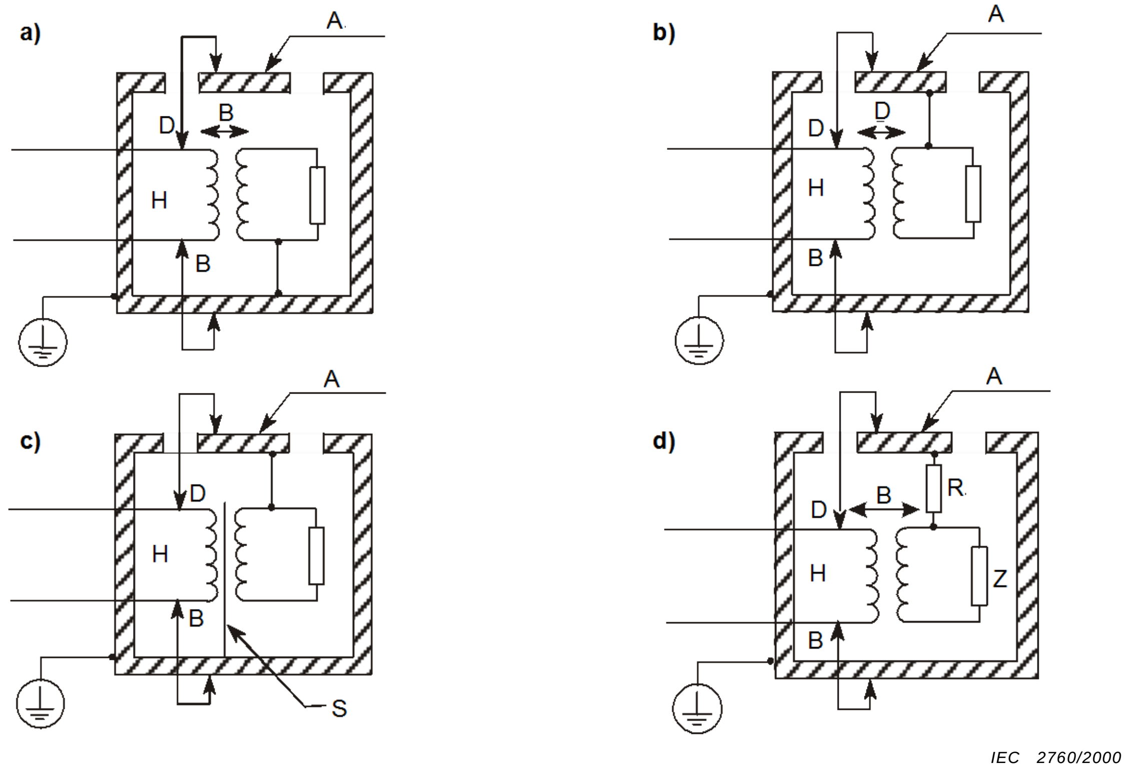
S protective screen

T_A ACCESSIBLE external TERMINAL (not exceeding the values of 6.3.1 in NORMAL CONDITION)

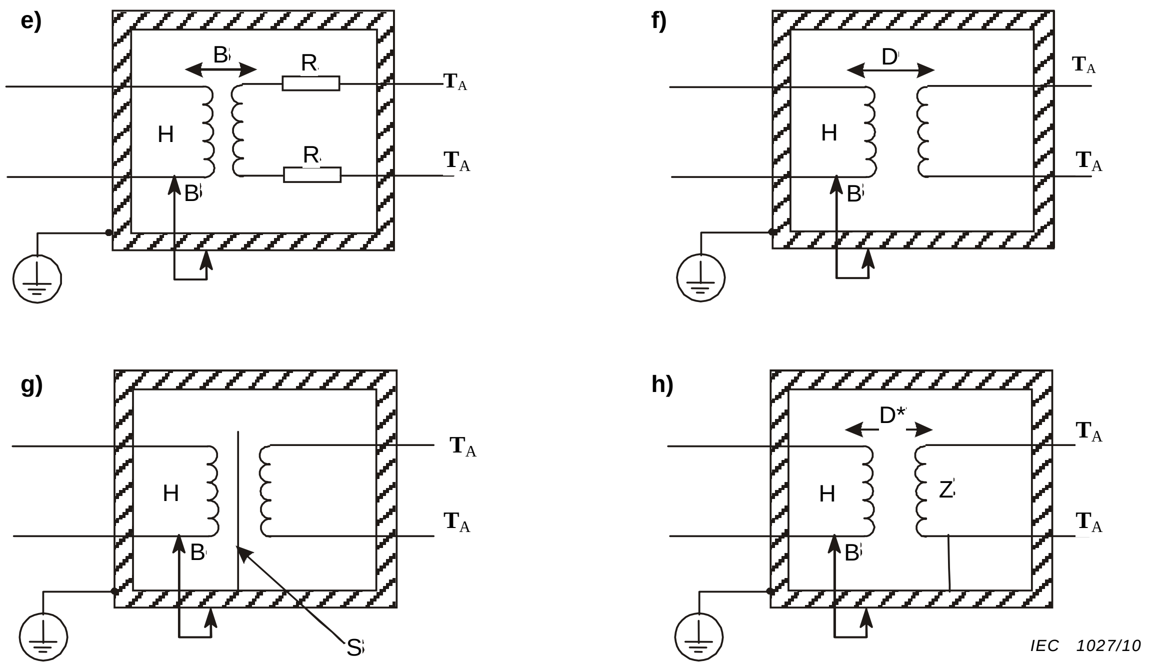
T_N TERMINAL (which may exceed the values of 6.3.1 in NORMAL CONDITION, and therefore shall not be ACCESSIBLE)

Z impedance of secondary circuit

The secondary circuits shown may also be regarded merely as parts.

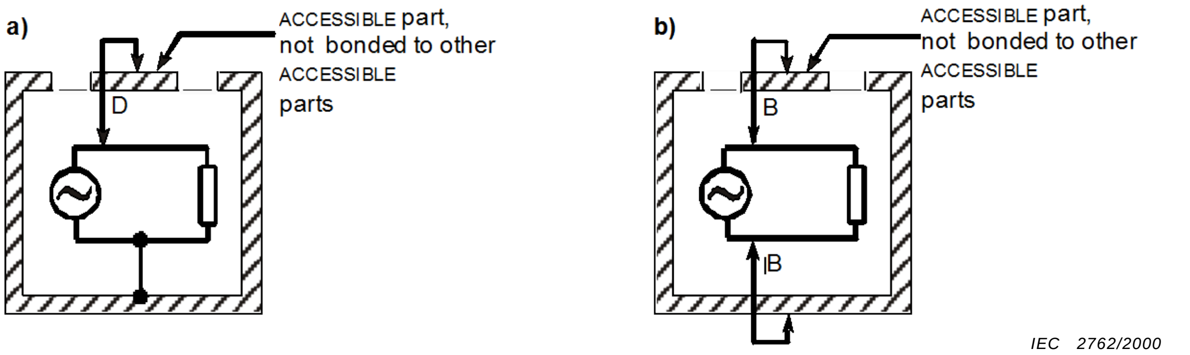


Figures D.1a) to d) – Protection between HAZARDOUS LIVE circuits and ACCESSIBLE parts

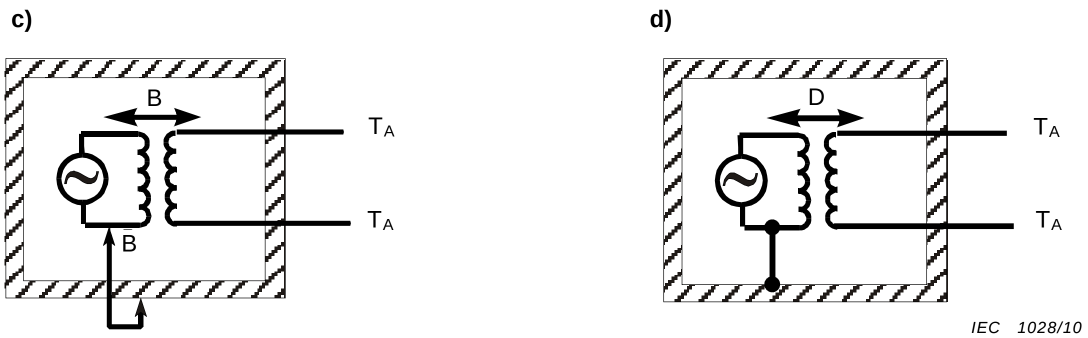


D* may be B if Z is sufficiently low

Figures D.1e) to h) – Protection between HAZARDOUS LIVE circuits and circuits with ACCESSIBLE external TERMINALS



Figures D.2 a) and D.2 b) – Protection between a HAZARDOUS LIVE internal circuit and an ACCESSIBLE part which is not bonded to other ACCESSIBLE parts



Figures D.2 c) and D.2 d) – Protection between a HAZARDOUS LIVE primary circuit and circuits which have ACCESSIBLE external TERMINALS

NOTE 1 Other means of protection are also possible for the circuits shown in Figures D.2 c) and D.2 d), such as protective screening, PROTECTIVE BONDING of circuits (see 6.5.2) and PROTECTIVE IMPEDANCE (see 6.5.4).

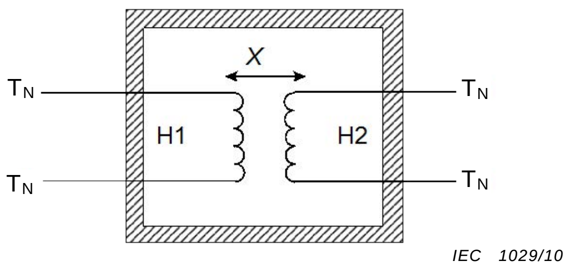


Figure D.3 – Protection of external ACCESSIBLE TERMINALS of two HAZARDOUS LIVE circuits

NOTE 2 The requirement for insulation between an ACCESSIBLE part not bonded to the PROTECTIVE CONDUCTOR TERMINAL and either of the two HAZARDOUS LIVE circuits is as shown in D.1 a) to D.1 d).

The requirement for the insulation between H1 and H2 (*X)* is the most severe of the following:

B BASIC INSULATION – if H1 and H2 are both connected, the insulation requirement is based on the highest RATED WORKING VOLTAGE that stresses the insulation between the circuits;

D DOUBLE INSULATION or REINFORCED INSULATION – if H1 is connected and the TERMINALS of H2 are ACCESSIBLE for connection purposes, the insulation requirement is based on the highest RATED WORKING VOLTAGE that stresses the insulation of H1;

D DOUBLE INSULATION or REINFORCED INSULATION – if H2 is connected and the TERMINALS of H1 are ACCESSIBLE for connection purposes, the insulation requirement is based on the highest RATED WORKING VOLTAGE that stresses the insulation of H2.

Annex E
(informative)

Guideline for reduction of POLLUTION DEGREES

The micro-environment inside equipment is determined by the environmental conditions to which the equipment is exposed during operation, installation, maintenance, and any POLLUTION generated by the equipment itself as well as by the effectiveness of applied sealing measures.

Equipment can be divided into environmental situations as depicted in Table E.1.

Table E.1 – Environmental situations

Environmental situation	Equipment operated in ...	Installation or maintenance of equipment in ...
A	controlled environment[a]	controlled environment
B	uncontrolled environment	controlled environment or equipment is not opened during installation or maintenance
C	uncontrolled environment	uncontrolled environment

[a] A controlled environment is an environment having the conditions of 1.4.1 c) and d).

NOTE The environmental situation of Table E.1 provides a systematic classification of the environments to which the equipment is exposed and whether the equipment may be opened for installation and maintenance purposes.

