Standard ECMA-287
2nd edition - December 2002

ECMA International

Standardizing Information and Communication Systems

Safety of electronic equipment

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Brief History

The advent of multimedia products has blurred the borderline between different classes of products, like IT equipment, audio-video equipment, communication equipment, and the environment within which the equipment is used.

Personal computers which used to be connected only to printers and occasionally modems are now frequently connected to audio amplifiers, loudspeakers, scanners, video and audio tape recorders or TV sets. The environment has changed from the office (or home office), to include all the rooms of the house, and, for portable equipment, outdoor leisure areas. The age of the user and of the bystander is continuously reducing.

This changing situation has generated a new set of conditions that are to be taken into account when designing new equipment. In order to take into account these conditions ECMA has prepared the first edition of Standard ECMA-287.

Included in the scope of the Standard are ICT equipment, audio and video equipment, and in general electronic equipment with a rated voltage not exceeding 600 V and intended for domestic or professional use and environment. The equipment may be an independent unit or a system of interconnected units.

The philosophy applied to this new Standard has been to define hazard-based requirements, using engineering principles and taking into account relevant IEC product standards and pilot safety documents. Where technical discrepancies between standards emerged, a conclusion was based on engineering principles.

For the preparation of the second edition ECMA has opened TC12 to representatives of EICTA members, JEITA members and of test houses. The structure of the standard has been presented at meetings held in Japan, the United States and Europe, in order to make designers and test house representatives aware of the work in ECMA.

The final draft of the second edition has been contributed to IEC TC108 to be used by the "Hazard Based Development Team".

During the development of this second edition, ECMA TC12 came across a number of issues where TC12 could not reach consensus or where TC12, because of time constraints was not able to find a proper solution. A list of these issues has been provided to IEC TC108 with the request that IEC TC108 takes those issues into account when producing the new IEC standard that is based on this ECMA Standard.

This ECMA Standard has been adopted by the ECMA General Assembly of 19th December 2002

Table of contents

1 Guidance principles and basic information

1.1 Scope

The requirements and tests specified in this Standard apply only if safety is involved.

NOTE
In order to establish whether or not safety is involved, the circuits and construction should be carefully investigated by means of fault tree analysis, failure modes and effect analysis, or similar techniques, to take into account the normal conditions and the consequences of possible failure of components.

This Standard does not include requirements for performance or functional characteristics of equipment.

- **Applicability**
  This Standard is applicable to electronic equipment with a RATED VOLTAGE not exceeding 600 V r.m.s. or 600 V d.c. and intended for domestic or professional use. The equipment may be powered from an a.c. or d.c. supply and can be an independent unit or a system of interconnected units.

  The electronic equipment considered in this Standard can be:

  – office equipment;
  – consumer electronic equipment;
  – communication equipment;
  – or a combination of the above.

  NOTE
  For a non-comprehensive list of equipment which is within the scope of this Standard see annex A.

- **Protection**
  The requirements of this Standard are intended to provide protection to persons as well as to the surrounding of the equipment.

  There are three categories of persons who are normally concerned with electronic equipment, ORDINARY PERSON, SKILLED PERSON and INSTRUCTED PERSON.

  – "ORDINARY PERSON" is a person who can be affected by the equipment, other than a SKILLED PERSON or an INSTRUCTED PERSON;

  – "SKILLED PERSON" is a person having appropriate technical training and experience necessary to be aware of hazards to which the person may be exposed in performing a maintenance or repair task, and of measures to minimise the risks. A SKILLED PERSON can supervise an INSTRUCTED PERSON performing repair or maintenance tasks.

  This Standard specifies methods to provide protection to ORDINARY PERSONS, SKILLED PERSONS and INSTRUCTED PERSONS and to the surroundings. It is intended to be applied to all areas accessible to ORDINARY PERSONS.

  Where specific precautions are required for SKILLED PERSONS or INSTRUCTED PERSONS, these are given in the appropriate parts of the Standard. Necessary warnings may be provided in the service manual.

- **Hazards**
  The application of this Standard is intended to reduce the risk of injury and damage under NORMAL CONDITIONS or ABNORMAL CONDITIONS due to the following hazards:

  – Electrical shock (clause 3)
  – Fire (clause 4)
  – Burn (clause 5)
  – Mechanical (clause 6)
  – Radiation (clause 7)
  – Chemical (clause 8)

- **Users of the Standard**
  This Standard is intended to be used by:

- designers of electronic equipment;
- safety validation engineers, from equipment manufacturers or from test houses.

1.2 Additional requirements

Additional or more rigorous requirements than those specified in this Standard, may be necessary for:

- equipment intended for operation while exposed, for example, to extremes of temperature, to excessive moisture, to vibration, to flammable gases, to corrosive or explosive atmospheres;
- equipment having an intrinsic safety function, examples are process controllers and air traffic controls the failure of which may have a catastrophic effect;
- electromedical equipment;
- equipment intended to be installed in vehicles, on board ships or aircraft;
- equipment intended to be used at elevations greater than 2 000 m;
- equipment intended for use where ingress of water and dust is possible; for guidance on such requirements, and on relevant testing, see IEC 60529.

1.3 References

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the edition indicated was valid. All standards are subjected to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent edition of the standards listed below.

ECMA

ECMA-328 (2001)	Detection and measurement of chemical emissions from electronic equipment

IEC

IEC 60027 series	Letter symbols to be used in electrical technology
IEC 60060 series	High-voltage test techniques
IEC 60068 series	Environmental testing
IEC 60085 (1984-01)	Thermal evaluation and classification of electrical insulation
IEC 60107 series	Methods of measurement on receivers for television broadcast transmissions
IEC 60112 (1979-01)	Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions
IEC 60127 series	Miniature fuses
IEC 60216 series	Guide for the determination of thermal endurance properties of electrical insulating materials.
IEC 60227 series	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V
IEC 60245 series	Rubber insulated cables - Rated voltages up to and including 450/750 V
IEC 60309 series	Plugs, socket-outlets and couplers for industrial purposes
IEC 60320 series	Appliance couplers for household and similar general purposes
IEC 60331 series	Tests for electric cables under fire conditions – Circuit integrity
IEC 60332 series	Tests on electric cables under fire conditions
IEC 60384 series	Fixed capacitors for use in electronic equipment
IEC 60417 series	Graphical symbols for use on equipment
IEC 60479 series	Effects of current on human beings and livestock
IEC 60529 (1989-11)	Degrees of protection provided by enclosures (IP Code)
IEC 60664 series	Insulation co-ordination for equipment within low-voltage systems
IEC 60691 (1993-03)	Thermal-links - Requirements and application guide
IEC 60695 series	Fire hazard testing
IEC 60707 (1999-03)	Flammability of solid non-metallic materials when exposed to flame sources - List of Test methods
IEC 60730 series	Automatic electrical controls for household and similar use
IEC 60738 series	Thermistors - Directly heated positive step-function temperature coefficient
IEC 60825 series	Safety of laser products
IEC 60851 series	Methods of test for winding wires
IEC 60885 series	Electrical Test methods for electric cables
IEC 60990 (1990-06)	Methods of measurement of touch-current and protective conductor current
IEC 61032 (1997-12)	Protection of persons and equipment by enclosures - Probes for verification

