

INTERNATIONAL STANDARD

NORME INTERNATIONALE

GROUP SAFETY PUBLICATION
PUBLICATION GROUPEE DE SÉCURITÉ

**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: Prescriptions générales**

WILSON



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

Part 1: General requirements

FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 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 second edition cancels and replaces the first edition published in 1990, amendment 1 (1992) and amendment 2 (1995). It constitutes a technical revision.

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

FDIS	Report on voting
66/233/FDIS	66/244/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A to H form an integral part of this standard.

In this standard, the following print types are used:

- requirements and definitions: in roman type;
- NOTES: in smaller roman type;
- *conformity: 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 this publication will remain unchanged until 2002. At this date, the publication will be

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- withdrawn;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

The contents of the corrigenda of May 2002 and April 2003 have been included in this copy.

Withdrawn

INTRODUCTION

This part 1 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.

Withdrawn

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 part of IEC 61010 specifies general safety requirements for electrical equipment intended for professional, industrial process, and educational use, any of which may incorporate computing devices, as defined in a) to d) below, when used under the environmental conditions of 1.4.

a) Electrical test and measurement equipment

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

NOTE All indicating and recording electrical measuring instruments (except those excluded in 1.1.2) fall within the scope of IEC 61010 unless they are panel meters designed only for building-in to other equipment. Built-in panel meters are considered to be components and only need to meet the relevant requirements of IEC 61010, or other standards, as part of the equipment into which they are built.

b) Electrical 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 or analyses substances, or is used to prepare materials, and includes in vitro diagnostic (IVD) equipment

This equipment may also be used in areas other than laboratories, for example self-test IVD equipment may be used in the home.

d) Accessories intended for use with the above (for example, sample handling equipment).

1.1.2 Equipment excluded from scope

This standard does not apply to equipment within the scope of

- a) IEC 60065 (Safety requirements for audio, video and similar electronic apparatus);
- b) IEC 60204 (Controls for electrical machines);
- c) IEC 60335 (Safety of household and similar electrical appliances);
- d) IEC 60364 (Electrical installations of buildings);
- e) IEC 60439-1 (Low-voltage switchgear and controlgear assemblies);
- f) IEC 60521 (Class 0,5; 1 and 2 alternating current watt-hour meters);
- g) IEC 60601 (Medical electrical equipment);

- h) IEC 60950 (Safety of information technology equipment including electrical business equipment, except as specified in 1.1.3);
- i) IEC 61558 (Power transformers, power supply units and similar).

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. If HAZARDS from moisture or liquids could affect equipment that conforms to IEC 60950 and is used with equipment which conforms to this standard, the instructions for use should specify any additional precautions required.

1.2 Object

1.2.1 Aspects included in scope

The purpose of the requirements of this part 1 is to ensure that the design and methods of construction used provide adequate protection for the OPERATOR and the surrounding area against

- a) electric shock or burn (see clause 6);
- b) mechanical HAZARDS (see clauses 7 and 8);
- c) excessive temperature (see clauses 9 and 10);
- d) spread of fire from the equipment (see clause 9);
- 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).

NOTE Attention is drawn to the existence of additional requirements which may be specified by national authorities responsible for 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, which are covered by IEC 61326;
- d) protective measures for explosive atmospheres (see IEC 60079);
- e) servicing (repair);
- f) protection of servicing (repair) personnel.

NOTE Servicing personnel are expected to be reasonably careful in dealing with obvious HAZARDS, but the design should protect against mishap by the use of warning labels, shields for hazardous voltage TERMINALS, segregation of low-voltage circuits from hazardous voltages, etc. More important, servicing personnel should be trained to recognize unexpected HAZARDS and to react accordingly.

1.3 Verification

This standard also specifies methods of verifying, through inspection and type testing, that the equipment meets the requirements of this standard.

NOTE Requirements for ROUTINE TESTS are given in annex F.

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 typically present on the MAINS supply.

NOTE The normal level of transient overvoltages is impulse withstand (overvoltage) category II of IEC 60364-4-443.

- g) applicable RATED POLLUTION degree.

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 for which the equipment is RATED by the manufacturer:

- 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.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61010. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61010 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60027, *Letter symbols to be used in electrical technology*

IEC 60060, *High-voltage test techniques*

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

IEC 60085, *Thermal evaluation and classification of electrical insulation*

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

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

IEC 60309, *Plugs, socket-outlets and couplers for industrial purposes*

IEC 60335, *Safety of household and similar electrical appliances*

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

IEC 60651, *Sound level meters*

IEC 60664-3, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coatings to achieve insulation coordination of printed board assemblies*

IEC 60707, *Flammability of solid non-metallic materials when exposed to flame sources – List of test methods*

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

IEC 60804, *Integrating-averaging sound level meters*

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

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

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

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

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 4126-1, *Safety valves – Part 1: General requirements*

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

3 Terms and definitions

For the purpose of this part of IEC 61010 the following definitions apply.

Unless otherwise specified, values of "voltage" and "current" are the r.m.s. values of an alternating, direct or composite voltage or current.

NOTE An index of defined terms is given in annex H.

3.1 Equipment and states of equipment

3.1.1

fixed equipment

equipment fastened to a support, or otherwise secured in a specific location [IEV 826-07-07]

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

3.2 Parts and accessories

3.2.1

TERMINAL

a component provided for the connection of a device (equipment) to external conductors [IEV 151-01-03, 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 direct 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 termed measuring earth TERMINAL.

3.2.3

PROTECTIVE CONDUCTOR TERMINAL

TERMINAL which is bonded to conductive parts of an 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

3.2.5

BARRIER

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

NOTE ENCLOSURES and BARRIERS may provide protection against the spread of fire (see 9.2.1 b)).

3.3 Electrical quantities

3.3.1

RATED (value)

quantity value assigned, generally by a manufacturer, to a specified operating condition of a component, device or equipment [IEV 151-04-03]

3.3.2

RATING

set of RATED values and operating conditions [IEV 151-04-04]

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 are disregarded.

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 [IEV 151-04-15, modified]

NOTE This is an amplification of the IEC 151-04-15 definition to cover both design and construction requirements.

3.4.2

ROUTINE TEST

test to which each individual device (equipment) is subjected during or after manufacture to ascertain whether it conforms to certain criteria [IEV 151-04-16, modified] (See annex F)

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 in NORMAL CONDITION or SINGLE FAULT CONDITION

NOTE See 6.3.1 for values applicable to NORMAL CONDITION and 6.3.2 for the higher values deemed to be appropriate in SINGLE FAULT CONDITION.

3.5.4

HIGH INTEGRITY

not liable to become defective in such a manner as to cause a risk of HAZARD; a HIGH INTEGRITY part is considered as not subject to failure when tests under fault conditions are made

3.5.5

MAINS

low-voltage electricity supply system (above the values of 6.3.2 a)) to which the equipment concerned is designed to be connected for the purpose of powering the equipment

NOTE Some measuring circuits may also be connected to the MAINS for measuring purposes.

3.5.6

MAINS CIRCUIT

circuit which is intended to be conductively connected to the MAINS for the purpose of powering the equipment

NOTE Measuring circuits and circuits that are inductively derived from MAINS CIRCUITS are not MAINS CIRCUITS.