Reduction of the POLLUTION DEGREE of the micro-environment may be achieved by the methods of Table E.2.

Table E.2 – Reduction of POLLUTION DEGREES

	POLLUTION DEGREE of micro-environment						
POLLUTION DEGREE of macro environment	2			3		4	
	Environmental situation			Environmental situation		Environmental situation	
	A	B	C	B	C	B	C
ENCLOSURE IPx5, IPx6	1	2	2	3	3	4	4
ENCLOSURE IPx7, IPx8	1	1	2	2	3	2	4
Constant heating within the equipment with an ENCLOSURE of IPx4 or higher	1	2	2	3	3	4	4
IP RATINGS are according to IEC 60529.							

Annex F
(normative)

ROUTINE TESTS

F.1 General

The manufacturer shall perform the tests of F.2 to F.4 on 100 % of equipment produced which has both HAZARDOUS LIVE parts and ACCESSIBLE conductive parts. Unless it can be clearly shown that the result of the tests cannot be invalidated by subsequent manufacturing stages, tests shall be made with equipment fully assembled. Components shall not be unwired, modified or disassembled for the test, but snap-on covers and friction-fit knobs may be removed if they would interfere with the tests. The equipment shall not be energized during the tests, but the MAINS switch shall be in the on-position.

Wrapping the equipment in foil is not required, nor is humidity preconditioning necessary.

Test site altitude correction of the test voltage is not required.

The voltage test equipment shall be able to maintain the required voltage for the specified period of time. No other requirements apply.

Conformity is checked by inspection.

F.2 Protective earth

A continuity test is made between the earth pin of the appliance inlet or the MAINS plug of plug-connected equipment, or the PROTECTIVE CONDUCTOR TERMINAL of PERMANENTLY CONNECTED EQUIPMENT on the one side, and all ACCESSIBLE conductive parts which are required by 6.5.2 to be connected to the PROTECTIVE CONDUCTOR TERMINAL on the other side.

NOTE No value is specified for the test current.

F.3 MAINS CIRCUITS

F.3.1 General

A test voltage is applied between:

a) the MAINS TERMINALS connected together, and

b) all ACCESSIBLE conductive parts including the PROTECTIVE CONDUCTOR TERMINAL, if any, connected together.

During this test, the equipment shall be electrically isolated from any external earthing. This test is not applied to small metal parts such as name plates, screws or rivets, if they are separated from parts which are HAZARDOUS LIVE by REINFORCED INSULATION or its equivalent.

NOTE For equipment which has all ACCESSIBLE conductive parts connected to the PROTECTIVE CONDUCTOR TERMINAL, the interconnection of the ACCESSIBLE conductive parts is not necessary because the correct interconnections are tested by F.2.

The test voltage may be a.c. or d.c. or impulse, and is selected from Table F.1 for the appropriate OVERVOLTAGE CATEGORY. For the a.c. and d.c. tests, the test voltage is raised to its specified value within 5 s, and maintained for at least 2 s. Impulse tests are the 1,2/50 μs *test specified in IEC 61180, conducted for a minimum of three pulses of each polarity at 1 s minimum intervals.*

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test, nor shall the test device indicate failure.

Table F.1 – Test voltages for ROUTINE TESTS of MAINS CIRCUITS

Nominal line-to-neutral voltage of MAINS supply	OVERVOLTAGE CATEGORY II			OVERVOLTAGE CATEGORY III			OVERVOLTAGE CATEGORY IV		
a.c. r.m.s. or d.c.	a.c.	d.c.	1,2/50 µs Impulse	a.c.	d.c.	1,2/50 µs Impulse	a.c.	d.c.	1,2/50 µs Impulse
V	V r.m.s.	V	V peak	V r.m.s.	V	V peak	V r.m.s.	V	V peak
≤150	840	1 200	1 200	1 400	2 000	2 000	2 200	3 100	3 100
>150 ≤ 300	1 400	2 000	2 000	2 200	3 100	3 100	3 300	4 700	4 700
>300 ≤ 600	2 200	3 100	3 100	3 300	4 700	4 700	4 300	6 000	6 000
>600 ≤ 1 000	3 300	4 700	4 700	4 300	6 000	6 000	5 300	7 500	7 500

F.3.2 MAINS CIRCUITS with voltage limiting devices

For MAINS CIRCUITS with voltage limiting devices that meet the requirements of 14.8, the a.c. or d.c. test of F.3.1 can be carried out using a test voltage of 0,9 times the clamping voltage of the voltage limiting device but not less than twice the WORKING VOLTAGE of the MAINS CIRCUIT.

F.4 Floating circuits

A test voltage is applied between

a) the TERMINALS of floating input and output circuits, which can be HAZARDOUS LIVE in NORMAL USE, connected together, and

b) ACCESSIBLE conductive parts connected together.

The value of the applied voltage in each case is 1,5 times the maximum RATED voltage to earth but not less than 350 V a.c. r.m.s or 500 V d.c. If voltage-limiting (clamping) devices clamp below the applied voltage, the value of the applied voltage is 0,9 times the clamping voltage, but not less than that of the maximum RATED voltage to earth.

The test voltage is raised to its specified value within 5 s and maintained for at least 2 s, with the circuit electrically isolated from any external earthing means.

No flashover of CLEARANCES or breakdown of solid insulation shall occur during the test nor shall the test device indicate failure.

Annex G
(informative)

Leakage and rupture from fluids under pressure

The requirements and tests of this annex are accepted in the USA, Canada, and in some other countries, as proof of conformity with national regulations relating to high pressures. These requirements are not adequate for equipment intended for toxic, flammable, or otherwise hazardous materials. Refer to national authorities for requirements for such equipment.

G.1 General

Fluid-containing parts of equipment under pressure shall not cause a HAZARD through rupture or leakage in NORMAL CONDITION or SINGLE FAULT CONDITION.

Conformity is checked as specified in Clause G.2 to G.4.

G.2 Pressures above 2 MPa and a product pressure and volume greater than 200 kPa·l

G.2.1 General

Fluid-containing parts of equipment which in NORMAL USE have both of the following characteristics shall not cause a HAZARD through rupture or leakage:

a) a product of pressure and volume greater than 200 kPa·l;

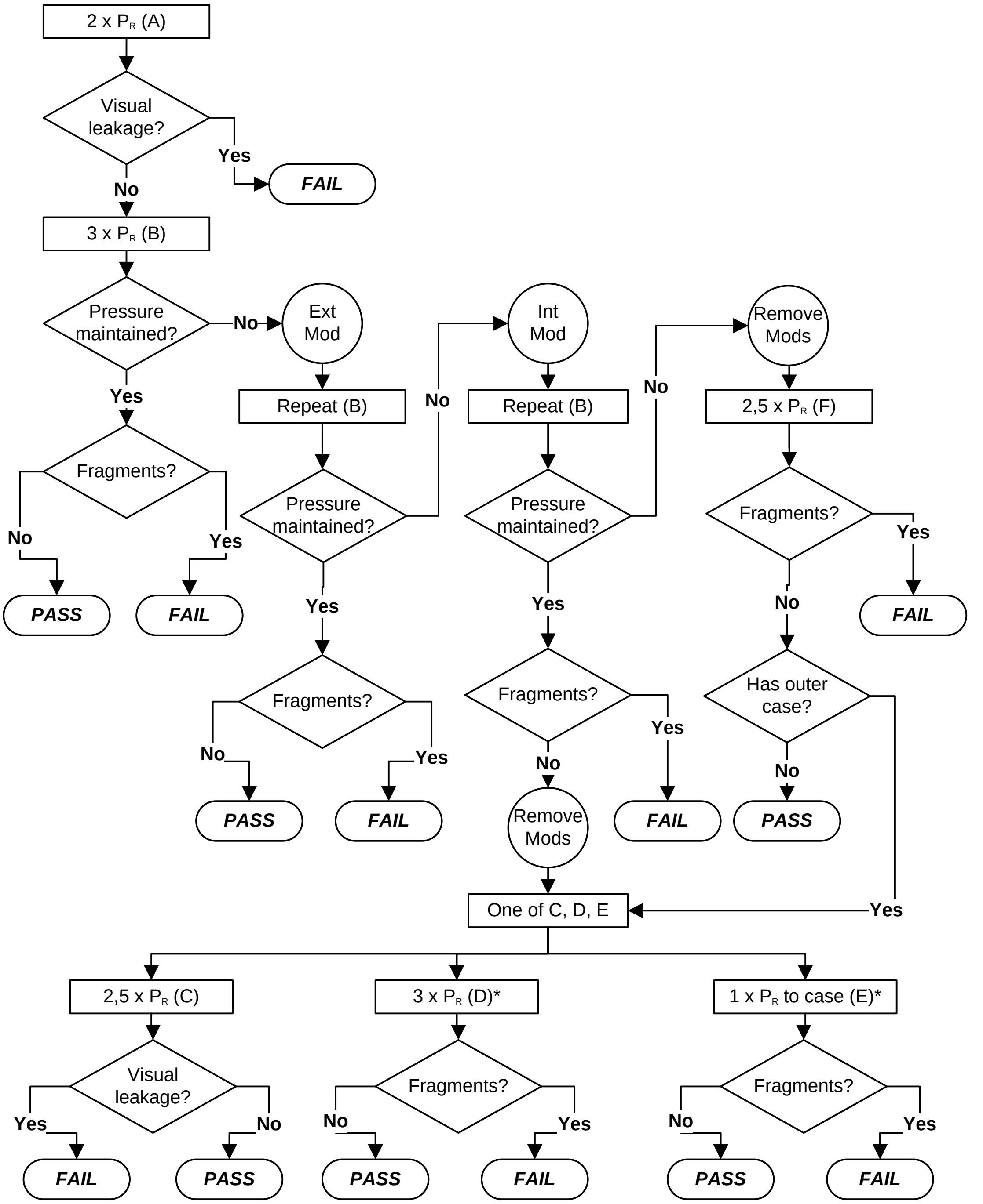
b) a pressure above 2 MPa.

NOTE Such equipment includes fluid-pressure-actuated equipment employing flexible bellows, diaphragms, Bourdon tubes, etc. and equipment such as flowmeters that are connected to process pressures RATED at or above 2 MPa.

Conformity is checked by inspection and by performing the hydrostatic tests of G.2.2 to G.2.6. Any overpressure safety device which is used to limit the maximum working pressure is inactivated during the tests.

Figure G.1 is a flow chart showing methods of conformity verification.

Throughout Clause G.2, values are based on RATED pressure P_R. This is the maximum pressure as marked on the equipment or, if no value is marked, the maximum transient overpressure (maximum pressure which may be applied without permanent change in performance). In the case of differential pressure equipment, the RATED pressure is the higher of the working pressure and the static pressure.



Subclause references for tests A to F:

A = G.2.3 a) - B = G.2.3 b) - C = G.2.5 a) - D = G.2.5 b) - E = G.2.5 c) - F = G.2.6 - P_R = RATED pressure

Figure G.1 – Conformity verification process (see G.2)

G.2.2 Conduct of hydrostatic tests for G.2.1

The part of the equipment that is normally subjected to the fluid pressure is filled with a suitable liquid, such as water, to exclude air, and is then connected to a hydraulic pump. The pressure is raised gradually to the specified test pressure.

Those portions of the equipment which normally receive indirect pressure loading, as in hydraulically coupled systems, are subjected to the test pressure at the same time, either through the original hydraulic filling fluid or, in its absence, by filling with the test liquid.

Test pressure values are based on RATED pressure P_R, see G.2.1.

Test pressure values specified in G.2.3 to G.2.6 apply to equipment with RATED pressure up to 14 MPa. For higher RATED pressures the values of Table G.1 apply.