IEC 61051 series	Varistors for use in electronic equipment
IEC 61058 series	Switches for appliances
IEC 61201 (1992-09)	Extra-low voltage (ELV) - Limit values
IEC 61558 series	Safety of power transformers, power supply units and similar
IEC 61965 (200-09)	Mechanical safety of cathode ray tubes

ISO

ISO 306:1994	Plastics - Thermoplastic materials -- Determination of Vicat softening temperature (VST)
ISO 3864:1984	Safety colours and safety signs
ISO 4046:1978	Paper, board, pulp and related terms -- Vocabulary
ISO 7000:1989	Graphical symbols for use on equipment -- Index and synopsis
ISO 9772:2001	Cellular plastics -- Determination of horizontal burning characteristics of small specimens subjected to a small flame
ISO 9773:1998	Plastics - Determination of burning behaviour of thin flexible vertical specimens in contact with a small-flame ignition source

ITU-T

ITU-T Rec. K.27	Bonding configurations and earthing inside a telecommunication building
ITU-T Rec. K.17	Tests on power-fed repeaters using solid-state devices in order to check the arrangements for protection from external interference

EN

EN 563	Safety of machinery. Temperatures of touchable surfaces. Ergonomic data to establish temperature limit values for hot surfaces

1.4 Acronyms

VDR	Voltage dependent resistor	CTI	Comparative Tracking Index
PTC-S	Positive Temperature Coefficient-Type S resistor	LPS	Limited Power Source
PS	Power source	TFE	tetrafluoroethene
PTFE	Polytetrafluoroethene	FEP	fluorinated ethylene propylene
LED	Light emitting diode	PVC	Poly-Vinyl-Chloride
UPS	Uninterruptible Power Supply	CRT	Cathode ray tube

2 Definitions

2.1 Abnormal condition

Operating condition not specified by the manufacturer, or one means of protection against a hazard is defective or one fault is present that could cause a hazard.

NOTE 1
These conditions are specified in annex B.7.

NOTE 2
ABNORMAL CONDITIONS can be introduced by an ORDINARY PERSON or be the result of an overload or a single failure.

2.2 Basic insulation

Insulation to provide basic protection against electric shock.

2.3 Clearance

The shortest distance in air between two conductive parts.

2.4 Creepage distance

The shortest distance along the surface of an insulating material between two conductive parts.

2.5 Disconnect device

Means to physically disconnect equipment from the MAINS.

2.6 Double insulation

Insulation comprising both BASIC INSULATION and SUPPLEMENTARY INSULATION.

2.7 Electrical enclosure

Enclosure intended to minimise the accessibility of ES 2 and ES 3 parts.

2.8 Enclosure

Housing affording the type and degree of protection suitable for the intended application. (IEV 195-02-35)

NOTE
The same enclosure may provide multiple types and degrees of protection for several intended applications such as ELECTRICAL ENCLOSURE, FIRE ENCLOSURE or MECHANICAL ENCLOSURE. Likewise, one part of an enclosure may provide one type and degree of protection for one intended application, and another part of the same enclosure may provide another type and degree of protection for another intended application.

2.9 External circuit

Circuit that is, in whole or in part, external to the equipment and is neither a MAINS nor a d.c. power distribution system.

2.10 Fire enclosure

Enclosure intended to minimise the spread of fire from within.

2.11 Functional insulation

Insulation between conductive parts, necessary for the proper functioning of the equipment.

NOTE 1
BASIC INSULATION may also perform as FUNCTIONAL INSULATION.

NOTE 2
FUNCTIONAL INSULATION by definition does not protect against electric shock. It may however reduce the likelihood of ignition and fire.

2.12 Instructed person

Person adequately advised or supervised by a SKILLED PERSON to enable him or her to avoid dangers and to prevent risks which may be created by the equipment. [IEV 826-09-02 modified]

2.13 Intermittent operation

Operation in a series of specified cycles each composed of a period of operation under NORMAL CONDITIONS, followed by a rest period with the equipment switched off or running idle.

2.14 Mains

External a.c. power distribution system supplying power to the equipment.

NOTE
MAINS include public or private utilities and, unless otherwise specified in the Standard, equivalent sources such as motor-driven generators and uninterruptible power supplies.

2.15 Mains transient voltage

Highest peak voltage expected at the power input to the equipment, arising from external transients on the mains.

2.16 Mechanical enclosure

Enclosure intended to reduce the risk of injury due to hazards other than burn, fire and electric shock.

2.17 Non-detachable power supply cord

Flexible cord fixed to or assembled with the equipment.

2.18 Normal condition

Operating conditions as specified by the manufacturer, with all means of protection intact.

NOTE
In the absence of specification the most unfavorable default values as specified in annex B.4 are used.

2.19 Ordinary person

Person who is neither a SKILLED PERSON nor an INSTRUCTED PERSON. [IEV 826-09-03]

2.20 Peak working voltage

Peak value of a working voltage, including any d.c. component and any repetitive peak impulses generated in the equipment.

NOTE
Where peak-to-peak ripple exceeds 10 % of the average value, the requirements related to peak or a.c. voltages are applicable.

2.21 Permanently connected equipment

Equipment which can only be disconnected from the electrical supply by the use of a TOOL.

2.22 Pluggable equipment type A

Equipment which is intended for connection to the MAINS via a non-industrial plug and socket-outlet or via an appliance coupler, or both.

2.23 Pluggable equipment type B

Equipment which is intended for connection to the electrical supply via an industrial plug and socket-outlet complying with IEC 60309, or with national standards for similar applications.

2.24 Pollution degree

Numeral characterising the expected pollution of the micro-environment

2.25 Potential ignition source

Location where electrical energy can cause ignition under an ABNORMAL CONDITION.

2.26 Potential ignition source 1

Location where an arc may occur due to the opening of a conductor or a contact.

NOTE
An electronic protection circuit or additional constructional measures may be used to prevent such a fault from becoming a potential ignition source 1.

Such a faulty contact or interruption in an electric connection includes those which may occur in conductive patterns on printed boards.

2.27 Potential ignition source 2

Location where a component may ignite due to excessive power dissipation.

2.28 Principal safeguard

SAFEGUARD that is effective under normal conditions.