3.5.7

PROTECTIVE IMPEDANCE

component, assembly of components or the combination of BASIC INSULATION and a current or voltage-limiting device, whose impedance, construction and reliability are such that, when connected between ACCESSIBLE conductive parts and parts which are HAZARDOUS LIVE, it provides protection to the extent required by this standard in NORMAL CONDITION and SINGLE FAULT CONDITION

3.5.8

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

3.5.9

NORMAL USE

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

NOTE In most cases, NORMAL USE also implies NORMAL CONDITION, because the instructions for use will warn against using the equipment when it is not in NORMAL CONDITION.

3.5.10

NORMAL CONDITION

condition in which all means for protection against HAZARDS are intact

3.5.11

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 another SINGLE FAULT CONDITION, the two failures are considered as one SINGLE FAULT CONDITION

3.5.12

OPERATOR

person operating equipment for its intended purpose

NOTE The OPERATOR should have received training appropriate for this purpose.

3.5.13

RESPONSIBLE BODY

individual or group responsible for the use and maintenance of equipment and for ensuring that OPERATORS are adequately trained

3.5.14

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

3.6 Insulation

3.6.1

BASIC INSULATION

insulation, the failure of which could cause a risk of electric shock

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

3.6.3

DOUBLE INSULATION

insulation comprising both BASIC INSULATION and SUPPLEMENTARY INSULATION

3.6.4

REINFORCED INSULATION

insulation which provides protection against electric shock not less than that provided by DOUBLE INSULATION. It may comprise several layers which cannot be tested singly as SUPPLEMENTARY INSULATION OF BASIC INSULATION

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

for the purpose of evaluating spacings, the following degrees of POLLUTION in the micro-environment are defined

3.6.6.1

POLLUTION DEGREE 1

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

3.6.6.2**POLLUTION DEGREE 2**

normally only non-conductive POLLUTION occurs. Occasionally, however, a temporary conductivity caused by condensation must be expected

3.6.6.3**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.

3.6.7**CLEARANCE**

shortest distance in air between two conductive parts

3.6.8**CREEPAGE DISTANCE**

shortest distance along the surface of the insulating material between two conductive parts [IEV 151-03-37]

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.

Tests on subassemblies of the equipment meeting 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 demonstrates conclusively that the equipment would pass the test. Tests are carried out under

- a) reference test conditions (see 4.3);*
- b) fault conditions (see 4.4).*

NOTE 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:

- the manufacturer should ensure that at least the specified test value is applied;
- the test house 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 in this standard. 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. If tests under fault conditions may be destructive, these tests may follow those under reference test conditions.

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

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 4.3.2.1 to 4.3.2.13.

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

Equipment intended to be built into a wall, recess, cabinet, etc., shall be installed as specified in the manufacturer's instructions.

4.3.2.1 Position of equipment

The equipment shall be in any position of NORMAL USE and with any ventilation unimpeded.

4.3.2.2 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.

4.3.2.3 Covers and removable parts

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

4.3.2.4 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 d.c. or single-phase supply shall be connected both with normal and reverse polarity.
- e) Unless the equipment is specified for use only on a non-earthed MAINS supply, one pole of the reference test supply shall be at or near earth potential.
- f) If the means of connection permits reversal, battery-operated equipment shall be connected with both reverse and normal polarity.

4.3.2.5 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.

4.3.2.6 Earth TERMINALS

PROTECTIVE CONDUCTOR TERMINALS, if any, shall be connected to earth. FUNCTIONAL EARTH TERMINALS shall be connected or not connected to earth.

4.3.2.7 Controls

Controls which the OPERATOR can adjust by hand 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.

4.3.2.8 Connections

The equipment shall be connected for its intended purpose, or not connected.

4.3.2.9 Load on motors

Load conditions of motor-driven parts of equipment shall be in accordance with the intended purpose.

4.3.2.10 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.

4.3.2.11 Duty cycle

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

4.3.2.12 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 1 In case of doubt, tests should be performed in more than one loading condition.

NOTE 2 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.

4.3.2.13 Heating equipment

When measuring temperatures to evaluate the spread of fire, heating equipment shall be tested in a test corner as required by 10.4.1.

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 unless it can be demonstrated that no HAZARD could arise from a particular fault condition, or specified alternative methods of checking conformity are chosen in place of fault testing (see clause 9 b) and c)).
- 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.

4.4.2 Application of fault conditions

Fault conditions shall include those specified in 4.4.2.1 to 4.4.2.12. 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.

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

4.4.2.1 PROTECTIVE IMPEDANCE

- 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.

Parts of PROTECTIVE IMPEDANCE which are HIGH-INTEGRITY components need not be short-circuited or disconnected (see 6.5.3 and 14.6).

4.4.2.2 Protective conductor

The protective conductor shall be interrupted, except for PERMANENTLY CONNECTED EQUIPMENT or equipment utilizing a connector in accordance with IEC 60309.

4.4.2.3 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.

4.4.2.4 Motors

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

4.4.2.5 Capacitors

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

4.4.2.6 MAINS transformers

The secondary windings of MAINS transformers shall be short-circuited as specified in 4.4.2.6.1, and overloaded as specified in 4.4.2.6.2.

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 14.7.

4.4.2.6.1 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.

4.4.2.6.2 Overload

Each untapped output winding, and each section of 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 4.4.2.6.1 need not be subjected to overload tests.

4.4.2.7 Outputs

Outputs shall be short-circuited one at a time.

4.4.2.8 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.

4.4.2.9 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.

4.4.2.10 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;
- c) loss of cooling liquid shall be simulated.

4.4.2.11 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.

NOTE See clause 9 a) and b) for alternative methods of checking protection against spread of fire.

4.4.2.12 Interlocks

Each part of an interlock system for the protection of OPERATORS 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.

HIGH INTEGRITY components of interlock systems (see 14.6 and 15.3) need not be short-circuited or open-circuited.

4.4.3 Duration of tests

4.4.3.1 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 risk of electric shock, spread of fire or injury to persons may eventually occur, the test shall be continued until one of these HAZARDS does occur or for a maximum period of 4 h, unless a HAZARD occurs before then.

4.4.3.2 Where 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 the equipment shall be measured, whether the device operates or not.

4.4.3.3 If a fault is terminated by the opening of a fuse and if the fuse does not operate within approximately 1 s, the current through the fuse under the relevant fault condition shall be measured. Evaluation with the pre-arcing time/current characteristics shall be made to find out whether the minimum operating current of the fuse is reached or exceeded and what 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.

4.4.4 Conformity after application of fault conditions

4.4.4.1 *Conformity with requirements for protection against electric shock is checked after the application of single faults 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 there is still one level of protection by insulation. The voltage test is made as specified in 6.8 (without conformity 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 16 shall not be exceeded.*

4.4.4.2 *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.*

Except for heated surfaces of heating equipment, the temperature of these parts shall not exceed 105 °C at an ambient temperature of 40 °C or the maximum RATED ambient temperature if higher.

This temperature is determined by measuring the temperature rise of the surface or part and adding it to 40 °C or the maximum RATED ambient temperature if higher.