Where it is specified in these test procedures that pressure is to be applied to "the equipment", the pressure shall be applied to that part of the equipment that is subjected to pressure in NORMAL USE.

Where it is specified in these test procedures that pressure is to be applied to "the outer casing", the pressure shall be applied to any unpressurized case, cover, enclosure, or housing that encloses all or part of the pressurized equipment, but that is not itself intended to be pressurized in NORMAL USE.

G.2.3 Initial tests

The following tests are performed.

a) *A pressure of 2 $\times$ P_R is applied to the equipment for 1 min without any visible leakage.*

b) *A pressure of 3 $\times$ P_R is applied to the equipment for 1 min without any rupture or failure which results in fragments flying outside the equipment.*

   During test b), leakage may occur because of splits in Bourdon tubes, diaphragms, or bellows, or because of joint or gasket failure. These are not considered to be test failures if the pressure can be maintained for 1 min. However, if leakage is at a rate which prevents pressure being maintained for 1 min, the modifications specified in G.2.4 may be made, and the test repeated.

   1) *If the equipment passes the test of G.2.3 b) after modification only as specified in G.2.4 a), no further tests are performed.*
   2) *If the equipment passes the test of G.2.3 b) after modification as specified in G.2.4 b), the modifications are removed, and one of the tests of G.2.5 is performed.*
   3) *If the equipment again fails the test of G.2.3 b), the modifications are removed and the test of G.2.6 is performed.*

G.2.4 Modifications to minimize leakage

The following modifications may be made.

a) *External fittings may be modified to reduce leakage.*

b) *A leaking gasket or a flexible seal (not part of the measuring element) which forms a structural partition between the part of the equipment that is under pressure in NORMAL USE and the outer casing may be replaced by a stronger non-functional member to reduce leakage.*

G.2.5 Additional tests if modification succeeded in minimizing leakage

If any modification as specified in G.2.4 b) was made before successfully repeating the test of G.2.3 b), the equipment is restored to its original state, and one of tests a), b) or c) below is performed on the unmodified equipment. For equipment intended for toxic, flammable or otherwise hazardous substances, test a) is performed.

a) *A pressure of 2,5 $\times$ P_R is applied to the equipment for 1 min without any visible leakage.*

b) *A pressure of 3 $\times$ P_R is applied to the equipment for 1 min without any rupture or failure which results in fragments flying outside the outer casing.*

   NOTE 1 In this case, even if the pressure of 3 $\times$ P_{RATED} cannot be maintained within the equipment, leakage from the outer casing takes place at a rate which prevents a build-up of hazardous pressure.

c) *If the equipment has an outer casing capable of being pressurized, it is subjected to a pressure of P_R for 1 min without any rupture or failure which results in fragments flying outside the outer casing.*

NOTE 2 In this situation, rupture and flying fragments are prevented by the capability of the outer casing to resist pressure.

G.2.6 Additional test if modifications failed to reduce leakage

If the equipment failed the test of G.2.3 b) after the modifications of G.2.4, but the leakage serves as a pressure relief mechanism, the equipment conforms to the requirements of G.2.3 b) if, after removal of the modifications, it passes the test specified below and, if the equipment has an outer casing, also passes one of tests a), b), and c) of G.2.5.

A pressure of 2,5 x P_R is applied to the equipment for 1 min without any rupture or failure which results in fragments flying outside the equipment.

Table G.1 – Test pressures for equipment with pressures above 14 Mpa

P_R	Pressure for test of G.2.5 c)	Pressure for test of G.2.3 a)	Pressure for tests of G.2.5 a) and G.2.6	Pressure for tests of G.2.3 b) and G.2.5 b)
>14 ≤ 70 MPa	P_R	1,75 × P_R plus 3,5 MPa	2,0 × P_R plus 7 MPa	2,5 × P_R plus 7 MPa
>70 MPa	P_R	1,3 × P_R plus 35 MPa	1,5 × P_R plus 42 MPa	2,0 × P_R plus 42 MPa

G.3 Pressures between 50 kPa and 2 MPa, and pressure times volume above 200 kPa·l

Fluid-containing parts of equipment which in NORMAL USE have both of the following characteristics shall not cause a HAZARD through rupture or leakage:

a) a product of pressure and volume greater than 200 kPa·l;

b) a pressure between 50 kPa and 2 MPa.

Conformity is checked by a hydrostatic test conducted as specified in G.2.2. Any overpressure safety device which is used to limit the maximum working pressure is inactivated during the test.

A pressure of 3 × P_R is applied to the equipment for 1 min without leakage, permanent (plastic) deformation, or bursting. However, for equipment not intended for use with toxic, flammable, or otherwise hazardous substances, leakage at a gasket at a pressure above 1,2 × P_R is acceptable.

If a hydrostatic test cannot be performed on unmarked fluid-containing parts or pipes, their integrity is verified by suitable equivalent tests, such as pneumatic tests at 3 × P_R.

For refrigeration systems see applicable national standards for example ANSI/UL 471, CSA C22.2 No 120.

G.4 Pressures below 50 kPa, or pressure times volume below 200 kPa·l

Leakage from fluid-containing parts at lower pressures, or with a product of pressure and volume below 200 kPa·l, shall not cause a HAZARD.

Conformity is checked by inspection of the RATINGS *of parts and, if necessary, by subjecting the parts to a fluid pressure of twice the maximum pressure in* NORMAL USE*. The pressure is applied for 1 min. No leakage is to occur which could cause a* HAZARD*.*

G.5 Overpressure safety devices

An overpressure safety device shall not operate in NORMAL USE and shall conform to all the following requirements.

a) It shall be connected as close as possible to the fluid-containing parts of the system that it is intended to protect.

b) It shall be installed so as to provide easy access for inspection, maintenance and repair.

c) It shall not be capable of being adjusted without the use of a TOOL.

d) It shall have its discharge outlet located and directed so that the released material is not directed towards any person.

e) It shall have its discharge outlet located and directed so that operation of the device will not cause a HAZARD by depositing material that could cause deterioration of parts.

f) It shall have sufficient discharge capacity to ensure that the pressure will not exceed $1,1 \times P_R$ if there is a failure of the supply pressure control.

g) There shall be no shut-off valve between any overpressure safety device and the parts that it is intended to protect.

Also see 11.7.4.

Conformity is checked by inspection and test.

Annex H
(normative)

Qualification of conformal coatings for protection against POLLUTION

H.1 General

This annex covers requirements for conformal coatings used on printed wiring boards to reduce the POLLUTION DEGREE.

Conformal coatings shall meet the requirements of Clause H.2 and H.3.

NOTE 1 The requirements of Clause H.2 assure that the conformal coating has been suitably RATED for the purpose of coating printed wiring boards. The requirements of H.3 assure that the coating will continue to adhere to the printed wiring board after environmental and physical stresses.

Conformity is checked as specified in Clauses H.2 and H.3.

NOTE 2 Conformal coatings that meet the requirements of ANSI/UL 746E are considered to meet these requirements.

H.2 Technical properties

The technical properties of conformal coatings shall be suitable for the intended application. In particular:

a) the manufacturer of the coating material shall state that it is a coating for printed wiring boards;
b) the RATED operating temperature range shall include the temperature range of the intended application;
c) the comparative tracking index (CTI), the insulation resistance and the dielectric strength shall be suitable for the intended application;
d) if the printed wiring board coating is to be exposed to sunlight, the coating shall have adequate UV resistance;
e) the flammability RATING of the coating shall be at least the required flammability RATING of the printed wiring board to which it is applied.

Conformity is checked by inspection of the manufacturer's data.

H.3 Qualification of coatings

The coating shall meet the conformity requirements of Figure H.1 after the tests of Table H.1.

Conformity is checked as specified in Table H.1 and Figure H.1, on 6 specimens of the coated printed wiring board.

Table H.1 – Test parameters, test conditions and test procedures

Item	Test, conditioning	Test parameter, conditions	Test procedure
1	Cold conditioning	Conditioning temperature: T_{min}. T_{min} is the minimum RATED ambient temperature or the minimum RATED storage temperature, whichever is lower, of the specimen. Any humidity is acceptable. Conditioning time: 24 h	The specimens are placed in a temperature chamber and held at T_{min} for the specified conditioning time.
2	Dry heat	Conditioning temperature: T_{max}. T_{max} is the maximum RATED surface temperature, maximum RATED ambient temperature, or maximum RATED storage temperature, whichever is higher, of the specimen. Any humidity is acceptable. Conditioning time: 48 h	The specimen is placed in a temperature chamber and held at T_{max} for the specified conditioning time.
3	Rapid change of temperature	Maximum temperature: T_{max} T_{max} is the maximum RATED surface temperature, maximum RATED ambient temperature, or maximum RATED storage temperature, whichever is highest, of the specimen. Minimum temperature: T_{min}. T_{min} is the minimum RATED ambient temperature or the minimum RATED storage temperature, whichever is lower, of the specimen. Rate of change of temperature: within 30 s Cycle time (duration of one cycle): T_{max} and T_{min} are each held until steady state conditions of the specimens are achieved and then maintained for 10 min. The cycle starts when the specimen has reached the target within 2° C. Number of cycles: 50 cycles	The conditioning procedure follows test Na of IEC 60068-2-14.
4	Damp heat	Temperature: 40 °C ± 2 °C Humidity: 90 %...95 % R.H. Conditioning time: 24 h	The specimens are placed in the humidity chamber and held at the specified temperature and humidity for the specified conditioning time.
5	Adhesion of coating	Temperature: 15 °C.... 35 °C Humidity: 45 %.... 75 % R.H. Pull force: 5 N	The test procedure follows the test described in 5.8.2 of IEC 60664-3 using the specified pull force.
6	Humidity conditioning	Temperature: 40 °C ± 2 °C Humidity: 90 %...95 % R.H. Conditioning time: 48 h	The specimens are placed in the humidity chamber and held at the specified temperature and humidity for the specified conditioning time.
7	Insulation resistance of conductors	Temperature : 40 ± 2 °C Humidity: 90 %...95 % R.H. Insulation resistance: ≥100 MΩ	Insulation resistance is measured between the two outer conductors with the smallest CREEPAGE DISTANCE for at least 1 min. The test voltage shall be as close to the WORKING VOLTAGE as possible.

Figure H.1 (below) describes the test sequence and conformity.

Preparation and scratch resistance	
Preparation of the test specimens	Each specimen is to be assembled in the normal manner, using the normal soldering procedure, including any cleaning and protection steps that are normally applied.
Visual inspection	*Conformity is checked by inspection.* The specimens shall show no: ▪ separation from base material, ▪ cracks, ▪ voids, ▪ areas with adjacent unprotected conductive parts where the CREEPAGE DISTANCE between the parts is less than the required CREEPAGE DISTANCE for uncoated printed wiring boards. *NOTE Areas of the specimens where scratch resistance test is applied need not be involved in the subsequent testing and inspection.*

Conditioning of the test specimens	
Table H.1, item 1	Cold conditioning
Table H.1, item 2	Dry heat
Table H.1, item 3	Rapid change of temperature
Table H.1, item 4	Damp heat test

Mechanical and electrical tests after conditioning	
Table H.1, item 5	Adhesion of coating (tape test)
Visual inspection	*Conformity is checked by inspection.* On all specimens, the coating shall not have loosened and there shall be no material transferred to the tape that is visible to the naked eye. *NOTE In order to assess whether there has been any transfer of material, the tape can be placed on a sheet of white paper or card. If a white or light-coloured coating is being tested, a suitably contrasting coloured paper or card is used instead.*
Table H.1, item 6	Humidity conditioning
Table H.1, item 7	Insulation resistance *Conformity is checked by measuring of the insulation resistance of Table H.1, item 7. All specimens shall meet the required value.*

Visual inspection	*Conformity is checked by inspection.* All specimens shall show no ▪ blistering, ▪ swelling, ▪ separation from base material, ▪ cracks, ▪ voids, ▪ areas with adjacent unprotected conductive parts where the CREEPAGE DISTANCE between the parts is less than the required CREEPAGE DISTANCE for uncoated printed wiring boards.