2.29 Protective conductor

Conductor provided for the purposes of safety, for example protection against electric shock. [IEV 195-02-09]

2.30 Protective bonding conductor

PROTECTIVE CONDUCTOR in the equipment, or a combination of conductive parts in the equipment, connecting a main protective earthing terminal to a part of the equipment that is required to be earthed for safety purposes. [IEV 195-02-10 modified]

2.31 Protective earthing conductor

PROTECTIVE CONDUCTOR connecting a main protective earthing terminal in the equipment to an earth point in the building installation for protective earthing. [IEV 195-02-11 modified]

2.32 Rated current

The input current of the equipment as declared by the manufacturer and defined at NORMAL CONDITIONS.

2.33 Rated frequency

The supply frequency as declared by the manufacturer.

2.34 Rated voltage

The supply voltage as declared by the manufacturer.

NOTE
For three-phase supply, the phase-to-phase voltage.

2.35 Reinforced insulation

Single insulation system which provides a degree of protection against electric shock equivalent to DOUBLE INSULATION.

NOTE
The term "insulation system" does not imply that the insulation has to be in one homogeneous piece. It may comprise several layers which cannot be tested as SUPPLEMENTARY INSULATION or BASIC INSULATION.

2.36 Reinforced safeguard

Single, robust safeguard that is deemed equivalent to a system comprised of a principal safeguard and a supplementary safeguard.

2.37 Required withstand voltage

Peak voltage that the insulation under consideration is required to withstand.

2.38 Ripple-free

Voltage with an a.c. component having an r.m.s. value of not more than 10 % of the d.c. component.

2.39 Safeguard

Device or system specifically provided to impede (slow the rate) or attenuate (reduce the value) the energy being transferred to a body part.

NOTE
For fire, a safeguard is a device or system specifically provided to impede ignition or impede spread of fire.

2.40 Safety interlock

Means either preventing access to a hazardous area until the hazard is removed, or automatically removing the hazardous condition when access is gained.

2.41 Short-time operation

Operation under NORMAL CONDITION for a specified period, starting from cold, the intervals after each period of operation being sufficient to allow the equipment to cool down to room temperature.

2.42 Skilled person

Person with relevant education and experience to enable him or her to avoid dangers and to prevent risks which may be created by the equipment. [IEV 826-09-01 modified]

2.43 Stationary equipment

Equipment that is not TRANSPORTABLE EQUIPMENT.

2.44 Supplementary insulation

Independent insulation applied in addition to BASIC INSULATION in order to reduce the risk of electric shock in the event of a failure of the BASIC INSULATION.

2.45 Supplementary safeguard

SAFEGUARD that is effective in the event of failure of the PRINCIPAL SAFEGUARD.

2.46 Temperature limiter

Temperature-sensing control which is intended to keep a temperature below or above one particular value during NORMAL CONDITIONS and which may have provision for setting by an ORDINARY PERSON.

NOTE
A TEMPERATURE LIMITER may be of the automatic reset or of the manual reset type.

2.47 Thermal cut-out

Temperature-sensing control intended to operate under ABNORMAL CONDITION and which has no provision for the ORDINARY PERSON to change the temperature setting.
NOTE
A THERMAL CUT-OUT may be of the automatic reset or of the manual reset type.

2.48 Thermostat

Cycling temperature-sensing control, which is intended to keep a temperature between two particular values under NORMAL CONDITION and which may have provision for setting by the ORDINARY PERSON.

2.49 Transportable equipment

Equipment that is intended to be routinely carried.

NOTE
Examples include laptop personal computers, CD players, and portable accessories.

2.50 Tool

Screwdriver or any other object which can be used to operate a screw, latch or similar fixing means.

2.51 Touch current

Electric current through a human body when it touches two or more accessible parts or one accessible part and earth.

2.52 Working voltage

The highest voltage to which the insulation or the component under consideration is, or can be, subjected when the equipment is under NORMAL CONDITION.

3 Electric shock hazards

Electric shock is due to current passing through the human body. Depending on the magnitude, the duration, the wave shape and the frequency of the current, the effect to the human body varies from no reaction to dangerous patho-physiological effects such as cardiac arrest and respiratory arrest. To avoid dangerous effects to the human body equipment shall be provided with the protection measures specified in this Standard.

Sources of voltage and current are classified in 3.2.

3.1 Electrical parameters relating to the human body

The body is presumed to be electrically connected to the earth.

Unless otherwise stated, the area of electrical connections to the body is presumed to be up to 8 000 mm^2.

Up to and equal 10 mm^2 is small area of contact, provided the area could only be touched and is not grippable.

Above 10 mm^2 is large area of contact.

NOTE 1
The value, 8 000 mm^2, is from IEC 60479-1 and IEC 61201. The value, 10 mm^2 is from IEC 60479-1.

NOTE 2
The value, 8 000 mm^2, is considered to be the maximum area of the human hand.

NOTE 3
The value, 10 mm^2, is considered to be the area of a pin contact (finger tip, see IEC 60479 fig. 10).

When subjected to energy class ES 1, the impedance of the body is presumed to be infinite.

When subjected to energy class ES 3, the impedance of the body is presumed to be that shown in figure 4 of IEC 60990.

When subjected to energy class ES 2, the impedance of the body is between infinite and figure 4 of IEC 60990.

3.2 Electric shock energy sources

Electric shock energy sources are classified as ES 1, ES 2, or ES 3, see 3.2.1. The limits for these energy source classes are given in 3.2.2.

Each conductive part, whether current-carrying or not, or whether earthed or not, shall be classed ES 1, ES 2, or ES 3 with respect to earth and with respect to any other simultaneously accessible conductive part.

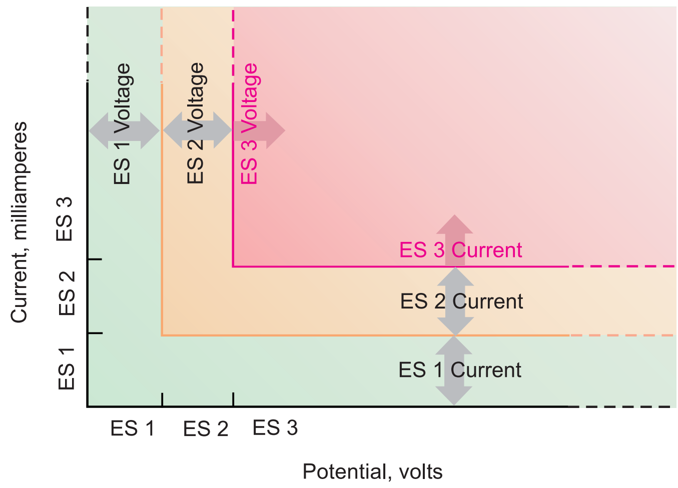
Conductive parts may be classed ES 3 without measurement or evaluation.

3.2.1 Classification

ES 1 source
Energy source with levels not exceeding ES 1 limits under NORMAL CONDITIONS and not ES 2 limits under ABNORMAL CONDITIONS.