4.4.4.3 *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 *Conformity with requirements for protection against other HAZARDS is checked as specified in clauses 7 and 8, and 11 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 in accordance with 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 value(s) of the supply voltage(s) or the RATED range of the 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;
- d) equipment which the 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 of 5.1.3 c). The measurement is made after the current has reached a stationary stage (usually after 1 min) so as to exclude any initial inrush current. The equipment shall be in the condition of maximum power consumption. Transients are ignored. The measured value shall not exceed the marked value by more than 10 %.

Table 1 – Symbols

Number	Symbol	Reference	Description
1		IEC 60417 – 5031	Direct current
2		IEC 60417 – 5032	Alternating current
3		IEC 60417 – 5033	Both direct and alternating current
4			Three-phase alternating current
5		IEC 60417 – 5017	Earth (ground) TERMINAL
6		IEC 60417 – 5019	PROTECTIVE CONDUCTOR TERMINAL
7		IEC 60417 – 5020	Frame or chassis TERMINAL
8		IEC 60417 – 5021	Equipotentiality
9		IEC 60417 – 5007	On (Supply)
10		IEC 60417 – 5008	Off (Supply)
11		IEC 60417 – 5172	Equipment protected throughout by DOUBLE INSULATION or REINFORCED INSULATION
12			Caution, risk of electric shock
13		IEC 60417 – 5041	Caution, hot surface
14		ISO 7000 – 0434	Caution, risk of danger (See note.)
15		IEC 60417 – 5268	In position of a bi-stable push control
16		IEC 60417 – 5269	Out position of a bi-stable push control
NOTE 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

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.

5.1.5.1 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 close to, or on, the TERMINAL;
- c) TERMINALS of measuring and control circuits which are permitted by 6.6.3 to be connected to ACCESSIBLE conductive parts with symbol 7 of table 1 if this connection is not 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 the 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;
- e) ACCESSIBLE FUNCTIONAL EARTH TERMINALS connected to ACCESSIBLE conductive parts, with an indication that this is the case, unless it is self-evident. Symbol 8 of table 1 is acceptable for this marking.

Conformity is checked by inspection.

5.1.5.2 Measuring circuit TERMINALS

Unless a clear indication (see note below) is provided on a measuring instrument that voltage and current measuring circuit TERMINALS are not intended to be connected to voltages to earth above 50 V a.c. or 120 V d.c., the TERMINALS shall be marked as follows.

- a) Measuring circuit TERMINALS for measurements within measurement category I (see 6.7.4) shall be marked with the RATED voltage or current as applicable and with symbol 14 of table 1 (see also 5.4.1 f) and g)).
- b) Measuring circuit TERMINALS for measurements within measurement categories II, III and IV (see 6.7.4) shall be marked with the RATED voltage or current as applicable and the relevant measurement category. The measurement category markings shall be "CAT II", "CAT III" or "CAT IV" as applicable.

NOTE Examples of acceptable indications that the inputs in all cases are intended to be less than 50 V a.c. or 120 V d.c. to earth include

- a) the full-scale deflection marking of a single-range indicating voltmeter or maximum marking of a multi-range voltmeter;
- b) the maximum range marking of a voltage selector switch;
- c) the marked intended function of the instrument (for example, millivoltmeter).

Voltage and current measuring circuit TERMINALS that are permanently connected and not ACCESSIBLE need not be marked (see 5.4.3 i)). The measurement category and the RATED maximum WORKING VOLTAGE or RATED maximum current for such TERMINALS shall be stated in the equipment installation instructions (see 5.4.3).

An exception is also permitted for circuit TERMINALS (connectors) which are dedicated only for connection to specific TERMINALS of other equipment, provided that there is a means for identifying these TERMINALS.

Markings shall be placed adjacent to the TERMINALS. However, if there is insufficient space (as in multi-input equipment), it is permissible for the marking to be on the RATING plate or scale plate, or for the TERMINAL to be marked with symbol 14 of table 1.

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 on-position or the off-position shall be clearly marked. Symbols 9 and 10 of table 1 can, in some cases, also be suitable as the device identification (see 6.11.2.5). A lamp alone is not considered to be a satisfactory marking. Symbols 9 and 10 shall not be used for switches other than the power supply switch.

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 protected throughout by DOUBLE INSULATION OR REINFORCED INSULATION shall be marked with symbol 11 of table 1 unless it is provided with a PROTECTIVE CONDUCTOR TERMINAL.

Equipment which is only partially protected by DOUBLE INSULATION OR REINFORCED INSULATION shall not bear 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 the maximum RATED ambient temperature if higher, there shall be a marking of the minimum temperature RATING of the cable to be connected to the TERMINALS. The marking shall be visible before and during connection, or be beside the TERMINALS.

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 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 to, this 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 instruction manual 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 with symbols which are explained in the manual.

If the instructions for use state that an OPERATOR is permitted to gain access, using a TOOL, to a part which in NORMAL USE may be HAZARDOUS LIVE, there shall be a warning marking which states that the equipment must be isolated or disconnected from the HAZARDOUS LIVE voltage before access.

Warning markings are specified in 5.1.5.1 c), 6.1.2 b), 6.5.1.2 g), 6.6.2, 7.2 c), 7.3, 10.1, 13.2.2.

Conformity is checked by inspection.

5.3 Durability of markings

Markings in accordance with 5.1.2 to 5.2 shall remain clear and legible under conditions of NORMAL USE and resist the effects of cleaning agents specified by the manufacturer.

Conformity is checked by inspection and 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 the specified cleaning agent (or, if not specified, with isopropyl alcohol).

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

5.4 Documentation

5.4.1 General

Equipment shall be accompanied by documentation for safety purposes as follows:

- a) intended use of the equipment;
- b) technical specification;
- c) instructions for use;
- d) name and address of manufacturer or supplier from whom technical assistance may be obtained;
- e) the information specified in 5.4.2 to 5.4.5;
- f) definition of the relevant measurement category if marking of TERMINALS is required on the equipment (see 5.1.5.2);

- g) for equipment marked with measurement category I, a warning shall be given not to use the equipment for measurements within measurement categories II, III and IV, and a detailed RATING including the RATED transient overvoltages is given in the documentation.

If applicable, warning statements and a clear explanation of warning symbols marked on the equipment shall be provided in the documentation or shall be durably and legibly marked on the equipment. In particular, there shall be a statement that documentation needs to be consulted in all cases where symbol 14 of table 1 is used, in order to find out the nature of the potential HAZARD and any actions which have to be taken.

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

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;
- c) the RATING of the insulation of external circuits, appropriate for SINGLE FAULT CONDITIONS, if such circuits are nowhere ACCESSIBLE (see 6.6.2);
- d) a statement of the range of environmental conditions for which the equipment is designed (see 1.4);
- e) a statement of the degree of protection, if the equipment is RATED according to IEC 60529.

Conformity is checked by inspection.