IEC 1031/10

Figure H.1 – Test sequence and conformity

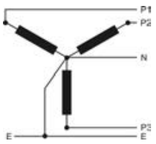
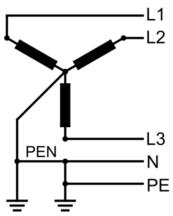
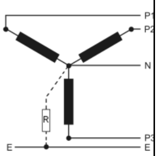
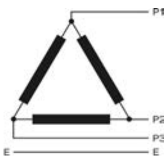
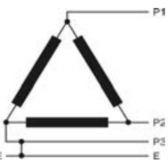
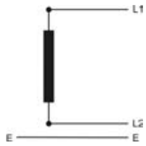
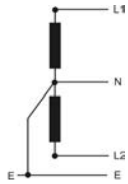
Annex I
(informative)

Line-to-neutral voltages for common MAINS supply systems

For the purposes of this standard, Table I.1 gives the line-to-neutral voltage that should be used for determining CLEARANCE, CREEPAGE DISTANCE, and solid insulation requirements of MAINS circuits.

Table I.1 is derived from Table B.1 of IEC 60664-1. It is applicable to MAINS supply systems with inherent control (see IEC 60664-1, 4.3).

Table I.1 – Line-to-neutral voltages for common MAINS supply systems

MAINS systems and nominal voltages						Line-to-neutral voltage pertinent to MAINS system type and nominal voltage
Three-phase four-wire systems [a] with earthed neutral TT system  TN-C-S System 	Three-phase four-wire systems [a] with unearthed neutral (IT systems) [b, c] 	Three-phase three-wire systems unearthed 	Three-phase three-wire systems with earthed phase 	Single-phase two-wire systems a.c. or d.c. 	Single-phase (split-phase) three-wire systems [a] a.c. or d.c. 	
V	V	V	V	V	V	V
				12,5 to 48	30/60	50
66/115		66		60		100
120/208 127/220	120/208	110, 115 120, 127	100 120	100 110, 115 120, 127	100/200 [d] 110/220 115/230 120/240	150
220/380 230/400 240/415 260/440 277/480	230/400 277/480	200 220, 230, 240 260, 277, 347 380, 400, 415 440, 480	200 240 347 380, 400, 415 440, 480	220 230 240	220/440 240/480	300

347/600 380/660 400/690 417/720 480/830	347/600 400/690	500 577 600	600	480	480/960	600
		660 690, 720 830, 1 000		1 000		1 000

[a] Voltages shown as two voltages separated by a "/" represent the phase-to-neutral (or line-to-neutral) voltage followed by the phase-to-phase (or line-to-line) voltage. For example, "120/208" indicates that the voltage from any phase to neutral is 120 V, and the voltage from any phase to another phase is 208 V. Likewise, "220/440" indicates that the voltage from either line-to-neutral is 220 V, and the voltage from line-to-line is 440 V.

[b] *Z* is an impedance which may connect neutral to earth (usually 1 500 Ω).

[c] When insulation is monitored, neutral of these systems is considered to be earthed.

[d] Practise in Japan.

Annex J
(informative)

RISK assessment

A RISK assessment process based on ISO/IEC Guide 51 (1999) is given below. Other RISK assessment procedures are contained in ISO 14971, SEMI S10, IEC 61508, ISO 14121-1, and ANSI TR3. Other established procedures which implement similar steps can also be used.

J.1 RISK assessment procedure

TOLERABLE RISK is achieved by the iterative process of RISK assessment (RISK analysis and RISK evaluation) and RISK reduction (see Figure J.1).

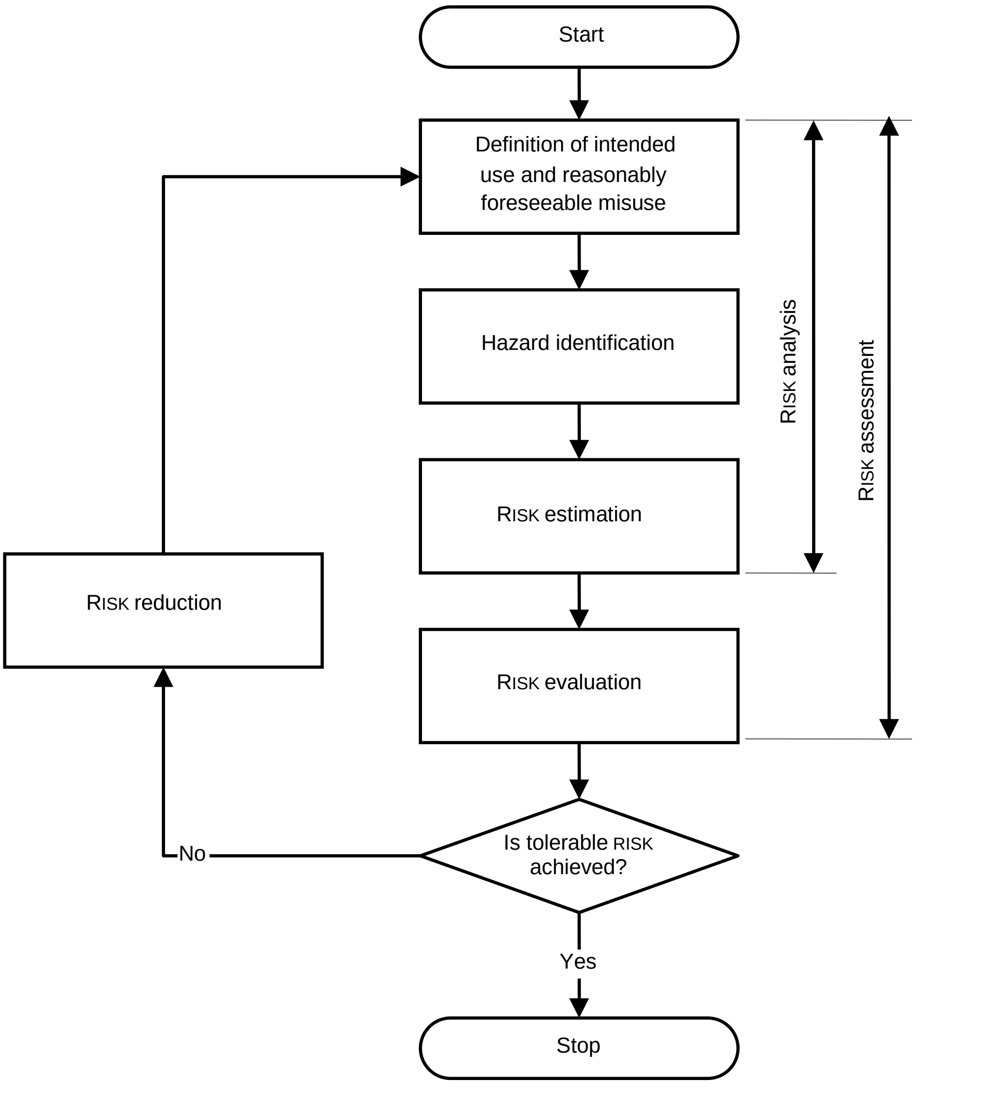


Figure J.1 – Iterative process of RISK assessment and RISK reduction

J.2 Achieving TOLERABLE RISK

The following procedure (see Figure J.1) should be used to reduce RISKS to a tolerable level:

a) identify the likely user group(s) for the product, process, or service (including those with special needs and the elderly), and any known contact group (e.g. use or contact by children);

b) identify the intended use and assess the REASONABLY FORESEEABLE MISUSE of the product, process or service;

c) identify each HAZARD (including any hazardous situation and harmful event) arising in all stages and conditions for the use of the product, process or service, including installation, maintenance, repair, and destruction or disposal;

d) estimate and evaluate the RISK (see Figure J.1) to each identified user/contact group arising from each HAZARD identified;

e) judge if the RISK is tolerable (e.g. by comparison with similar products, processes or services);

f) if the RISK is not tolerable, reduce the RISK until it becomes tolerable.

When reducing RISKS the order of priority should be as follows:

1) eliminate or reduce RISKS as far as possible (inherently safe design and construction);

2) take the necessary protection measures in relation to RISKS that cannot be eliminated (protection devices);

3) inform users of the residual RISKS due to any shortcomings of the protection measures adopted, indicate whether any particular training is required, and specify any need to provide personal protection equipment (information for safety).

This procedure is based on the assumption that the user has a role to play in the RISK reduction procedure by complying with the information provided by the manufacturer (see Figure J.2).

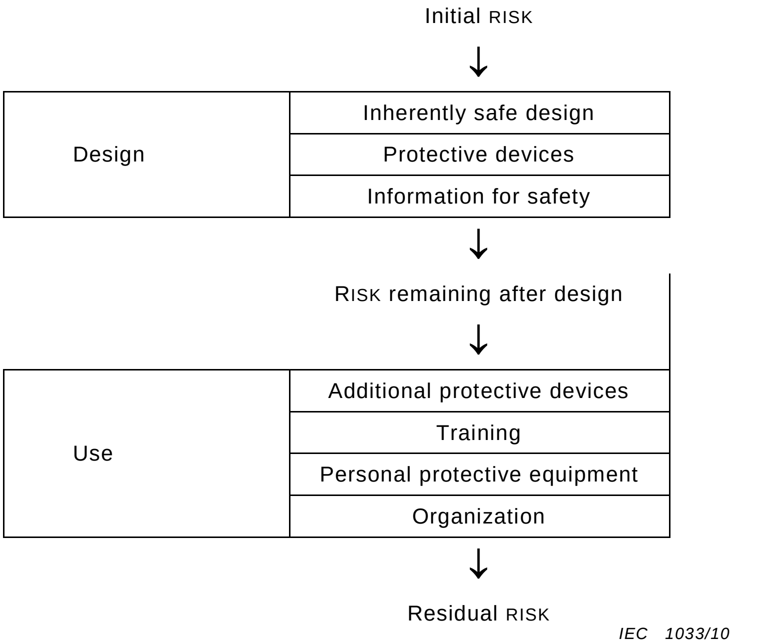


Figure J.2 – RISK reduction

The steps taken in the design procedure are shown in order of priority. The steps to be taken by the user are not in order of priority because this would depend on the application. It is emphasized that the additional protection devices, personal protection equipment and provision of information to users should not be used as substitutes for design improvements.

J.3 An application of RISK assessment procedures

For HAZARDS in the scope of this standard, examples of severity of harm are given in Table J.1. Probability of harm is given in Table J.2. The RISK category, which is selected based on severity and probability, is given in Table J.3.

Table J.1 – Severity of harm

Severity group	People	Equipment / Facility	Environment
Catastrophic	One or more fatalities	System or facility loss	Chemical release with acute or public health impact
Severe	Disabling injury/illness	Major subsystem loss or facility damage	Chemical release with temporary environmental or public health impact
Moderate	Medical treatment or restricted work activity	Minor subsystem loss or facility damage	Chemical release triggering external reporting requirements
Minor	First aid only	Non-serious equipment or facility damage	Chemical release requiring only routine cleanup without reporting

Table J.2 – Probability of harm

Likelihood	Expected rate of occurrence
Frequent	More than five times a year
Likely	More than once per year, but not more than five times a year
Possible	More than once in five years, but not more than one a year
Rare	More than once in ten years, but not more than one in five years
Unlikely	No more than once in ten years

Table J.3 – RISK category

RISK assessment / RISK category						
Severity of harm		Probability of harm				
		Frequent	Likely	Possible	Rare	Unlikely
Severity	Catastrophic	3	3	3	2	2
	Severe	3	3	2	2	1
	Moderate	3	2	1	1	1
	Minor	2	1	1	1	1

Key	Category	Description
1	Broadly acceptable	This fulfils the requirement for TOLERABLE RISK.
2	As low as reasonably practicable	This does not automatically fulfil the requirement for TOLERABLE RISK. If possible, these RISKS should be reduced further to Category 1. If not possible, then the instructions should contain a description of the RISK so that the RESPONSIBLE BODY can take appropriate steps to protect the safety of OPERATORS.
3	Intolerable	This contains RISKS that are not TOLERABLE RISKS.