ES 2 source
Energy source with levels not exceeding ES 2 limits under NORMAL CONDITIONS and under ABNORMAL CONDITIONS, but not an ES 1 source.

ES 3 source
Energy source with levels exceeding ES 2 limits under NORMAL CONDITIONS or ABNORMAL CONDITIONS, or any energy source declared to be an ES 3 source.



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For any voltage up to the limit voltage, there is no limit for the current, respectivly for any current up to the limit current, there is no limit for the voltage. However, in no case can both the current limit and the voltage limit be exceeded.

Figure 3.1 – Relationship of voltage and current limit

3.2.2 Limits

3.2.2.1 Voltage and current limits

Energy source class is determined from both the available voltage and the available current, see table 3.1 and 3.2.

The voltage is the maximum that can be delivered by the source on any resistive load.

The current is the maximum that can be delivered by the source into any resistive load.

NOTE 1
The voltage limits are derived from IEC 61201 for dry conditions (environmental situation 3) and contact area up to 8000 mm^2.

NOTE 2
The current limits are derived from IEC 60479.

Table 3.1 – Electric Shock Energy Source Classes for DC and low frequency AC

	Energy source level		ES 1 limit	ES 2 limit	ES 3 limit
1a	DC	voltage	≤ 60 V	> 60 V ≤ 120 V	> ES 2 limit (figure 3.2)
1b		current	≤ 2 mA	>2 mA ≤ 25 mA	
2a	AC (up to 1 kHz)	voltage	≤ ES 1 limit (figure 3.2)	> ES 1 limit (figure 3.2)	
2b		current	≤ 0,5 mA r.m.s.	> 0,5 mA ≤ 10 mA r.m.s.	
3a	combined AC and DC	voltage	Udc/60 + Uac/(value below ES 1 limit(figure 3.2)) ≤ 1	Udc/120 + Uac/(value below ES 2 limit (figure 3.2)) ≤ 1	

Table 3.2 – Electric Shock Energy Source Classes for medium and high frequency AC

	Energy source level		ES 1 limit	ES 2 limit	ES 3 limit
3a	AC (1 kHz up to 100 kHz)	voltage	≤ ES1 limit (figure 3.2) U max = 50 V r.m.s	≥ ES 1 limit < ES 2 limit (figure 3.2) U max = 120 V r.m.s.	> Values of ES 2 limit (figure 3.2)
3b		current	≤ 0,5 mA r.m.s. × f (kHz) I max = 50 mA	≤ 10 mA r.m.s. × 0,5 f (kHz) max ≤ 140 mA I max = 140 mA	
4a	AC (above 100 kHz)	voltage	≤ 50 V r.m.s (values for 100 KHz apply)	≤ 120 V r.m.s. (values for 100 KHz apply)	
4b		current	≤ 50 mA r.m.s. (values for 100 KHz apply)	≤ 140 mA r.m.s. (values for 100 KHz apply)	

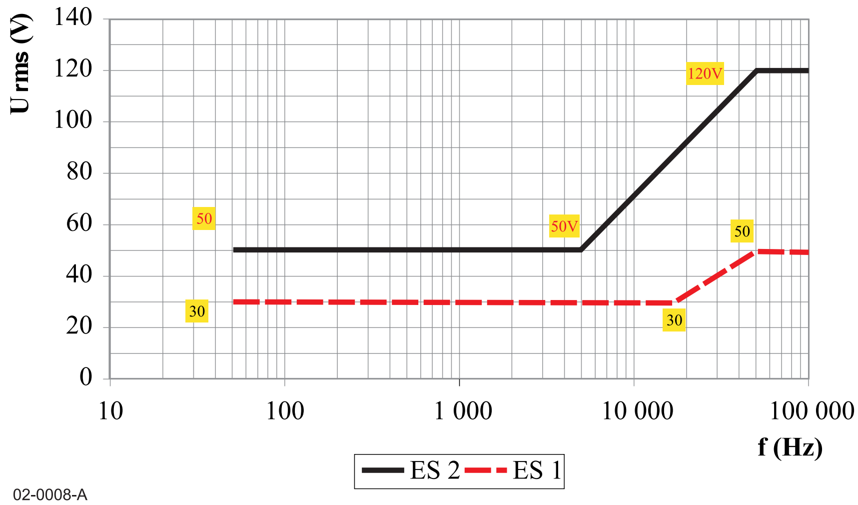

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Figure 3.2 – Voltage limits depending on the frequency

3.2.1.2 Capacitance limits

Where the energy source is a capacitor, the energy source class is determined from both the charge voltage and the capacitance. For any voltage up to the limit voltage, there is no limit for the capacitance; respectively for any capacitance up to the limit capacitance, there is no limit for the voltage. However, in no case can both the capacitance limit and the voltage limit be exceeded.

NOTE 1
The capacitance limits are derived from IEC 61201.

The capacitance is the rated value of the capacitor plus the specified tolerance.

Table 3.3 – Electric Shock Energy Source Classes for capacity discharge

Energy source level	ES 1	ES 2	ES 3
Capacitive discharge permitted capacitance and voltage	≤ A (figure 3.3)	> A ≤ B (figure 3.3)	> B (figure 3.3)

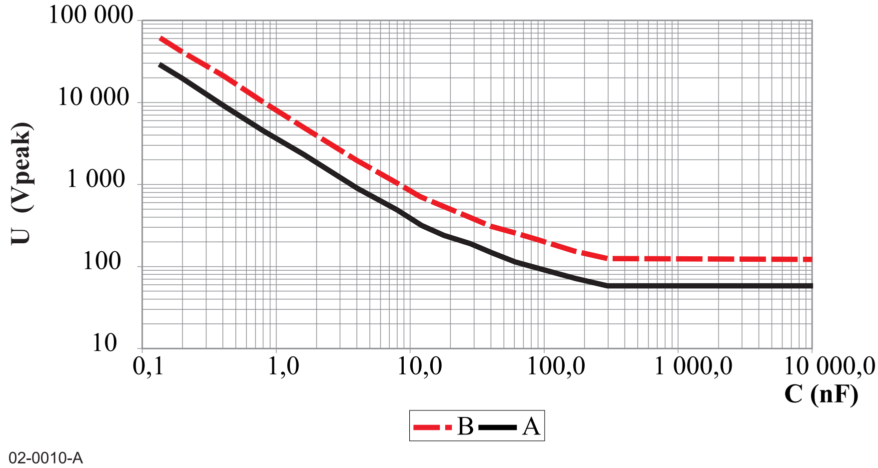

Figure 3.3 – Value of charged capacitances

The limits for capacitances shown in figure 3.3 are listed in table 3.4.

NOTE 2
The values for ES 2 are derived from table 2 of IEC 61201.

NOTE 3
The values for ES 1 are calculated by dividing the values from table 2 of IEC 61201 by two (2).