5.4.3 Equipment installation

The documentation shall include installation and specific commissioning instructions (examples are listed below) and, if necessary for safety, warnings against HAZARDS which could arise during installation or commissioning of the equipment:

- 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 6.11.2.1) and external overcurrent protection devices (see 9.5.1) and a recommendation that the switch or circuit-breaker be near the equipment;
- e) ventilation requirements;
- f) requirements for special services, for example, air, cooling liquid;
- g) the maximum sound power level produced by equipment which emits sound, if measurement is required by 12.5.1;
- h) instructions relating to sound pressure level (see 12.5.1);

- i) for voltage- and current-measuring circuit TERMINALS that are permanently connected and not ACCESSIBLE, information regarding the measurement category, RATED maximum WORKING VOLTAGE or RATED maximum current (see 5.1.5.2).

Conformity is checked by inspection.

5.4.4 Equipment operation

Instructions for use shall include, if applicable:

- a) identification of operating controls and their use in all operating modes;
- b) an instruction 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) specification of limits for intermittent operation;
- e) an explanation 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 any potentially poisonous or injurious gases that can be liberated from the equipment, and possible quantities;
- i) detailed instructions about risk-reduction procedures relating to flammable liquids (see 9.4 c)).

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

Instructions for the RESPONSIBLE BODY concerning preventive maintenance and inspection necessary for safety shall be given in sufficient detail. These shall include the inspection and replacement, if necessary, of any hoses or other parts containing liquids, if their failure could cause a HAZARD (See 11.7).

NOTE Instructions should advise the RESPONSIBLE BODY of any tests necessary to check that equipment is still in a safe condition. They should also warn against the repetition of any tests of this standard which could damage the equipment and reduce protection against HAZARDS.

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.

Conformity is checked by inspection.

6 Protection against electric shock

6.1 General

6.1.1 Requirements

Protection against electric shock shall be maintained in NORMAL CONDITION (see 6.4) and SINGLE FAULT CONDITION (see 6.5). ACCESSIBLE parts of equipment shall not be HAZARDOUS LIVE (see 6.3).

Conformity is checked by the determination of ACCESSIBLE parts as specified in 6.2 and the measurements of the levels of 6.3, 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 the 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 the 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);
- c) locking and screw-held type measuring TERMINALS, including TERMINALS which do not require the use of a TOOL.

If any of the parts in a) and b) receive 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

Unless obvious, determination of whether a part is ACCESSIBLE shall be made as specified in 6.2.1 to 6.2.3. Test fingers (see annex B) and pins shall be applied without force unless a force is specified. Parts are considered to be ACCESSIBLE if they can be touched with a test finger or 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). For HAZARDOUS LIVE parts at a voltage to earth exceeding 1 kV r.m.s. or 1,5 kV d.c., a part is considered to be ACCESSIBLE if the test finger or pin reaches a point nearer to the HAZARDOUS LIVE part than the applicable CLEARANCE for BASIC INSULATION for the WORKING VOLTAGE.

If the OPERATOR is intended to perform any actions in NORMAL USE (with or without a TOOL) which will increase the accessibility of parts, such actions shall be taken before performing the examinations of 6.2.1 to 6.2.3. Examples include:

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

For rack- or panel-mounted equipment, the equipment is installed as specified in the manufacturer's instructions before making the examinations of 6.2.1 to 6.2.3. For such equipment, the OPERATOR is assumed to be in front of the panel.

6.2.1 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.

6.2.2 Openings above parts that are HAZARDOUS LIVE

A metal test pin 100 mm long and 4 mm in diameter is inserted in 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 for protection in SINGLE FAULT CONDITION are not required solely because a part is ACCESSIBLE by this test only.

This test is not applied to TERMINALS.

6.2.3 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 Permissible limits for ACCESSIBLE parts

The voltage, current, charge or energy between an ACCESSIBLE part and reference test 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 values of 6.3.1 in NORMAL CONDITION nor of 6.3.2 in SINGLE FAULT CONDITION.

6.3.1 Values in NORMAL CONDITION

Values above the following levels in NORMAL CONDITION are deemed to be HAZARDOUS LIVE. The limits of 6.3.1 b) and c) apply only if the voltage exceeds the values of 6.3.1 a).

- a) The voltage levels are 33 V r.m.s. and 46,7 V peak or 70 V d.c. For equipment RATED for use in WET LOCATIONS, the voltage levels are 16 V r.m.s. and 22,6 V peak or 35 V d.c.
- b) The current levels are:
 - 1) 0,5 mA r.m.s. for sinusoidal waveforms, 0,7 mA peak for non-sinusoidal waveform or mixed frequencies, or 2 mA d.c., when measured with the measuring circuit of figure A.1. Alternatively, the measuring circuit of figure A.2 can be used if the frequency does not exceed 100 Hz. The measuring circuit of figure A.4 is used for equipment RATED 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 charge or energy of capacitance levels are:

- 1) 45 μC charge for voltages up to 15 kV peak or d.c.;
- 2) 350 mJ stored energy for voltages above 15 kV peak or d.c.

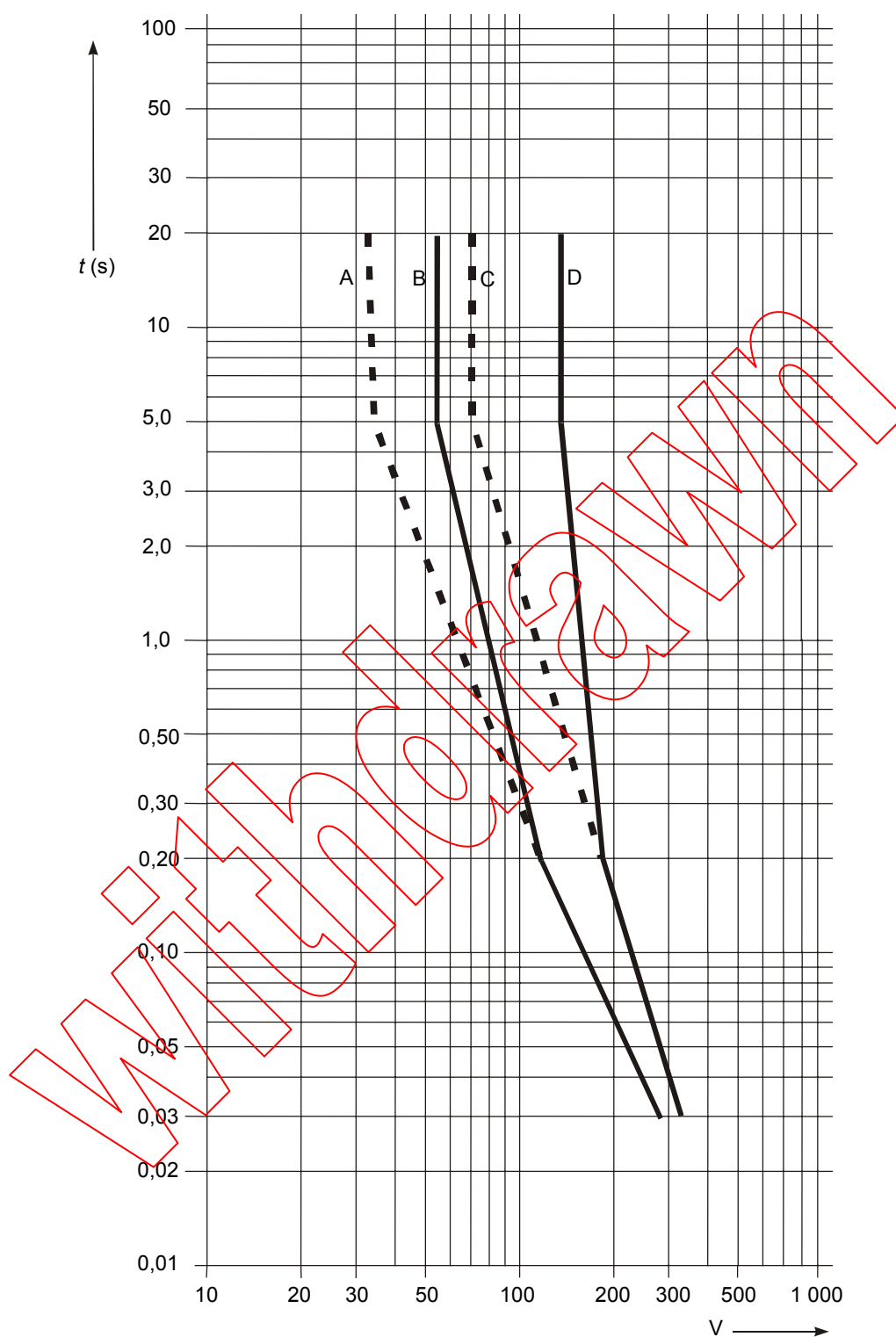
See figure 2.