Annex K
(normative)

Insulation requirements not covered by 6.7

K.1 Insulation for MAINS CIRCUITS

K.1.1 General

The concept of OVERVOLTAGE CATEGORIES is elaborated in IEC 60364 and in IEC 60664-1. The descriptions below are made up of edited extracts from these two standards.

An OVERVOLTAGE CATEGORY is, as the definition 3.5.17 states, a numeral defining a TRANSIENT OVERVOLTAGE condition. The OVERVOLTAGE CATEGORIES are created to achieve insulation coordination between different parts of the MAINS supply installation. IEC 60364-4-44 says that 'Impulse withstand (overvoltage) categories are to distinguish different degrees of availability of equipment with regard to required expectations on continuity of service and on an acceptable probability of failure'. This means that the decision of the appropriate RATING of the OVERVOLTAGE CATEGORY of a piece of equipment may be made on grounds of reliability as well as on grounds of safety. In this standard, requirements in Clauses 5 to 16 apply to equipment not forming part of the building installation, and the requirements for CLEARANCES and CREEPAGE DISTANCES are based on OVERVOLTAGE CATEGORY II, with MAINS voltages up to 300 V.

Equipment forming part of the building installation may include installation material, equipment intended to measure or control the MAINS supply within the building, and similar equipment. All such equipment is permanently connected to the MAINS, and is permanently installed in the building. However, equipment that utilizes the MAINS supply only for powering itself and associated equipment is not considered to be part of the building installation, even if it is permanently connected or permanently installed in the building.

If a manufacturer rates equipment for OVERVOLTAGE CATEGORY III OR OVERVOLTAGE CATEGORY IV, the relevant requirements of this annex apply.

OVERVOLTAGE CATEGORY I is used, within the context of IEC 60364-4-44, for equipment intended to be connected to a MAINS supply in which means have been taken to substantially and reliably reduce TRANSIENT OVERVOLTAGES to a level where they cannot cause a HAZARD. OVERVOLTAGE CATEGORY I is not relevant to this standard.

OVERVOLTAGE CATEGORY II is for equipment intended to be supplied from the building wiring. It applies both to plug-connected equipment and to PERMANENTLY CONNECTED EQUIPMENT. Subclause 6.7 covers only the requirements for OVERVOLTAGE CATEGORY II with a nominal supply voltage up to 300 V. The requirements for higher OVERVOLTAGE CATEGORIES and for OVERVOLTAGE CATEGORY II with a nominal supply voltage above 300 V are covered by this annex.

OVERVOLTAGE CATEGORY III is for equipment intended to form part of a building wiring installation. Such equipment includes socket outlets, fuse panels, and some MAINS installation control equipment. Manufacturers may also design equipment for OVERVOLTAGE CATEGORY III when a higher degree of reliability and availability is desired.

OVERVOLTAGE CATEGORY IV is for equipment installed at or near the origin of the electrical supply to a building, between the building entrance and the main distribution board. Such equipment may include electricity tariff meters and primary overcurrent protection devices. Manufacturers may also design equipment for OVERVOLTAGE CATEGORY IV when an even higher degree of reliability and availability is desired.

K.1.2 CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS

CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS shall meet the values of the following tables as applicable:

a) for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II, with nominal supply voltages above 300 V, Table K.2;
b) for MAINS CIRCUITS of OVERVOLTAGE CATEGORY III, Table K.3;
c) for MAINS CIRCUITS of OVERVOLTAGE CATEGORY IV, Table K.4.

NOTE 1 See Annex I for nominal voltages of MAINS supplies.

The values in the following tables are for BASIC INSULATION and SUPPLEMENTARY INSULATION. Values for REINFORCED INSULATION shall be twice the values for BASIC INSULATION.

If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCES shall be multiplied by the applicable factor of Table K.1.

NOTE 2 Material group IIIb is not recommended for application in POLLUTION DEGREE 3 above line-to-neutral voltages of 630 V.

Conformity is checked by inspection and measurement and, in case of doubt, by the impulse voltage test of 6.8.3.3 or the a.c. test of 6.8.3.1 with a duration of at least 5 s using the applicable test voltage from Table K.16 for the required CLEARANCE.

No flashover of CLEARANCES shall occur during the test.

Table K.1 – Multiplication factors for CLEARANCES for equipment RATED for operation at altitudes up to 5 000 m

RATED operating altitude m	Multiplication factor
Up to 2 000	1,00
2 001 to 3 000	1,14
3 001 to 4 000	1,29
4 001 to 5 000	1,48

Table K.2 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS of OVERVOLTAGE CATEGORY II above 300 V

Voltage line-to-neutral a.c. r.m.s. or d.c.	Values for CLEARANCE	Values for CREEPAGE DISTANCE								
		Printed wiring board material		Other insulating material						
		POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
		All material groups	Material groups I, II, IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
>300 ≤ 600	3,0	3,0	3,0	3,0	3,0	4,3	6,0	7,5	8,3	9,4
>600 ≤ 1 000	5,5	5,5	5,5	5,5	5,5	7,2	10,0	12,5	14,0	16,0

Table K.3 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS of OVERVOLTAGE CATEGORY III

Voltage line-to-neutral a.c. r.m.s. or d.c.	Values for CLEARANCE	Values for CREEPAGE DISTANCE								
		Printed wiring board material		Other insulating material						
		POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
		All material groups	Material groups I, II, IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
≤150	1,5	1,5	1,5	1,5	1,5	1,5	1,6	2,0	2,2	2,5
>150 ≤ 300	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,8	4,1	4,7
>300 ≤ 600	5,5	5,5	5,5	5,5	5,5	5,5	6,0	7,5	8,3	9,4
>600 ≤ 1 000	8,0	8,0	8,0	8,0	8,0	8,0	10,0	12,5	14,0	16

Table K.4 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS of OVERVOLTAGE CATEGORY IV

Voltage line-to-neutral a.c. r.m.s. or d.c.	Values for CLEARANCE	Values for CREEPAGE DISTANCE								
		Printed wiring board material		Other insulating material						
		POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
		All material groups	Material groups I, II, IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III
V	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
≤150	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
>150 ≤ 300	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5
>300 ≤ 600	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,0	8,3	9,4
>600 ≤ 1 000	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	16,0

Coatings that meet the requirements of Annex H when applied to the outer surfaces of printed wiring boards reduce the POLLUTION DEGREE of the coated area to POLLUTION DEGREE 1.

Conformity of coatings is checked as specified in Annex H.

K.1.3 Solid insulation for MAINS CIRCUITS

K.1.3.1 General

Solid insulation of MAINS CIRCUITS shall withstand the electrical and mechanical stresses that may occur in NORMAL USE, in all RATED environmental conditions (see 1.4), during the intended life of the equipment.

NOTE 1 The manufacturer should take the expected life of the equipment into account when selecting insulating materials.

Conformity is checked by both of the following tests:

a) *the a.c. test of 6.8.3.1 with a duration of at least 5 s or the peak impulse test of 6.8.3.3 using the applicable voltages from Tables K.5, K.6 or K.7;*

b) *the a.c. test of 6.8.3.1 with a duration of at least 1 min, or for* MAINS CIRCUITS *stressed only by d.c. the 1 min d.c. test of 6.8.3.2 using the applicable voltages from Table K.8.*

NOTE 2 These two different voltage tests are required for these circuits for the following reasons. Test a) checks the effects of TRANSIENT OVERVOLTAGES, while test b) checks the effects of long-term stress of solid insulation.

NOTE 3 If the test from Tables K.5 to K.7 is performed for at least 1 min, there is no need to repeat the test of b) above.

Table K.5 – Test voltages for solid insulation in MAINS CIRCUITS of OVERVOLTAGE CATEGORY II above 300 V

Voltage line-to-neutral a.c. r.m.s. or d.c. V	Test voltage			
	5 s a.c. test V a.c. r.m.s.		Impulse test V peak	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION
>300 ≤ 600	2 210	3 510	4 000	6 400
>600 ≤ 1 000	3 310	5 400	6 000	9 600

Table K.6 – Test voltages for solid insulation in MAINS CIRCUITS of OVERVOLTAGE CATEGORY III

Voltage line-to-neutral a.c. r.m.s. or d.c. V	Test voltage			
	5 s a.c. test V r.m.s.		Impulse test V peak	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION
≤150	1 390	2 210	2 500	4 000
>150 ≤ 300	2 210	3 510	4 000	6 400
>300 ≤ 600	3 310	5 400	6 000	9 600
>600 ≤ 1 000	4 260	7 400	8 000	12 800

Table K.7 – Test voltages for solid insulation in MAINS CIRCUITS of OVERVOLTAGE CATEGORY IV

Voltage line-to-neutral a.c. r.m.s. or d.c. V	Test voltage			
	5 s a.c. test V r.m.s.		Impulse test V peak	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION
≤150	2 210	3 510	4 000	6 400
>150 ≤ 300	3 310	5 400	6 000	9 600
>300 ≤ 600	4 260	7 400	8 000	12 800
>600 ≤ 1 000	6 600	11 940	12 000	19 200

Table K.8 – Test voltages for testing long-term stress of solid insulation in MAINS CIRCUITS

Voltage line-to-neutral a.c. r.m.s. or d.c. V	Test voltage			
	1 min a.c. test V r.m.s.		1 min d.c. test voltage V d.c.	
	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION	BASIC INSULATION and SUPPLEMENTARY INSULATION	REINFORCED INSULATION
≤150	1 350	2 700	1 900	3 800
> 150 ≤ 300	1 500	3 000	2 100	4 200
> 300 ≤ 600	1 800	3 600	2 550	5 100
> 600 ≤ 1 000	2 200	4 400	3 100	6 200

Solid insulation shall also meet the following requirements, as applicable:

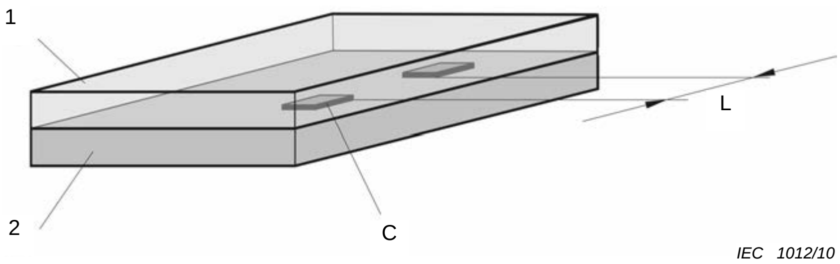
1) for solid insulation used as an ENCLOSURE or BARRIER, the requirements of Clause 8;
2) for moulded and potted parts, the requirements of K.1.3.2;
3) for inner layers of printed wiring boards, the requirements of K.1.3.3;
4) for thin-film insulation, the requirements of K.1.3.4;

Conformity is checked as specified in K.1.3.2 to K.1.3.4, and in Clause 8, as applicable.