Table 3.4 – Limit values for capacitances

C (nF)	ES 1 U_{peak} (V)	ES 2 U_{peak} (V)
10 000	60	120
300	60	120
170	85	150
91	45,5	200
61	30,5	250
41	20,5	300
28	14	400
18	9	500
12	6	700
8,0	4	1 000
4,0	2	2 000
1,6	0,8	5 000
0,8	0,4	10 000
0,4	0,2	20 000
0,2	0,1	40 000
0,133	0,0665	60 000

3.2.1.3 Single long term pulse limits

Where the energy source is a single pulse, the energy source class is determined from both the voltage and the duration.

Values are given in table 3.5.

For the purposes of this Standard, for pulse durations of 1 ms up to 10 ms, the voltage limit for 10 ms applies.

NOTE 1
The pulse limits are derived from IEC 61201 clause 6.3.

NOTE 2
These long term pulses do not include transients.

Table 3.5 – Electric Shock Energy Source Classes for single pulses

Energy source level	ES 1	ES 2	ES 3
Single pulse (unidirectional pulse) Peak value Pulses > 10 ms	≤ limit A (figure 3.4)	> limit A ≤ limit B (figure 3.4)	> limit B (figure 3.4)

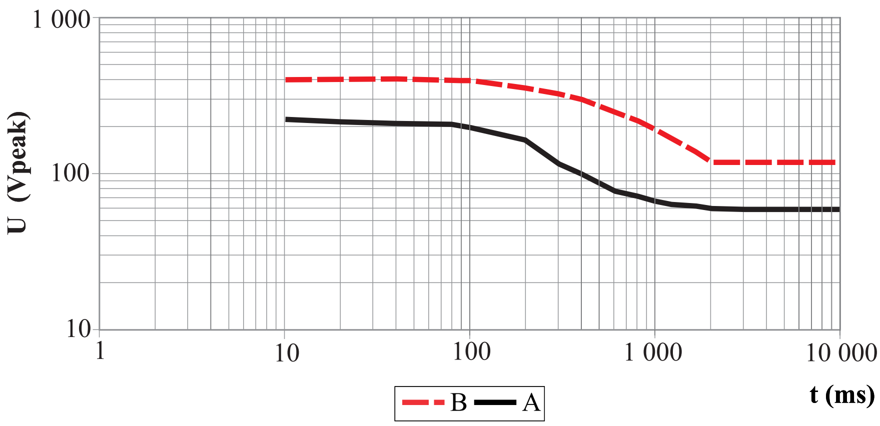

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Figure 3.4 – Limits for pulses > 10 ms

3.2.2.4 Special

Where the energy source is an analog telephone network ringing signal as defined in annex H, the energy source class is taken as ES 2.

3.3 Protection against energy sources

3.3.1 Protection of ordinary persons

3.3.1.1 Protection of an ordinary person against energy source ES 1

No safeguards need be interposed between an ORDINARY PERSON and energy source ES 1.

Energy source ES 1 may be accessible by an ORDINARY PERSON.

3.3.1.2 Protection of an ordinary person against energy source ES 2

At least one safeguard shall be interposed between an ORDINARY PERSON and energy source ES 2.

With respect to energy source ES 2, the principal safeguard may be accessible by an ORDINARY PERSON.

Where the contact area is not more than 10 mm^2 , no safeguard need be interposed between ES 2 and an ORDINARY PERSON. See 3.4.

3.3.1.3 Protection of an ordinary person against energy source ES 3

At least one PRINCIPAL SAFEGUARD and one SUPPLEMENTARY SAFEGUARD shall be interposed between an ORDINARY PERSON and energy source ES 3.

With respect to energy source ES 3, the SUPPLEMENTARY SAFEGUARD may be accessible, however the principal safeguard shall not be accessible by an ORDINARY PERSON.

3.3.2 Protection of instructed persons

3.3.2.1 Protection of an instructed person against energy source ES 1 and ES 2

No safeguards need be interposed between an INSTRUCTED PERSON and energy source ES 1 and ES 2.

3.3.2.2 Protection of an instructed person against energy source ES 3

At least one PRINCIPAL SAFEGUARD and one SUPPLEMENTARY SAFEGUARD shall be interposed between an INSTRUCTED PERSON and energy source ES 3.

With respect to energy source ES 3, the SUPPLEMENTARY SAFEGUARD may be accessible, however the PRINCIPAL SAFEGUARD shall not be accessible.

3.3.3 Protection of skilled persons

3.3.3.1 Protection of a skilled person against energy source ES 1 and ES 2

No safeguards need be interposed between a SKILLED PERSON and energy source ES 1 and ES 2.

3.3.3.2 Protection of a skilled person against energy source ES 3

Bare parts at energy source ES 3 shall be located or guarded so that unintentional contact with such parts is unlikely during service operations involving other parts of the equipment.

3.3.4 Safeguards between ES 1; ES 2 and ES 3

3.3.4.1 Protection of ES 1 from ES 2 and ES 3

At least one SAFEGUARD shall be interposed between ES 1 and ES 2.

At least one PRINCIPAL SAFEGUARD and one SUPPLEMENTARY SAFEGUARD shall be interposed between ES 1 and ES 3.

3.3.4.2 Protection of ES 2 from ES 3

At least two safeguards shall be interposed between ES 2 and ES 3.

Table 3.6 – Overview on 3.3 requirements

	Required number of interposed safeguards		
	ES 1	ES 2	ES 3
Ordinary person	0	1	2
Instructed person	0	0	2
Skilled person	0	0	1
ES 1	0	1	2
ES 2	1	0	2
ES 3	2	2	0

3.4 Accessible parts

An accessible part is determined by means of the straight and jointed test fingers defined as test probes 11 and B of IEC 61032, and the small finger probes defined as test probes 18 and 19 of IEC 61032.

NOTE
List of test probes used in this Standard
- *Unjointed test probe 11 (adult test finger)*
- *Jointed test probe B (adult test finger)*
- *Small finger test probe 18 (36 months up to 14 years; child test finger))*
- *Small finger test probe 19 (up to 36 months; child test finger)*

The jointed test finger is applied, without appreciable force and in any possible position, to the surface and openings of the equipment. Where access behind a door, panel, removable cover, etc. is possible without the use of a tool, or access is directed, with or without the use of a tool, the test finger is applied to surfaces and openings in those areas.

The straight unjointed test finger is applied with a force of 30 N in any possible position to the surface and openings of the equipment. If the unjointed test finger enters the equipment, the jointed test finger is pushed through the aperture to determine if any parts behind the aperture are accessible.

The test is repeated with the appropriate small finger test probes 18 and 19 of IEC 61032, applied with a force of 10 N, if the equipment is likely to be accessible to children.