6.3.2 Values in SINGLE FAULT CONDITION

Values above the following levels in SINGLE FAULT CONDITION are deemed to be HAZARDOUS LIVE. The limits of 6.3.2 b) and c) apply only if the voltage exceeds the values of 6.3.2 a).

- a) The voltage levels are 55 V r.m.s. and 78 V peak or 140 V d.c. For equipment RATED for use in WET LOCATIONS, the voltage levels are 33 V r.m.s. and 46,7 V peak or 70 V d.c. For temporary voltages, the levels are those of figure 1, measured across a 50 k Ω 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. Alternatively, the measuring circuit of figure A.2 can be used if the frequency does not exceed 100 Hz. The measuring circuit of figure A.4 is used for equipment RATED 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 that of figure 2.

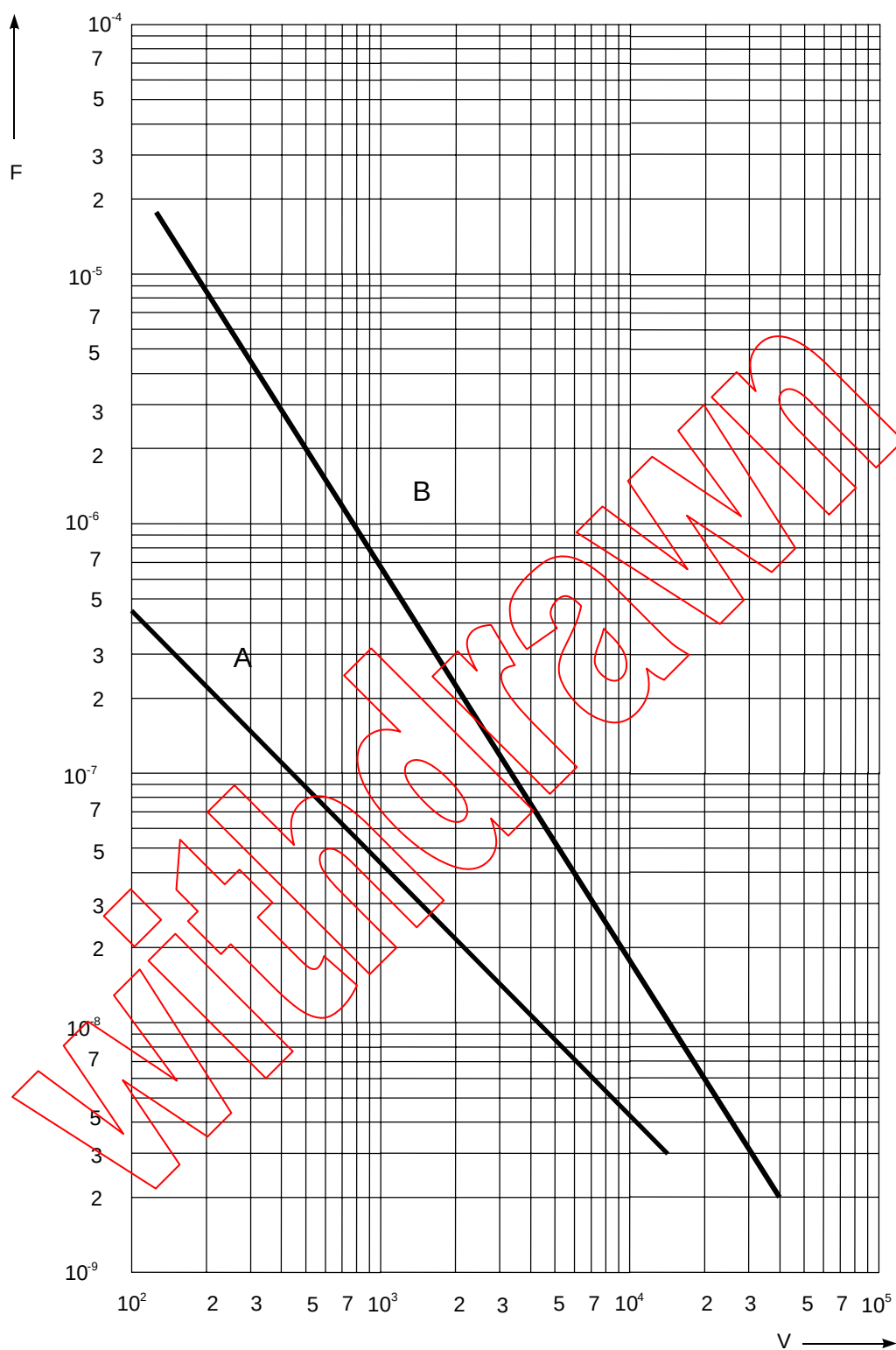
Withdrawn

**Key**

A a.c. level in wet conditions
 B a.c. level in dry conditions

C d.c. level in wet conditions
 D d.c. level in dry conditions

Figure 1 – Maximum duration of short-term temporary accessible voltages in SINGLE FAULT CONDITION (see 6.3.2 a))



Key

A NORMAL CONDITION

B SINGLE FAULT CONDITION

IEC 2734/2000

Figure 2 – Charged capacitance level in NORMAL CONDITION and SINGLE FAULT CONDITION
(see 6.3.1 c) and 6.3.2 c))

6.4 Protection in NORMAL CONDITION

ACCESSIBLE parts shall be prevented from becoming HAZARDOUS LIVE by one or more of the following means:

- a) BASIC INSULATION (see annex D);
- b) enclosures or barriers;
- c) impedance.

ENCLOSURES and BARRIERS shall meet the rigidity requirements of 8.1. If ENCLOSURES or BARRIERS provide protection by insulation, they shall meet the requirements of BASIC INSULATION.

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.