K.1.3.2 Moulded and potted parts

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers moulded together (see Figure K.1, item L) shall be separated by at least the applicable minimum distance of Table K.9 after the moulding is completed.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications*.*



Key

1 Layer 1

2 Layer 2

C Conductor

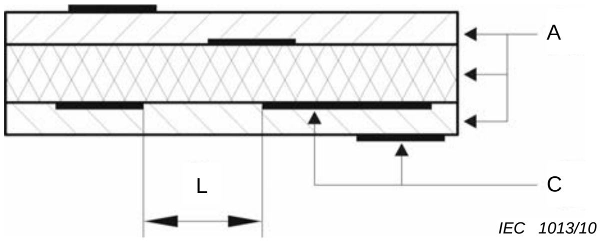
L Distance between conductors

Figure K.1 – Distance between conductors on an interface between two layers

K.1.3.3 Inner insulating layers of printed wiring boards

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers (see Figure K.2, item L) shall be separated by at least the applicable minimum distance of Table K.9.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key:

L Distance between adjacent conductors

A Layers

C Conductors

Figure K.2 – Distance between adjacent conductors along an interface of an inner layer

Table K.9 – Minimum values for distance or thickness of solid insulation

Line-to-neutral voltage V r.m.s. or d.c.	**Minimum thickness** [a] mm	**Minimum distance L (see Figure K.2)** [a, b] mm
≤ 300	0,4	0,4
> 300 ≤ 600	0,6	0,6
> 600 ≤ 1 000	1,0	1,0

[a] These values are independent of the OVERVOLTAGE CATEGORY.

[b] These values apply for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION.

REINFORCED INSULATION of inner insulating layers of printed wiring boards shall also have adequate electric strength through the respective layers. One of the following methods shall be used:

a) the thickness through the insulation is at least the value of Table K.9.

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation is assembled from at least two separate layers of printed wiring board materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltage of the applicable Table K.5, Table K.6 or Table K.7 for BASIC INSULATION.

   Conformity is checked by inspection of the manufacturer's specifications.

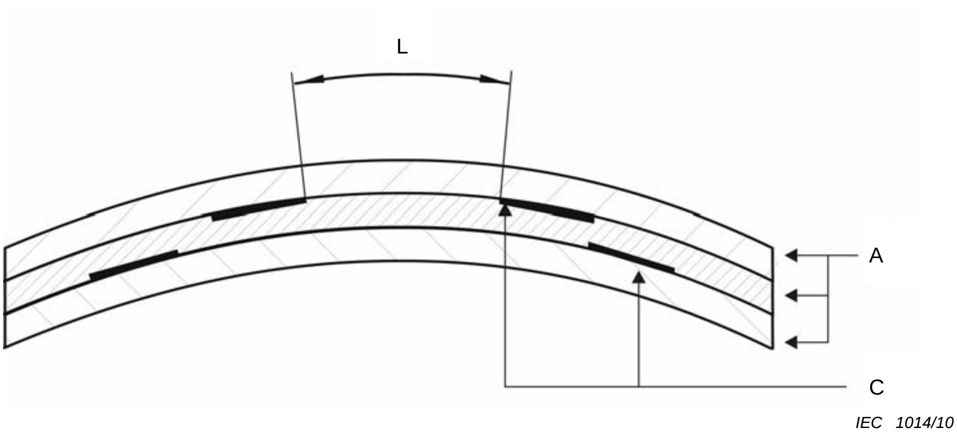
c) the insulation is assembled from at least two separate layers of printed wiring board materials, and the combination of layers is RATED by the manufacturer of the material for an electric strength of at least the value of the applicable Table K.5, Table K.6 or Table K.7 for REINFORCED INSULATION.

Conformity is checked by inspection of the manufacturer's specifications.

K.1.3.4 Thin-film insulation

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers (see Figure K.3, item L) shall be separated by at least the applicable CLEARANCE and CREEPAGE DISTANCE of K.1.2.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.



Key:

L Distance between adjacent conductors

A Layers of thin-film material such as tape and polyester film

C Conductors

NOTE There may be air present between the layers

Figure K.3 – Distance between adjacent conductors located between the same two layers

REINFORCED INSULATION through the layers of thin-film insulation shall also have adequate electric strength. One of the following methods shall be used.

a) The thickness through the insulation is at least the value of Table K.9.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) The insulation consists of at least two separate layers of thin-film materials, each of which is RATED by the manufacturer of the material for an electric strength of at least the value of the test voltages from Table K.5, Table K.6 or Table K.7 as applicable for BASIC INSULATION.

Conformity is checked by inspection of the manufacturer's specifications.

c) The insulation consists of at least three separate layers of thin-film materials, any two of which have been tested to exhibit adequate electric strength.

Conformity is checked by the a.c. test of 6.8.3.1 with a duration of at least 1 min or for MAINS CIRCUITS stressed only by d.c. the 1 min d.c. test of 6.8.3.2 applied to two of the three layers using the applicable voltage for REINFORCED INSULATION of Table K.5, Table K.6 or Table K.7.

NOTE For the purposes of this test a special sample may be assembled with only two layers of the material.

K.2 Insulation in secondary circuits

K.2.1 General

In this standard, secondary circuits are circuits where separation from MAINS CIRCUITS is achieved by a transformer in which the primary windings are separated from the secondary windings by REINFORCED INSULATION, DOUBLE INSULATION, or a screen connected to the PROTECTIVE CONDUCTOR TERMINAL.

NOTE These circuits are assumed to be subjected to lower TRANSIENT OVERVOLTAGE levels than the MAINS CIRCUIT.

K.2.2 CLEARANCES

CLEARANCES for secondary circuits shall:

a) for BASIC INSULATION or SUPPLEMENTARY INSULATION, meet the applicable values of Tables K.10, K.11 and K.12, or for REINFORCED INSULATION meet twice that value; or

b) pass the voltage test of 6.8 using the applicable value of Table K.10, Table K.11 or Table K.12.

For the application of Tables K.10 to K.12, the following applies:

1) values for test voltages for REINFORCED INSULATION are 1,6 times the values for BASIC INSULATION;

2) if the equipment is RATED to operate at an altitude greater than 2 000 m, the values for CLEARANCES are multiplied by the applicable factor of Table K.1;

3) minimum CLEARANCE is 0,2 mm for POLLUTION DEGREE 2 and 0,8 mm for POLLUTION DEGREE 3.

Conformity is checked by inspection and measurement and for b) by the a.c. test of 6.8.3.1 with a duration of at least 5 s, or by the 1 min d.c. test of 6.8.3.2, using the applicable test voltage from Tables K.10 to K.12. The value of the d.c. test voltage is $\sqrt{2}$ *times the a.c. r.m.s. test voltage.*

Table K.10 – CLEARANCES and test voltages for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY II above 300 V

Secondary WORKING VOLTAGE		MAINS VOLTAGE >300 ≤ 600 V r.m.s.		MAINS VOLTAGE >600 ≤ 1 000 V r.m.s.	
a.c. r.m.s.	d.c. or a.c. peak	CLEARANCE	Test voltage	CLEARANCE	Test voltage
V	V	mm	V r.m.s.	mm	V r.m.s.
16	22,6	1,5	1 390	2,9	1 590
33	46,7	1,5	1 390	3,0	2 210
50	70	1,5	1 390	3,0	2 210
100	140	1,6	1 450	3,1	2 260
150	210	1,6	1 450	3,2	2 300
300	420	1,8	1 540	3,4	2 400
600	840	2,4	1 620	3,9	2 630
1 000	1 400	3,5	2 450	5,0	3 110
1 250	1 750	4,2	2 770	5,8	3 430
1 600	2 240	5,2	3 190	6,9	3 850
2 000	2 800	6,5	3 700	8,2	4 330
2 500	3 500	8,1	4 300	9,8	4 920
3 200	4 480	10	4 950	12	5 780
4 000	5 600	12	5 780	15	7 000
5 000	7 000	16	7 400	18	8 200
6 300	8 820	20	8 980	22	9 700
8 000	11 200	26	11 200	28	11 900
10 000	14 000	33	13 800	35	14 500
12 500	17 500	42	16 900	44	17 600
16 000	22 400	55	21 200	57	21 900
20 000	28 000	71	26 300	73	27 000
25 000	35 000	91	32 600	93	33 200
32 000	44 800	120	41 600	122	42 200
40 000	56 000	154	52 200	157	53 100
50 000	70 000	199	66 100	202	67 000
63 000	88 200	261	85 300	262	85 600
Linear interpolation is allowed.					

Table K.11 – CLEARANCES and test voltages for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY III

Secondary WORKING VOLTAGE		MAINS voltage ≤150 V a.c. r.m.s.		MAINS voltage >150 ≤ 300 V a.c. r.m.s.		MAINS voltage >300 ≤ 600 V a.c. r.m.s.		MAINS voltage >600 ≤ 1 000 V a.c. r.m.s.	
a.c. r.m.s. V	**d.c. or a.c. peak** V	CLEARANCE mm	**Test voltage** V a.c. r.m.s.	CLEARANCE mm	**Test voltage** V a.c. r.m.s.	CLEARANCE mm	**Test voltage** V a.c. r.m.s.	CLEARANCE mm	**Test voltage** V a.c. r.m.s.
16	22,6	0,48	1 100	1,5	1 800	2,9	2 820	5,4	4 240
33	46,7	0,50	1 100	1,5	1 800	3,0	2 900	5,4	4 240
50	70	0,53	1 120	1,5	1 800	3,0	2 900	5,5	4 300
100	140	0,61	1 170	1,6	1 880	3,1	2 960	5,6	4 360
150	210	0,69	1 200	1,6	1 880	3,2	3 020	5,7	4 420
300	420	0,94	1 360	1,8	2 040	3,4	3 140	6,0	4 600
600	840	1,6	1 880	2,4	2 440	3,9	3 440	6,6	4 860
1 000	1 400	2,5	2 500	3,5	3 200	5,0	4 000	7,4	5 240
1 250	1 750	3,2	3 020	4,2	3 620	5,8	4 480	8,1	5 560
1 600	2 240	4,1	3 560	5,2	4 120	6,9	5 040	9,3	6 120
2 000	2 800	5,3	4 180	6,5	4 800	8,2	5 620	11	7 000
2 500	3 500	6,9	5 040	8,1	5 560	9,8	6 320	12	7 500
3 200	4 480	9,2	6 080	10	6 400	12	7 500	15	9 100
4 000	5 600	12	7 500	12	7 500	15	9 100	17	10 100
5 000	7 000	15	9 100	16	9 600	18	10 600	20	11 600
6 300	8 820	19	11 200	20	11 600	22	12 600	25	14 100
8 000	11 200	25	14 100	26	14 600	28	15 500	31	16 900
10 000	14 000	32	17 400	33	17 800	35	18 700	38	20 000
12 500	17 500	41	21 500	42	21 900	44	22 800	47	24 200
16 000	22 400	54	27 200	55	27 600	57	28 400	60	29 700
20 000	28 000	69	33 500	71	34 300	73	35 200	76	36 400
25 000	35 000	89	41 600	91	42 400	93	43 200	96	44 400
32 000	44 800	118	53 000	120	53 700	122	54 500	125	55 600
40 000	56 000	153	66 100	154	66 500	157	67 600	160	68 700
50 000	70 000	198	82 400	199	82 700	202	83 800	205	84 900
63 000	88 200	260	104 000	261	104 400	262	104 700	265	105 700
Linear interpolation is allowed.									