3.4.1 Compliance in general

Compliance is checked by all the following:

- For ORDINARY PERSONS:
  - No contact to ES 3 and no contact to the PRINCIPAL SAFEGUARD of ES 3
  - No contact to ES 2 for areas >10 mm^2.
- For INSTRUCTED PERSONS:
  - No contact to ES 3 and no contact to the PRINCIPAL SAFEGUARD of ES 3

For voltages above 1 500 V peak there shall be an air gap between the bare part and the test finger. The air gap shall have a length equal to the minimum clearance for a PRINCIPAL SAFEGUARD.

Floor standing equipment having a mass exceeding 40 kg is not tilted during the test.

Parts may be designated accessible without test.

3.5 Safeguard

3.5.1 Principal safeguard

3.5.1.1 Basic Insulation

Requirements for CLEARANCES comprising BASIC INSULATION are specified in 3.6.2.

Requirements for creepage distances comprising BASIC INSULATION are specified in 3.6.3.

Requirements for solid insulation comprising BASIC INSULATION are specified in 3.6.4.

3.5.1.2 Components

Requirements for components comprising as PRINCIPAL SAFEGUARDS are specified in 3.7.1.

3.5.1.3 Protective equipotential bonding (earthing)

Requirements for protective bonding comprising as PRINCIPAL SAFEGUARDS are specified in 3.8.3.

3.5.2 Supplementary safeguards

3.5.2.1 Supplementary insulation

Requirements for CLEARANCES comprising SUPPLEMENTARY INSULATION are specified in 3.6.2.

Requirements for CREEPAGE DISTANCES comprising SUPPLEMENTARY INSULATION are specified in 3.6.3.

Requirements for solid insulation comprising SUPPLEMENTARY INSULATION are specified in 3.6.4.

3.5.2.2 Components

Requirements for components comprising as SUPPLEMENTARY SAFEGUARDS are specified in 3.7.2.

3.5.2.3 Protective equipotential bonding (earthing)

Requirements for protective bonding comprising as SUPPLEMENTARY SAFEGUARDS are specified in 3.8.4.

3.5.3 Reinforced safeguard

3.5.3.1 Reinforced insulation

Requirements for CLEARANCES comprising REINFORCED INSULATION are specified in 3.6.2.

Requirements for CREEPAGE DISTANCES comprising REINFORCED INSULATION are twice those specified for BASIC INSULATION in 3.6.3.

Requirements for solid insulation comprising REINFORCED INSULATION are specified in 3.6.4.

3.5.3.2 Components

Requirements for components comprising REINFORCED SAFEGUARDS are specified in 3.7.3.

3.5.3.3 Protective equipotential bonding (earthing)

Requirements for protective bonding comprising REINFORCED SAFEGUARDS are specified in 3.8.5.

3.5.4 Double safeguard

A double safeguard is required to be made of both a PRINCIPAL SAFEGUARD and a SUPPLEMENTARY SAFEGUARD.

3.6 Insulation system

3.6.1 General

3.6.1.1 Properties of insulating material

Insulating material shall have the electric strength, thermal strength, mechanical strength, dimensions, and other properties as specified in this sub-clause.

The choice and application of insulating material shall take into account the needs for electrical, thermal and mechanical strength, frequency of the working voltage and working environment (temperature, pressure, humidity and pollution).

Solid insulation shall not be hygroscopic.

NOTE
To protect solid insulation from damage due to transient overvoltages, the electric strength of solid insulation should be greater than the electric strength of the associated (parallel) CLEARANCE.

3.6.1.1.1 Test method

Compliance is checked by inspection and, where necessary, by evaluation of the data for the material.

Where necessary, if the data does not confirm that the material is non-hygroscopic, the hygroscopic nature of the material is determined by subjecting the component or subassembly employing the insulation in question to the humidity treatment of 3.6.13. The insulation is then subjected to the relevant electric strength test of 3.6.14 while still in the humidity cabinet, or in the room in which the samples were brought to the prescribed temperature.

3.6.1.2 Grade of insulation

Insulation providing a safeguard function is designated BASIC INSULATION, SUPPLEMENTARY INSULATION, REINFORCED INSULATION, or DOUBLE INSULATION.

BASIC INSULATION and SUPPLEMENTARY INSULATION, if they are elements of DOUBLE INSULATION, may be interchanged.

3.6.1.3 Frequency

The insulation requirements given in 3.6 are for frequencies up to 30 kHz. Insulation requirements for frequencies above 30 kHz were not available at the time of this Standard; until additional data is incorporated into this Standard, the requirements for frequencies up to 30 kHz shall be used for frequencies above 30 kHz.

NOTE
For information on insulation behaviour in relation to frequency see IEC 60664-1 and IEC 60664-4.

3.6.1.4 Maximum temperatures

Insulation temperatures under NORMAL CONDITION shall not degrade the insulation below the required safeguard properties of the insulation.

3.6.1.4.1 Test method

Compliance is checked by inspection of material data sheets and by determining and recording the temperatures in accordance with B.5 and B.6.

Taking into account the requirements of B.4, the equipment or parts of the equipment are operated under NORMAL CONDITION as follows:

- for continuous operation, until steady conditions are established; and
- for INTERMITTENT OPERATION, until steady conditions are established, using the rated "ON" and "OFF" periods; and
- for SHORT-TIME OPERATION, for the operating time specified by the manufacturer.

Components and other parts may be tested independent of the end-product provided that the test conditions applicable to the end-product are applied to the component or part.

Equipment intended for building-in or rack-mounting, or for incorporation in larger equipment, is tested under the most adverse actual or simulated conditions permitted in the installation instructions.

3.6.1.4.2 Compliance criteria

The temperature of the insulation shall not exceeding table 3.7 or the temperatures given in the material data sheets.

Table 3.7 – Temperature limits

Part	Maximum temperature (*T*max) °C
Insulation, including winding insulation: • of Class A material • of Class E material • of Class B material • of Class F material • of Class H material	 100 *1), 2), 3)* 115 *1), 2), 3)* 120 *1), 2), 3)* 140 *1), 2), 3)* 165 *1), 2), 3)*
Synthetic rubber or PVC insulation of internal and external wiring, including power supply cords: • without temperature marking • with temperature marking	 75 Temperature marking
Other thermoplastic insulation	*4)*
Terminals, including earthing terminals for external earthing conductors of STATIONARY EQUIPMENT, unless provided with a NON-DETACHABLE SUPPLY CORD	85
Components	See annex G

1) If the temperature of a winding is determined by thermocouples, these values are reduced by 10 °C, except in the case of
- *a motor, or*
- *a winding with embedded thermocouples.*

2) The classification of insulating materials (Classes A, E, B, F and H) is in accordance with IEC 60085.

3) For each material, account shall be taken of the data for that material to determine the appropriate maximum temperature.