Solid insulation between ACCESSIBLE parts and HAZARDOUS LIVE parts shall pass the voltage test of 6.8 for BASIC INSULATION.

NOTE There is no requirement for the minimum thickness of solid insulation, provided it is capable of passing the dielectric strength test of 6.8. However, under mechanical or thermal stress conditions, consideration needs to be given to the requirements of clauses 8, 9 and 10. Partial discharge testing for solid insulation is under consideration.

Conformity is checked by

- 1) *the determination of 6.2 and the measurements of 6.3.1, to establish that ACCESSIBLE conductive parts are not HAZARDOUS LIVE;*
- 2) *inspection or measurement of CLEARANCES and CREEPAGE DISTANCES as specified in 6.7;*
- 3) *the tests of 6.8 for dielectric strength of BASIC INSULATION;*
- 4) *the test of 8.1 for rigidity of ENCLOSURES and BARRIERS.*

6.5 Protection in SINGLE FAULT CONDITION

Additional protection shall be provided to ensure that ACCESSIBLE parts are prevented from becoming HAZARDOUS LIVE in SINGLE FAULT CONDITION. The protection shall consist of one or more of the protective means specified in 6.5.1 to 6.5.3, or by automatic disconnection of the supply in case of a fault (see 6.5.4).

Conformity is checked as specified in 6.5.1 to 6.5.4.

6.5.1 PROTECTIVE BONDING

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 protective means specified in 6.4. Alternatively, such ACCESSIBLE parts shall be separated from parts which are HAZARDOUS LIVE by a conductive protective screen or BARRIER bonded to the PROTECTIVE CONDUCTOR TERMINAL.

NOTE ACCESSIBLE conductive parts need not be bonded to the PROTECTIVE CONDUCTOR TERMINAL if they are separated from all HAZARDOUS LIVE parts by DOUBLE INSULATION or REINFORCED INSULATION.

Conformity is checked as specified in 6.5.1.1 to 6.5.1.5.

6.5.1.1 Integrity of protective bonding

The integrity of PROTECTIVE BONDING shall be assured by the following means.

- a) PROTECTIVE BONDING shall consist of direct 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 over-current protective means specified in 9.5 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. Screw connections shall be secured against loosening.
 - c) If a part of the equipment is removable by the OPERATOR, the PROTECTIVE BONDING for the remainder of the equipment shall not be interrupted (except when that part also carries the MAINS input connection to the whole equipment).
 - d) Movable conductive connections, for example, hinges, slides, etc., shall not be the sole PROTECTIVE BONDING path unless they are specifically designed for electrical inter-connection and meet the requirements of 6.5.1.3.
 - e) The exterior metal braid of cables, even if connected to the PROTECTIVE CONDUCTOR TERMINAL, shall not be regarded as PROTECTIVE BONDING.
 - f) 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 to the protective conductor path through the equipment shall not exceed that specified in 6.5.1.3.
 - g) 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. The bi-colour combination green-and-yellow shall be used only for identifying the protective conductor and for no other purpose.
- NOTE In some countries, the colour identification green for the protective conductor is used as equivalent to the two-colour combination green-and-yellow.
- h) Equipment using PROTECTIVE BONDING shall be provided with a TERMINAL meeting the requirements of 6.5.1.2 and suitable for connection to a protective conductor.

Conformity is checked by inspection.

6.5.1.2 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 close to 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 to 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 by hand, for example plugs and appliance couplers for MAINS cords or connector assemblies of plug-in units, shall be designed so that the protective conductor connection makes first and breaks last with respect to the other connections.
- 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 by servicing not involving the protective conductor or there shall be a warning marking (see 5.2) requiring the replacement of the protective conductor after removal.
- 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 the presence of any switching or interrupting device. Devices used for indirect bonding in test and measurement equipment (see 6.5.1.5) are permitted to be part of the PROTECTIVE BONDING.
- i) FUNCTIONAL EARTH TERMINALS (for example, measuring earth TERMINALS), if any, 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, it shall be of a suitable size for the bond wire but no smaller than M 4 (No. 6), with at least three turns of the screw engaged. The contact pressure required for a bonding connection shall not be capable of being reduced by deformation of materials forming part of the connection.

Conformity is checked by inspection. Conformity for j) is also checked by the following test. The assembly of a screw in a metal part or nut, together with the least favourable grounding conductor to be secured, and any associated conductor securing means shall withstand, without mechanical failure, three operations of assembly and disassembly when using the tightening torques specified in table 2.

Table 2 – Tightening torque for screw assemblies

Size of screw 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

6.5.1.3 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 . MAINS cord impedance does not form part of the specified bonding impedance.

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 d.c. or a.c. r.m.s. at RATED MAINS frequency;
- 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.

6.5.1.4 Bonding impedance of PERMANENTLY CONNECTED EQUIPMENT

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.

6.5.1.5 Indirect bonding for test and measurement equipment

Indirect bonding establishes a connection between the PROTECTIVE CONDUCTOR TERMINAL and ACCESSIBLE conductive parts if these become HAZARDOUS LIVE as a result of a fault. Devices to establish indirect bonding are:

- a) voltage-limiting devices which become conductive when the voltage across them exceeds the relevant values of 6.3.2 a), with overcurrent protection to prevent breakdown of the device.

Conformity is checked by connecting the ACCESSIBLE conductive parts to the MAINS supply TERMINALS while the equipment is connected to the MAINS supply as in NORMAL USE. The voltage between the ACCESSIBLE conductive parts and the PROTECTIVE CONDUCTOR TERMINAL shall not exceed the relevant values of 6.3.2 a) for more than 0,2 s.

- b) voltage-sensitive tripping devices which interrupt all poles of the MAINS supply, and connect the ACCESSIBLE conductive parts to the PROTECTIVE CONDUCTOR TERMINAL whenever the voltage across them reaches the relevant values of 6.3.2 a).

Conformity is checked by applying the relevant voltage of 6.3.2 a) between the ACCESSIBLE conductive parts and the PROTECTIVE CONDUCTOR TERMINAL. The tripping action shall take place within 0,2 s.

6.5.2 DOUBLE INSULATION and REINFORCED INSULATION

CLEARANCES and CREEPAGE DISTANCES forming part of DOUBLE INSULATION or REINFORCED INSULATION shall meet the applicable requirements of 6.7 (see annex D). ENCLOSURES shall meet the requirements of 6.9.2.

Solid insulation forming part of REINFORCED INSULATION shall pass the voltage test of 6.8 with the values for reinforced insulation.

Conformity is checked as specified in 6.7, 6.8 and 6.9.2. The parts of DOUBLE INSULATION are tested separately if this is possible; the tests for REINFORCED INSULATION are otherwise used. CLEARANCES and CREEPAGE DISTANCES necessary for safety can be checked by measurement.

6.5.3 PROTECTIVE IMPEDANCE

A PROTECTIVE IMPEDANCE which ensures that ACCESSIBLE conductive parts cannot become HAZARDOUS LIVE as a result of a SINGLE FAULT CONDITION shall be one or more of the following:

- a) an appropriate HIGH-INTEGRITY single component (see 14.6);
- b) a combination of components;
- c) a combination of BASIC INSULATION and a current- or voltage-limiting device.