Table K.12 – CLEARANCES and test voltages for secondary circuits derived from MAINS CIRCUITS of OVERVOLTAGE CATEGORY IV

Secondary WORKING VOLTAGE		MAINS voltage ≤150 V a.c. r.m.s.		MAINS voltage >150 ≤ 300 V a.c. r.m.s.		MAINS voltage >300 ≤ 600 V a.c. r.m.s.		MAINS voltage >600 ≤ 1 000 V a.c. r.m.s.	
a.c. r.m.s. V	d.c. or a.c. peak V	CLEARANCE mm	Test voltage V a.c. r.m.s.	CLEARANCE mm	Test voltage V a.c. r.m.s.	CLEARANCE mm	Test voltage V a.c. r.m.s.	CLEARANCE mm	Test voltage V a.c. r.m.s.
16	22,6	1,5	1 800	2,9	2 820	5,4	4 240	8,3	5 680
33	46,7	1,5	1 800	3,0	2 900	5,4	4 240	8,3	5 680
50	70	1,5	1 800	3,0	2 900	5,5	4 300	8,4	5 740
100	140	1,6	1 880	3,1	2 960	5,6	4 360	8,5	5 800
150	210	1,6	1 880	3,2	3 020	5,7	4 420	8,6	5 860
300	420	1,8	2 040	3,4	3 140	6,0	4 600	8,9	5 960
600	840	2,4	2 440	3,9	3 440	6,6	4 860	9,6	6 240
1 000	1 400	3,5	3 200	5,0	4 000	7,4	5 240	10	6 400
1 250	1 750	4,2	3 620	5,8	4 480	8,1	5 560	11	7 000
1 600	2 240	5,2	4 120	6,9	5 040	9,3	6 120	12	7 500
2 000	2 800	6,5	4 800	8,2	5 620	11	7 000	13	8 100
2 500	3 500	8,1	5 560	9,8	6 320	12	7 500	15	9 100
3 200	4 480	10	6 400	12	7 500	15	9 100	17	10 100
4 000	5 600	12	7 500	15	9 100	17	10 100	19	11 200
5 000	7 000	16	9 600	18	10 600	20	11 600	23	13 100
6 300	8 820	20	11 600	22	12 600	25	14 100	27	15 100
8 000	11 200	26	14 600	28	15 500	31	16 900	33	17 800
10 000	14 000	33	17 800	35	18 700	38	20 000	40	21 000
12 500	17 500	42	21 900	44	22 800	47	24 200	50	25 500
16 000	22 400	55	27 600	57	28 400	60	29 700	63	31 000
20 000	28 000	71	34 300	73	35 200	76	36 400	79	37 600
25 000	35 000	91	42 400	93	43 200	96	44 400	99	45 400
32 000	44 800	120	53 700	122	54 500	125	55 600	129	57 100
40 000	56 000	154	66 500	157	67 600	160	68 700	164	70 100
50 000	70 000	199	82 700	202	83 800	205	84 900	209	86 300
63 000	88 200	261	104 400	262	104 700	265	105 700	268	106 800
Linear interpolation is allowed.									

K.2.3 CREEPAGE DISTANCES

CREEPAGE DISTANCES for BASIC INSULATION or SUPPLEMENTARY INSULATION for secondary circuits shall meet the applicable values of Table K.13, based on the WORKING VOLTAGE which stresses the insulation. Values for REINFORCED INSULATION are twice the values for BASIC INSULATION.

Conformity is checked by inspection and measurement.

Coatings that meet the requirements of Annex H when applied to the outer surfaces of printed wiring boards reduce the POLLUTION DEGREE of the coated area to POLLUTION DEGREE 1.

Conformity is checked by inspection and as specified in Annex H.

Table K.13 – CREEPAGE DISTANCES for secondary circuits

Secondary WORKING VOLTAGE a.c. r.m.s. or d.c.	Printed wiring board material		Other insulating material						
	POLLUTION DEGREE 1	POLLUTION DEGREE 2	POLLUTION DEGREE 1	POLLUTION DEGREE 2			POLLUTION DEGREE 3		
	All material groups	Material group I, II or IIIa	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III [b]
V	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	0,025	0,04	0,08	0,40	0,40	0,40	1,00	1,00	1,00
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05
16	0,025	0,04	0,10	0,45	0,45	0,45	1,10	1,10	1,10
20	0,025	0,04	0,11	0,48	0,48	0,48	1,20	1,20	1,20
25	0,025	0,04	0,125	0,50	0,50	0,50	1,25	1,25	1,25
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3
40	0,025	0,04	0,16	0,56	0,80	1,10	1,4	1,6	1,8
50	0,025	0,04	0,18	0,60	0,85	1,20	1,5	1,7	1,9
63	0,040	0,063	0,20	0,63	0,90	1,25	1,6	1,8	2,0
80	0,063	0,10	0,22	0,67	0,95	1,3	1,7	1,9	2,1
100	0,10	0,16	0,25	0,71	1,00	1,4	1,8	2,0	2,2
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4
160	0,25	0,40	0,32	0,80	1,1	1,6	2,0	2,2	2,5
200	0,40	0,63	0,42	1,00	1,4	2,0	2,5	2,8	3,2
250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0
320	0,75	1,6	0,75	1,60	2,2	3,2	4,0	4,5	5,0
400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0
630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0
800	2,4	4,0	2,4	4,0	5,6	8,0	10,0	11	12,5
1 000	3,2 [a]	5,0 [a]	3,2	5,0	7,1	10,0	12,5	14	16
1 250			4,2	6,3	9,0	12,5	16	18	20
1 600			5,6	8,0	11	16	20	22	25
2 000			7,5	10,0	14	20	25	28	32
2 500			10,0	12,5	18	25	32	36	40
3 200			12,5	16	22	32	40	45	50
4 000			16	20	28	40	50	56	63
5 000			20	25	36	50	63	71	80
6 300			25	32	45	63	80	90	100
8 000			32	40	56	80	100	110	125
10 000			40	50	71	100	125	140	160
12 500			50	63	90	125			
16 000			63	80	110	160			
20 000			80	100	140	200			
25 000			100	125	180	250			
32 000			125	160	220	320			
40 000			160	200	280	400			
50 000			200	250	360	500			
63 000			250	320	450	600			

[a] For voltages above 1 000 V, CREEPAGE DISTANCES on printed wiring board material are the same as for other insulators of the same material group.

[b] Material group IIIb is not recommended for application in pollution degree 3 above 630 V.

Linear interpolation is allowed.

K.2.4 Solid insulation

K.2.4.1 General

Solid insulation in secondary circuits shall withstand the electrical and mechanical stresses that may occur in NORMAL USE, in all RATED environmental conditions (see 1.4), during the intended life of the equipment.

NOTE The manufacturer should take the expected life of the equipment into account when selecting insulating materials.

Conformity is checked by both of the following tests:

a) by the voltage test of 6.8.3.1 for 5 s using the applicable test voltage of Table K.10, Table K.11 or Table K.12 for BASIC INSULATION and SUPPLEMENTARY INSULATION. For REINFORCED INSULATION, the values are multiplied by 1,6;

b) additionally, if the WORKING VOLTAGE exceeds 300 V, by the voltage test of 6.8.3.1 for 1 min, with a test voltage of 1,5 times the WORKING VOLTAGE for BASIC INSULATION and SUPPLEMENTARY INSULATION and twice the WORKING VOLTAGE for REINFORCED INSULATION.

Solid insulation shall also meet the following requirements, as applicable:

1) for solid insulation used as an ENCLOSURE or BARRIER, the requirements of Clause 8;
2) for moulded and potted parts, the requirements of K.2.4.2;
3) for inner insulating layers of printed wiring boards, the requirements of K.2.4.3;
4) for thin-film insulation, the requirements of K.2.4.4.

Conformity is checked as specified in K.2.4.2 to K.2.4.4 and Clause 8, as applicable.

K.2.4.2 Moulded and potted parts

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, conductors located between the same two layers shall be separated by the applicable minimum distance of Table K.14 (see Figure K.1, item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

Table K.14 – Minimum values for distance or thickness (see K.2.4.2 to K.2.4.4)

Peak value of the a.c. or d.c WORKING VOLTAGE or recurring peak voltage kV	Minimum value mm	Peak value of the a.c. or d.c WORKING VOLTAGE or recurring peak voltage kV	Minimum value mm
>0,046 7 ≤ 0,33	0,05	>8,0 ≤ 10	3,5
>0,33 ≤ 0,8	0,1	>10 ≤ 12	4,5
>0,8 ≤ 1,0	0,15	>12 ≤ 15	5,5
>1,0 ≤ 1,2	0,2	>15 ≤ 20	8
>1,2 ≤ 1,5	0,3	>20 ≤ 25	10
>1,5 ≤ 2,0	0,45	>25 ≤ 30	12,5
>2,0 ≤ 2,5	0,6	>30 ≤ 40	17
>2,5 ≤ 3,0	0,8	>40 ≤ 50	22
>3,0 ≤ 4,0	1,2	>50 ≤ 60	27
>4,0 ≤ 5,0	1,5	>60 ≤ 80	35
>5,0 ≤ 6,0	2	>80 ≤ 100	45
>6,0 ≤ 8,0	3		

K.2.4.3 Inner insulating layers of printed wiring boards

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION conductors located between the same two layers shall be separated by the applicable minimum distance of Table K.14 (see Figure K.2, item L).

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

REINFORCED INSULATION of inner insulating layers of printed wiring boards shall also have adequate electric strength through the respective layers. One of the following methods shall be used:

a) the thickness of the insulation is at least the applicable minimum distance of Table K.14.

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation is assembled from at least two separate layers of printed wiring board materials, each of which is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of the applicable Table K.10 to K.12 for BASIC INSULATION.

   Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation is assembled from at least two separate layers of printed wiring board materials, and the combination of layers is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of the applicable Table K.10, Table K.11 or Table K.12 multiplied by 1,6 for REINFORCED INSULATION.

   Conformity is checked by inspection of the manufacturer's specifications.

K.2.4.4 Thin-film insulation

For BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION conductors located between the same two layers (see Figure K.3, item L) shall be separated by at least the applicable CLEARANCE and CREEPAGE DISTANCE of K.2.2 and K.2.3.

Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

REINFORCED INSULATION through the layers of thin-film insulation shall also have adequate electric strength. One of the following methods shall be used:

a) the thickness through the insulation is at least the applicable value of Table K.14;

   Conformity is checked by inspection and either by measurement of the separation or by inspection of the manufacturer's specifications.

b) the insulation consists of at least two separate layers of thin-film materials, each of which is RATED by the manufacturer of the material for an electric strength at least the value of the test voltage of the applicable Table K.10, Table K.11 or Table K.12 for BASIC INSULATION;

   Conformity is checked by inspection of the manufacturer's specifications.

c) the insulation consists of at least three separate layers of thin-film materials, any two of which have been tested to exhibit adequate electric strength.

   Conformity is checked by the a.c. test of 6.8.3.1 with a duration of at least 1 min, or for MAINS CIRCUITS stressed only by d.c., the 1 min d.c. test of 6.8.3.2, using the applicable voltages from Table K.10, Table K.11 or Table K.12 multiplied by 1,6, applied to two of the three layers.

   NOTE For the purposes of the test for option c), a special sample may be assembled with only two layers of the material.

K.3 Insulation in circuits not addressed in 6.7, Clause K.1 or Clause K.2

K.3.1 General

These circuits have one or more of the following characteristics:

a) the maximum possible TRANSIENT OVERVOLTAGE is limited by the supply source or within the equipment (see K.4.) to a known level below the level assumed for the MAINS CIRCUIT;

b) the maximum possible TRANSIENT OVERVOLTAGE is above the level assumed for the MAINS CIRCUIT;

c) the WORKING VOLTAGE is the sum of voltages from more than one circuit, or is a mixed voltage;

d) the WORKING VOLTAGE includes a recurring peak voltage that may include a periodic non-sinusoidal waveform or a non-periodic waveform that occurs with some regularity;

e) the WORKING VOLTAGE has a frequency above 30 kHz.