4) Due to their wide variety, it is not possible to specify maximum permitted temperatures for thermoplastic materials. In order to determine the softening temperature of a specific thermoplastic material, the softening temperature as determined by the test B50 of ISO 306 shall be used. If the material is not known or if the actual temperature of the parts exceeds the softening temperature, the test described below shall be used.

The softening temperature of the material is determined on a separate specimen, under the conditions specified in ISO 306 with a heating rate of 50 °C/h and modified as follows:
- *the depth of penetration is 0,1 mm;*
- *the total thrust of 10 N is applied before the dial gauge is set to zero or its initial reading noted.*

3.6.1.5 Pollution Degrees

Pollution Degree 1

There is no pollution, because components and subassemblies have been adequately enclosed by enveloping or hermetic sealing so as to exclude dust and moisture;

Pollution Degree 2
There is only non-conductive pollution which might temporarily become conductive due to occasional condensation. It is generally appropriate for equipment covered by the scope of this Standard;

Pollution Degree 3
A local internal environment within the equipment is subject to conductive pollution, or to dry non-conductive pollution, which could become conductive due to expected condensation.

3.6.1.6 Interposed conductive parts

A CLEARANCE or CREEPAGE DISTANCE may be interrupted (or divided) by an interposed unconnected (floating) conductive part. The CLEARANCE or CREEPAGE DISTANCE shall be taken as the sum of the individual insulation distances (see figure Q.4).

3.6.1.7 Insulation with varying dimensions

If the insulation of a transformer has different PEAK WORKING VOLTAGES or different WORKING VOLTAGES along the length of the winding, the CLEARANCES, CREEPAGE DISTANCES and distances through insulation may vary in a corresponding fashion.

NOTE
An example of such a construction is a 30 kV winding, consisting of multiple bobbins connected in series, and earthed at one end.

3.6.2 Clearances

The parameter, REQUIRED WITHSTAND VOLTAGE, accounts for overvoltages and transients which may enter the equipment or which may be generated within the equipment. The dimension for a CLEARANCE is determined from the withstand voltage for that clearance.

The dimensions for CLEARANCES functioning as BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION shall be not less than the values as specified in table 3.9.

If applicable, the following minimum air gaps shall be provided:

- 10 mm for an air gap serving as REINFORCED INSULATION between an ES 3 part and an accessible conductive part of the external ENCLOSURE of floor-standing equipment or of the non-vertical top surface of desk top equipment;
- 2 mm for an air gap serving as BASIC INSULATION between an ES 3 part and an earthed accessible conductive part of the external ENCLOSURE of PLUGGABLE EQUIPMENT TYPE A.

The specified minimum CLEARANCES do not apply to the air gap between the contacts of THERMOSTATS, THERMAL CUT-OUTS, overload protection devices, switches of microgap construction, and similar components where the air gap varies with the contacts.

NOTE
For air gaps between contacts of SAFETY INTERLOCKS, see annex L. For air gaps between contacts of DISCONNECT DEVICES, see annex M.

3.6.2.1 Test method

Compliance is checked by measurement taking into account annex Q.

The following conditions apply:

- Movable parts are placed in their most unfavourable position;
- CLEARANCES from an ENCLOSURE of insulating material through a slot or opening are measured to point B figure Q.13.
- When measuring CLEARANCES, the 250 N force test has to be applied as follows:
  External ENCLOSURES as fitted to the equipment are subjected to a steady force of 250 N ± 10 N for a period of 5 s applied by means of a suitable test tool providing contact over a circular plane surface 30 mm in diameter. This test does not apply to ENCLOSURES of TRANSPORTABLE EQUIPMENT and of equipment intended to be held in the hand when operating.

3.6.2.2 Compliance criteria

Each CLEARANCE shall be equal or greater than the minimum dimensions determined in 3.6.2.9.

3.6.2.3 Summary of the procedure for determining minimum clearances

NOTE

The minimum CLEARANCE for BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION, whether in a circuit connected to the MAINS or in another circuit, depends on the REQUIRED WITHSTAND VOLTAGE. The REQUIRED WITHSTAND VOLTAGE depends in turn on the combined effect of the PEAK WORKING VOLTAGE (including repetitive peaks due to internal circuitry such as switch mode power supplies) and overvoltages due to external transients.

To determine the minimum value for each required CLEARANCE, the following steps shall be used:

1. Measure the PEAK WORKING VOLTAGE across the CLEARANCE in question.
2. For equipment to be connected to the MAINS, determine the MAINS transient voltage (3.6.2.4) and calculate the peak value of the nominal MAINS voltage.
3. Use 3.6.2.7.1 and the above voltage values to determine the REQUIRED WITHSTAND VOLTAGE for MAINS transients and internal transients. In the absence of transients coming from an EXTERNAL CIRCUIT, go to step 8.
4. For equipment to be connected to the d.c. power distribution system determine the transient voltage (3.6.2.5) and the nominal d.c. voltage.
5. If the equipment is to be connected to an EXTERNAL CIRCUIT, determine the EXTERNAL CIRCUIT transient voltage (3.6.2.6).
6. Use the EXTERNAL CIRCUIT transient voltage and 3.6.2.7.3 to determine the required withstand voltage for EXTERNAL CIRCUIT transients. In the absence of MAINS transients and internal transients, go to step 8.
7. Use 3.6.2.7.4 to determine the REQUIRED WITHSTAND VOLTAGE.
8. Use the REQUIRED WITHSTAND VOLTAGE to determine the minimum CLEARANCE (3.6.2.9).

3.6.2.4 Determination of mains transient voltage

For equipment to be supplied from the MAINS, the value of the MAINS TRANSIENT VOLTAGE depends on the Overvoltage Category and the MAINS voltage. In general, CLEARANCES, in equipment intended to be connected to the MAINS, shall be designed for Overvoltage Category II.

Equipment that is likely, when installed, to be subjected to transient overvoltages that exceed those for its design Overvoltage Category will require additional protection to be provided external to the equipment. In this case, the installation instructions shall state the need for such external protection.

The applicable value of the MAINS TRANSIENT VOLTAGE shall be determined from the Overvoltage Category and the MAINS voltage using table 3.8.

Table 3.8 – Mains transient voltages

Mains voltage 5) V r.m.s.	Mains transient voltage 4) V_{peak} Overvoltage Category I	II	III	IV
≤ 50	330	500	800	1 500
≤ 100	500	800	1 500	2 500
≤ 150 1) 6)	800	1 500	2 500	4 000
≤ 300 2)	1 500	2 500	4 000	6 000
≤ 600 3)	2 500	4 000	6 000	8 000

1) *Including 120/208 or 120/240 V.*

2) *Including 230/400 or 277/480 V.*

3) *Including 400/690 V.*

4) *The MAINS TRANSIENT VOLTAGE is always one of the values in the table. Interpolation is not permitted.*

5) *For equipment designed to be connected to a three-phase 3 wire supply, where there is no neutral conductor, the MAINS voltage is the line-to-line voltage. In all other cases, where there is a neutral conductor, it is the line-to-neutral voltage.*

6) *In Japan, the value of the MAINS TRANSIENT VOLTAGES for the nominal MAINS voltage of 100 V is determined from columns applicable to the nominal MAINS voltage of 150 V.*

3.6.2.5 Determination of transient voltage on a d.c. power distribution system

If a d.c. power distribution system is connected to protective earth and is entirely within a single building, the transient voltage is considered to be zero.