Components, wires and connections shall be RATED for both NORMAL CONDITION and SINGLE FAULT CONDITION.

Conformity is checked by inspection and by the measurements of 6.3 in SINGLE FAULT CONDITION (see 4.4.2.1).

6.5.4 Automatic disconnection of the supply

If automatic disconnection of the supply is used for protection in SINGLE FAULT CONDITION, the automatic disconnection device shall meet all the following requirements.

- a) It shall be supplied with the equipment or the installation instruction shall specify the device to be fitted as part of the installation.
- b) It shall be RATED to disconnect the load within the time specified in figure 1.
- c) It shall be RATED for the maximum RATED load conditions of the equipment.

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

6.6 Connections to external circuits

6.6.1 General

Connections to external circuits shall not

- a) cause ACCESSIBLE parts of the external circuits to become HAZARDOUS LIVE in NORMAL CONDITION or SINGLE FAULT CONDITION;
- nor
- b) cause ACCESSIBLE parts of the equipment to become HAZARDOUS LIVE in NORMAL CONDITION or SINGLE FAULT CONDITION.

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 for each external TERMINAL as applicable for the purposes of the requirements above:

- 1) the 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.);
- 2) the RATING of the insulation required for the external circuit to conform to the requirements for protection against electric shock, in NORMAL CONDITION and SINGLE FAULT CONDITION, arising from the connection to the TERMINAL.

For accessibility of TERMINALS, see 6.6.2.

Conformity is checked by:

- i) *inspection;*
- ii) *the determinations of 6.2;*
- iii) *the measurements of 6.3 and 6.7;*
- iv) *the dielectric strength tests of 6.8 (without humidity preconditioning).*

6.6.2 TERMINALS for external circuits

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

TERMINALS which are energized from the interior, with HAZARDOUS LIVE voltage exceeding 1 kV r.m.s. or 1,5 kV d.c., or with floating voltage exceeding 1 kV r.m.s. or 1,5 kV d.c., shall not be ACCESSIBLE. Equipment with such TERMINALS shall be designed so that an ACCESSIBLE HAZARDOUS LIVE voltage is not present when connectors are not mated, or shall be marked with symbol 12 of table 1 (see 5.2) to warn the OPERATOR of the possible presence of an ACCESSIBLE HAZARDOUS LIVE voltage.

Unmated measuring TERMINALS which are HAZARDOUS LIVE when the maximum RATED voltage is applied to the TERMINAL shall not be ACCESSIBLE.

NOTE For locking and screw-held TERMINALS, see 6.1.2 c).

Conformity is checked by inspection, and by the determination of ACCESSIBLE parts as specified in 6.2.

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 ACCESSIBLE TERMINALS for stranded conductors

- a) ACCESSIBLE TERMINALS for stranded conductors shall be located or shielded so that there is no risk 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) ACCESSIBLE TERMINALS shall be marked to show whether or not they are connected to ACCESSIBLE conductive parts (see 5.1.6 c)).

Conformity is checked by inspection after fully inserting a stranded conductor with an 8 mm length of insulation removed, with one of the strands free. The 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 round BARRIERS.

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

Conformity is checked by manual test and inspection.

6.7 CLEARANCES and CREEPAGE DISTANCES

CLEARANCES and CREEPAGE DISTANCES are specified in 6.7.1 to 6.7.4 so as to withstand the voltages that appear on the system for which the equipment is intended. They also take account of RATED environmental conditions and of any protective devices fitted within the equipment or required by the manufacturer's instructions.

There are no CLEARANCE or CREEPAGE DISTANCE requirements for the interior of void-free moulded parts, including the inner layers of multi-layer printed circuit boards.

Conformity is checked by inspection and measurement. When determining a CLEARANCE or CREEPAGE DISTANCE to ACCESSIBLE parts, the ACCESSIBLE surface of an insulating ENCLOSURE is considered to be conductive as if it was covered by metal foil wherever it can be touched with a standard test finger (see annex B). Conformity for homogeneous construction is checked as specified in 6.7.3.1 c).

6.7.1 General requirements

6.7.1.1 CLEARANCES

CLEARANCES are specified to withstand the maximum transient overvoltage that can be present 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. If transient overvoltages cannot occur, CLEARANCES are based on the maximum WORKING VOLTAGE.

The value for CLEARANCE depends on

- a) the type of insulation (basic insulation, reinforced insulation, etc.);
- b) the POLLUTION degree of the micro-environment of the CLEARANCE.

In all cases, the minimum CLEARANCE for POLLUTION DEGREE 2 is 0,2 mm and for POLLUTION DEGREE 3 is 0,8 mm.

If the equipment is RATED to operate at an altitude greater than 2 000 m, the CLEARANCE is multiplied by a factor derived from table 3. The factors are not applied to CREEPAGE DISTANCE, but CREEPAGE DISTANCE shall always be at least as large as the value specified for CLEARANCE.

Table 3 – Multiplication factors for CLEARANCE for 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

6.7.1.2 CREEPAGE DISTANCES

For CREEPAGE DISTANCES between two circuits, the actual WORKING VOLTAGE which stresses the insulation between the circuits shall be used. Linear interpolation of CREEPAGE DISTANCE is permissible. CREEPAGE DISTANCE shall always be at least as large as the value specified for CLEARANCE. If the calculated CREEPAGE DISTANCE is smaller than the CLEARANCE, the CREEPAGE DISTANCE shall be increased to the value of the CLEARANCE.

For coated printed wiring boards whose coatings meet the requirements of IEC 60664-3 for type A coatings, the values for POLLUTION DEGREE 1 apply.

For REINFORCED INSULATION, the CREEPAGE DISTANCE shall be twice the value specified for BASIC INSULATION.

For the purposes of this subclause, materials are separated into four groups according to their CTI (Comparative Tracking Index) values, as follows:

Material group I	$600 \leq \text{CTI}$
Material group II	$400 \leq \text{CTI} < 600$
Material group IIIa	$175 \leq \text{CTI} < 400$
Material group IIIb	$100 \leq \text{CTI} < 175$

The CTI values above refer to values obtained, in accordance with IEC 60112, on samples specifically made for the purpose and tested with solution A.

For glass, ceramics or other inorganic insulating materials which do not track, CREEPAGE DISTANCES need not be greater than their associated CLEARANCE.

Annex E specifies measures which can be used to reduce the POLLUTION degree.

CREEPAGE DISTANCES are measured as specified in annex C.

6.7.2 MAINS CIRCUITS

CLEARANCES and CREEPAGE DISTANCES shall meet the values specified in table 4.