In cases a) to c), CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION are determined according to K.3.2.

In cases d) and e) CLEARANCES are determined according to K.3.3.

In all cases K.3.4 addresses CREEPAGE DISTANCE and K.3.5 solid insulation

NOTE Requirements for measuring circuits are given in IEC 61010-2-030.

K.3.2 CLEARANCE calculation

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION are determined from the following formula:

$$\text{CLEARANCE} = D_1 + F \times (D_2 - D_1)$$

where

F is a factor, determined from one of the equations:

$F = (1{,}25 \times U_w/U_m) - 0{,}25$ if $U_w/U_m > 0{,}2$

$F = 0$ if $U_w/U_m \leq 0{,}2$

where

$U_m = U_w + U_t$;

U_w = the maximum peak value of the WORKING VOLTAGE;

U_t = the maximum additional TRANSIENT OVERVOLTAGE

D_1 and D_2 are values taken from Table K.15 for U_m

where

D_1 represents the CLEARANCE that would be applicable to a TRANSIENT OVERVOLTAGE with the shape of a 1,2 × 50 μs impulse.

D_2 represents the CLEARANCE that would be applicable to the peak WORKING VOLTAGE without any TRANSIENT OVERVOLTAGE;

CLEARANCES for REINFORCED INSULATION are twice the values for BASIC INSULATION.

If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCES shall be multiplied by the applicable factor of Table K.1.

Minimum CLEARANCE, for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, is 0,2 mm for POLLUTION DEGREE 2 and 0,8 mm for POLLUTION DEGREE 3.

NOTE 1 The insulation between the primary and secondary winding of a transformer connected to MAINS is stressed by the common mode voltage component transferred during a transient event from the primary side and the WORKING VOLTAGE across the insulation. This common mode voltage expressed as additional TRANSIENT OVERVOLTAGE together with the maximum peak value of WORKING VOLTAGE U_w form the maximum impulse voltage U_m.

For example for a MAINS CIRCUIT with a line-to-neutral voltage of 230 V r.m.s. and an impulse withstand voltage of 2 500 V_{PEAK} the common mode voltage (additional TRANSIENT OVERVOLTAGE) is calculated as follows:

$U_w = 1{,}414 \times 230$ V r.m.s = 325 V_{PEAK}

$U_t = 2\,500\ V_{PEAK} - 325\ V_{PEAK} = 2\,175\ V_{PEAK}$

Conformity is checked by inspection and measurement or by the a.c. test of 6.8.3.1 with a duration of at least 5 s or the impulse voltage test of 6.8.3.3, using the applicable voltage from Table K.16 for the required CLEARANCE.

Table K.15 – CLEARANCE values for the calculation of K.3.2

Maximum voltage	CLEARANCE		Maximum voltage	CLEARANCE	
U_m	D_1	D_2	U_m	D_1	D_2
V	mm	mm	V	mm	mm
14,1 to 266	0,010	0,010	4 000	2,93	6,05
283	0,010	0,013	4 530	3,53	7,29
330	0,010	0,020	5 660	4,92	10,1
354	0,013	0,025	6 000	5,37	10,8
453	0,027	0,052	7 070	6,86	13,1
500	0,036	0,071	8 000	8,25	15,2
566	0,052	0,10	8 910	9,69	17,2
707	0,081	0,20	11 300	12,9	22,8
800	0,099	0,29	14 100	16,7	29,5
891	0,12	0,41	17 700	21,8	38,5
1 130	0,19	0,83	22 600	29,0	51,2
1 410	0,38	1,27	28 300	37,8	66,7
1 500	0,45	1,40	35 400	49,1	86,7
1 770	0,75	1,79	45 300	65,5	116
2 260	1,25	2,58	56 600	85,0	150
2 500	1,45	3,00	70 700	110	195
2 830	1,74	3,61	89 100	145	255
3 540	2,44	5,04	100 000	165	290
Linear interpolation is allowed.					

Table K.16 – Test voltages based on CLEARANCES

Required CLEARANCE	Test voltage	
	Impulse 1,2/50 μs	a.c. r.m.s. 50/60 Hz
mm	V peak	V r.m.s.
0,010	330	230
0,025	440	310
0,040	520	370
0,063	600	420
0,1	810	500
0,2	1 150	620
0,3	1 310	710
0,5	1 550	840
1,0	1 950	1 060
1,5	2 560	1 390
2,0	3 090	1 680
2,5	3 600	1 960
3,0	4 070	2 210
4,0	4 930	2 680
4,5	5 330	2 900
5,0	5 720	3 110
6,0	6 460	3 510
8,0	7 840	4 260
10,0	9 100	4 950
12,0	10 600	5 780
15,0	12 900	7 000
20	16 400	8 980
25	19 900	10 800
30	23 300	12 700
40	29 800	16 200
50	36 000	19 600
60	42 000	22 800
80	53 700	29 200
100	65 000	35 400
Liner interpolation is allowed.		

NOTE 2 Two examples of calculations follow:

EXAMPLE 1:

CLEARANCE for REINFORCED INSULATION for a WORKING VOLTAGE with peak value of 3 500 V and an additional transient voltage of 4 500 V (this can be expected within an electronic switching-circuit):

Maximum voltage U_m $U_m = U_w + U_t$ = (3 500 + 4 500) V = 8 000 V

U_w / U_m..= 3 500 / 8 000 = 0,44 > 0,2

thus $F = (1{,}25 \times U_w / U_m) - 0{,}25$ = (1,25 x 3 500 / 8 000) – 0,25 = 0,297

Values derived from Table K.15 at 8 000 V:

D_1 = 8,25 mm, D_2 = 15,2 mm

CLEARANCE = $D_1 + F \times (D_2 - D_1)$ = 8,25 + 0,297 × (15,2 – 8,25) = 8,25 + 2,06 = 10,3 mm

For REINFORCED INSULATION the value is doubled. CLEARANCE = 20,6 mm.

EXAMPLE 2:

CLEARANCE for BASIC INSULATION for a circuit driven from a MAINS transformer connected to an outlet of the distribution system with a MAINS voltage of 230 V and OVERVOLTAGE CATEGORY II. The circuit includes transient overvoltage limiting devices (see 14.8 and K.3.4) which limit the maximum voltage (including transients) in the circuit to 1 000 V.

The peak value (U_w) of the voltage in the circuit is 150 V.

The maximum value of the voltage U_m is therefore 1 000 V.

U_m = 1 000 V

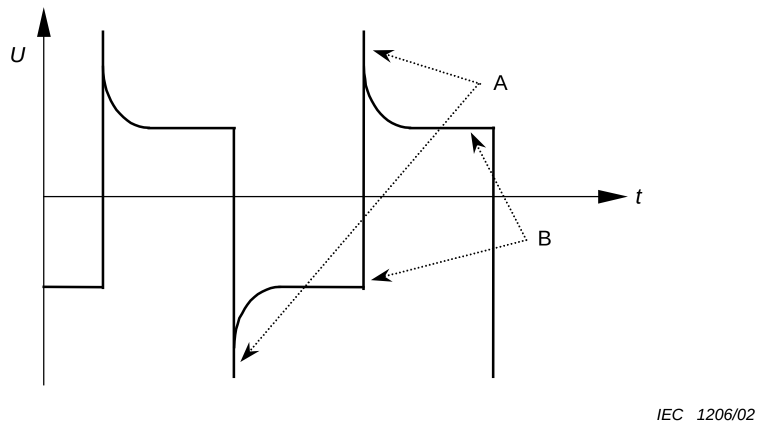
U_w / U_m = 150 / 1 000 = 0,15 < 0,2, thus F = 0

CLEARANCE D_1 = 0,15 mm interpolated from Table K.15

The CLEARANCE is then corrected for altitude and checked against POLLUTION DEGREE minimum CLEARANCES.

K.3.3 CLEARANCES in circuits having recurring peak voltages, or having WORKING VOLTAGES with frequencies above 30 kHz

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION for circuits having recurring peak voltages but not subjected to frequencies above 30 kHz shall meet the values of the second column of Table K.17, using the recurring peak voltage as the index. (See Figure K.4 for an example of a recurring peak voltage.)



Key

A Peak value of recurring voltage

B Working voltage value

Figure K.4 – Example of recurring peak voltage

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION for circuits that are subjected to frequencies above 30 kHz shall meet the values of the third column of Table K.17, using the peak value of the WORKING VOLTAGE as the index.

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION for circuits that may be subjected to both recurring peak voltages and to frequencies above 30 kHz shall meet the higher of these requirements.

CLEARANCES for REINFORCED INSULATION are twice the values for BASIC INSULATION.

If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCES are multiplied by the applicable factor of Table K.1.

The minimum CLEARANCE, for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, is 0,2 mm for POLLUTION DEGREE 2 and 0,8 mm for POLLUTION DEGREE 3.

Conformity is checked by inspection and measurement.

Table K.17 – CLEARANCES for BASIC INSULATION in circuits having recurring peak voltages or WORKING VOLTAGES with frequencies above 30 kHz

Voltage peak value	CLEARANCES	
	Frequencies up to 30 kHz	Frequencies above 30 kHz
V	mm	mm
0 to 330	0,01	0,02
400	0,02	0,04
500	0,04	0,07
600	0,06	0,11
800	0,13	0,26
1 000	0,26	0,48
1 200	0,42	0,76
1 500	0,76	1,1
2 000	1,27	1,8
2 500	1,8	2,6
3 000	2,4	3,5
4 000	3,8	5,7
5 000	5,7	8
6 000	7,9	10
8 000	11	15
10 000	15,2	20
12 000	19	25
15 000	25	32
20 000	34	44
25 000	44	58
30 000	55	72
40 000	77	100
50 000	100	
Linear interpolation is allowed.		

K.3.4 CREEPAGE DISTANCES

The requirements of K.2.3 apply.

Conformity is checked as specified in K.2.3.

K.3.5 Solid insulation

The requirements of K.2.4 apply except that in K.2.4.1 a), K.2.4.3 b) and c), and K.2.4.4 b) and c) the values of Table K.16 are used in place of the applicable values of Table K.10, Table K.11, or Table K.12.

To determine the required test voltage from Table K.16, the following procedure shall be applied:

a) Calculation of the theoretically required CLEARANCE according to K.3.2 considering the requirements of K.3.3. Minimum CLEARANCES for POLLUTION DEGREES 2 and 3 do not apply.
b) Application of the resulting theoretically required CLEARANCE value of Table K.16 to determine the required test voltage.

Conformity is checked as specified in K.2.4, using the test voltage determined above in place of the test voltage from Table K.10, Table K.11, or Table K.12.

K.4 Reduction of TRANSIENT OVERVOLTAGES by the use of overvoltage limiting devices

TRANSIENT OVERVOLTAGES in a circuit may be limited by combinations of circuits or components. Components suitable for this purpose include varistors and gas-filled surge arrestors.

If the overvoltage limiting device or circuit is intended to reduce TRANSIENT OVERVOLTAGES so that the circuit following it may have reduced CLEARANCES, a RISK assessment (see Clause 17) shall be performed, taking into account both of the following aspects:

a) the circuit shall reduce TRANSIENT OVERVOLTAGES to the lower level even under SINGLE FAULT CONDITIONS;
b) the circuit shall operate as intended even after withstanding repeated TRANSIENT OVERVOLTAGES.

Conformity is checked by evaluation of the RISK assessment documentation to ensure that the RISKS have been eliminated or that only TOLERABLE RISKS remain.

Annex L
(informative)

Index of defined terms

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