Table 4 – CLEARANCES and CREEPAGE DISTANCES for MAINS CIRCUITS

Voltage line-to- neutral a.c. r.m.s. or d.c. V	Values for CLEAR- ANCE (see note 1) mm	Values for CREEPAGE DISTANCES								
		POLLUTION DEGREE 1		POLLUTION DEGREE 2				POLLUTION DEGREE 3		
		Printed wiring boards CTI ≥ 100 mm	All material groups CTI ≥ 100 mm	Printed wiring boards CTI ≥ 100 mm	Material group I CTI ≥ 600 mm	Material group II CTI ≥ 400 mm	Material group III CTI ≥ 100 mm	Material group I CTI ≥ 600 mm	Material group II CTI ≥ 400 mm	Material group III CTI ≥ 100 mm
>50 ≤100	0,1	0,1	0,25	0,16	0,71	1,0	1,4	1,8	2,0	2,2
>100 ≤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
>300 ≤600	3,0	3,0	3,0	3,0	3,0	4,3	6,0	7,5	8,3	9,4

NOTE 1 Minimum values for clearance for different POLLUTION DEGREES are:
POLLUTION DEGREE 2: 0,2 mm;
POLLUTION DEGREE 3: 0,8 mm.

NOTE 2 Values specified are for BASIC INSULATION or SUPPLEMENTARY INSULATION. Values for REINFORCED INSULATION are twice the values for basic insulation.

6.7.3 Circuits other than MAINS CIRCUITS

6.7.3.1 CLEARANCE values – General

- a) For circuits derived from MAINS CIRCUITS, CLEARANCES shall have the values as specified in table 5 except for the conditions specified in b) below.
- b) CLEARANCES for the following cases are specified in 6.7.3.2. Such cases include CLEARANCES where
 - 1) means have been taken within the equipment which limit overvoltages to levels below the applicable impulse withstand voltage of table 5 (see 14.9);
 - 2) the maximum possible transient overvoltage is above the applicable impulse withstand voltage of table 5;
 - 3) the WORKING VOLTAGE is the sum of voltages from more than one circuit, or is a mixed voltage;
 - 4) it is controlled by the source (external to the equipment, but as specified by the manufacturer) to levels below the impulse withstand voltage of table 5, provided that the equipment is not intended for connection to other sources which would permit higher impulse voltages.
- c) Reduced CLEARANCES may apply to homogeneous construction because the dielectric strength of an air gap is dependent on the shape of the electric field within the gap, as well as on the width of the gap. In homogeneous construction, conductive parts are shaped and arranged so that homogeneous or near-homogeneous electric field conditions exist between them. As a result, reduced CLEARANCES can be accepted between such conductive parts in circuits other than MAINS CIRCUITS.

No particular value can be specified for a reduced CLEARANCE for homogeneous construction, but it can be tested by a dielectric strength test. The test is an a.c. peak or d.c. test, using the test voltage (see table 9) for the CLEARANCE value which would apply for inhomogeneous construction.

Table 5 – CLEARANCES for circuits derived from MAINS CIRCUITS

WORKING VOLTAGE	CLEARANCE			
AC r.m.s. or d.c.	MAINS voltage ≤100 V RATED impulse voltage 500 V	MAINS voltage >100 V ≤ 150 V RATED impulse voltage 800 V	MAINS voltage >150 V ≤ 300 V RATED impulse voltage 1 500 V	MAINS voltage >300 V ≤ 600 V RATED impulse voltage 2 500 V
V	mm	mm	mm	mm
50	0,05	0,12	0,53	1,51
100	0,07	0,13	0,61	1,57
150	0,10	0,16	0,69	1,64
300	0,24	0,39	0,94	1,83
600	0,79	1,01	1,61	2,41
1 000	1,66	1,92	2,52	3,45
1 250	2,23	2,50	3,16	4,16
1 600	3,08	3,39	4,11	5,21
2 000	4,17	4,49	5,30	6,48
2 500	5,64	6,02	6,91	8,05
3 200	7,98	8,37	9,16	10,2
4 000	10,6	10,9	11,6	12,8
5 000	13,7	14,0	14,9	16,1
6 300	17,8	18,2	19,1	20,3
8 000	23,5	23,9	24,7	26,0
10 000	30,3	30,7	31,6	32,9
12 500	39,1	39,6	40,5	41,9
16 000	52,0	52,5	53,5	54,9
20 000	67,4	67,9	68,9	70,5
25 000	87,4	87,9	89,0	90,6
32 000	117	117	118	120
40 000	151	151	153	154
50 000	196	196	198	199
63 000	258	258	260	261

6.7.3.2 CLEARANCE values where table 5 does not apply and for circuits in measurement category I

CLEARANCES for BASIC INSULATION and SUPPLEMENTARY INSULATION are determined from the following formula:

$$\text{CLEARANCE} = D_1 + F(D_2 - D_1)$$

where

D_1 and D_2 are CLEARANCES taken from table 6;

D_1 is the CLEARANCE that would be applicable to the maximum voltage U_m if it consisted only of a $1,2 \times 50 \mu\text{s}$ impulse;

D_2 is the CLEARANCE that would be applicable to the maximum voltage U_m if it consisted only of the peak WORKING VOLTAGE U_w , without any transient overvoltage;

The maximum voltage (U_m) is the maximum peak WORKING VOLTAGE U_w plus the maximum transient overvoltage U_t ;

F is a factor, determined from one of the equations:

$$F = (1,25 U_w/U_m) - 0,25 \text{ if } 0,2 < U_w/U_m \leq 1$$

$$F = 0 \text{ if } U_w/U_m \leq 0,2$$

CLEARANCES for REINFORCED INSULATION are calculated using the same formula, but using the values of D_1 and D_2 specified in table 6 for a voltage 1,6 times the actual WORKING VOLTAGE.

NOTE The following are two examples.

- a) CLEARANCE for REINFORCED INSULATION for a peak WORKING VOLTAGE of 3 500 V and a maximum transient overvoltage of 4 500 V.

$$U_m = U_w + U_t = (3\,500 + 4\,500) \text{ V} = 8\,000 \text{ V}$$

$$F = (1,25 U_w/U_m) - 0,25 = (1,25 \times 3\,500/8\,000) - 0,25 = 0,347$$

$$D_1 = 16,7 \text{ mm}; D_2 = 29,5 \text{ mm (values for } 8\,000 \times 1,6 = 12\,800 \text{ V)}$$

$$\text{CLEARANCE} = D_1 + F (D_2 - D_1) = 16,7 + 0,347 (29,5 - 16,7) = 17,7 + 4,4 = 21,1 \text{ mm}$$

- b) CLEARANCE for BASIC INSULATION for a secondary peak WORKING VOLTAGE of 400 V derived from a primary voltage of 230 V a.c, but with overvoltage controlled within the equipment to a maximum of 2 100 V.

$$U_m = U_w + U_t = (400 + 2\,100) = 2\,500 \text{ V}$$

$$(U_w/U_m) < 0,2, \text{ so } F = 0$$

$$\text{CLEARANCE} = D_1 = 1,45 \text{ mm.}$$

Withdrawn

Table 6 – CLEARANCE values for the calculation of 6.7.3.2

$\hat{U}_m$	CLEARANCE		$\hat{U}_m$	CLEARANCE	
	D_1	D_2		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
NOTE 1 Interpolation of CLEARANCES is allowed.					
NOTE 2 Minimum CLEARANCE for POLLUTION DEGREE 2 is 0,2 mm, for POLLUTION DEGREE 3 is 0,8 mm.					

6.7.3.3 CREEPAGE DISTANCE values

Table 7 gives the CREEPAGE DISTANCES related to the WORKING VOLTAGE.