NOTE
The connection to protective earth can be at the source of the d.c. power distribution system or at the equipment location, or both (see ITU-T Recommendation K.27).

If a d.c. power distribution system is not earthed, the transient voltage shall be assumed to be equal to the MAINS TRANSIENT VOLTAGE in the MAINS from which the d.c. power is derived.

If equipment is supplied from a dedicated battery which has no provision for charging from an external mains supply, the transient voltage shall be assumed to be 0 V.

3.6.2.6 Determination of external circuit transient voltage

- It is expected that EXTERNAL CIRCUITS receive from sources outside the building a transient voltage of 1,5 kV peak with a waveform of 10/700µs. (see annex D.2)
- EXTERNAL CIRCUITS within the same building are expected to receive transient voltages of 0 V.

  NOTE
  the value 0 V was chosen, because no technical data is available.

The effect of a ringing signal shall not be taken into account.

For an EXTERNAL CIRCUIT using a coaxial cable, which is protectively earthed according to 3.8.3.1, the transient voltage is assumed to be 0 V.

3.6.2.7 Determination of required withstand voltage

3.6.2.7.1 Mains and internal repetitive peaks

The following rules 1) and 2) are used as indicated in a), b) and c) below.

Rule 1) If the PEAK WORKING VOLTAGE, U_{pw}, is less than the peak value of the MAINS voltage, the REQUIRED WITHSTAND VOLTAGE is the MAINS TRANSIENT VOLTAGE determined in 3.6.2.4;

$$U_{\text{required withstand}} = U_{\text{mains transient}}$$

Rule 2) If the PEAK WORKING VOLTAGE, U_{pw}, is greater than the peak value of the MAINS voltage, the REQUIRED WITHSTAND VOLTAGE is the MAINS TRANSIENT VOLTAGE determined in 3.6.2.4, plus the difference between the PEAK WORKING VOLTAGE and the peak value of the MAINS voltage.

$$U_{\text{required withstand}} = U_{\text{mains transient}} + U_{\text{pw}} - U_{\text{mains peak or d.c.}}$$

The supply voltage to be used in the above rules shall be the voltage in the first column of table 3.8 corresponding to the RATED VOLTAGE or the upper limit of the RATED VOLTAGE range.

a) Circuit supplied from the MAINS and receiving unattenuated transients from the MAINS:

In such a circuit the above rules 1) and 2) shall be applied.

b) Circuit supplied from a circuit that in turn is supplied from the MAINS, and receives unattenuated transients from the MAINS:

For such a circuit, the REQUIRED WITHSTAND VOLTAGE shall be determined as follows:

The above rules 1) and 2) are applied, with the MAINS TRANSIENT VOLTAGE determined in 3.6.2.4 replaced by a voltage that is one step smaller in the following list:

330, 500, 800, 1 500, 2 500, 4 000, 6 000 and 8 000 V_{peak}.

However, this reduction is not permitted for a floating circuit unless it is in equipment with a main protective earthing terminal and is separated from its supply circuit by an earthed metal screen, connected to protective earth.

Alternatively, the above rules 1) and 2) are applied but the voltage determined by measurement according to 3.6.2.8 a) shall be used as the MAINS TRANSIENT VOLTAGE.

c) Circuit receiving attenuated transients from the MAINS:

For such a circuit the REQUIRED WITHSTAND VOLTAGE is determined as follows.

The above rules 1) and 2) are applied, but the voltage determined by measurement according to 3.6.2.8 a) shall be used as the MAINS TRANSIENT VOLTAGE.

3.6.2.7.2 Transients on a d.c. supplied circuit

a) Circuit supplied from a d.c. power distribution system.

For such a circuit, the following rules 1) and 2) are used.

Rule 1) If the PEAK WORKING VOLTAGE, U_{pw}, is less than the voltage from the d.c. power distribution system, the REQUIRED WITHSTAND VOLTAGE is:

$$U_{\text{required withstand}} = U_{\text{actual transient}} \text{ or } U_{pw} \text{ whichever is higher}$$

Rule 2) If the PEAK WORKING VOLTAGE, U_{pw}, is greater than the d.c. power distribution system voltage, the REQUIRED WITHSTAND VOLTAGE is:

$$U_{\text{required withstand}} = (U_{\text{actual transient}} + U_{pw} - U_{\text{d.c. mains}}) \text{ or } U_{pw} \text{ whichever is higher.}$$

The $U_{\text{actual transient}}$ is measured according to 3.6.2.8 a).

b) Circuit other than connected to the d.c. power supply system, supplied by a d.c. source having capacitive filtering:

In such a circuit, earthed in accordance with 3.8, it is permitted to assume that the REQUIRED WITHSTAND VOLTAGE is equal to the d.c. voltage of the source.

3.6.2.7.3 External circuit transients

- For transients from an EXTERNAL CIRCUIT, the REQUIRED WITHSTAND VOLTAGE is the EXTERNAL CIRCUIT transient voltage determined in 3.6.2.6, or
- the value measured in accordance with 3.6.2.8 b).

3.6.2.7.4 Combination of transients

If the transients described in 3.6.2.7.1, 3.6.2.7.2 and 3.6.2.7.3 affect the same CLEARANCE, the REQUIRED WITHSTAND VOLTAGE is the larger of those voltages. The values shall not be added together.

3.6.2.8 Measurement of transient voltage levels

The following tests are conducted only if it is required to determine whether or not the transient voltage across the CLEARANCE in any circuit is lower than normal (for example, due to the effect of a filter in the equipment). The transient voltage across the CLEARANCE is measured using the following test procedure:

During the tests, the equipment is connected to its separate power supply unit, if any, but is not connected to the MAINS, and external d.c. power distribution system or to any EXTERNAL CIRCUIT, and any surge suppressors in circuits connected to the MAINS or the external d.c. power distribution system are disconnected.

A voltage measuring device is connected across the CLEARANCE in question.

a) Transients from a MAINS

To measure the transient voltage across a CLEARANCE due to transients on a MAINS the impulse test generator reference 2 of table D.1 is used to generate 1,2/50 µs impulses. U_C is equal to the MAINS TRANSIENT VOLTAGE determined in 3.6.2.4.

Three to six impulses of alternating polarity, with intervals of at least 1 s between impulses, are applied between each of the following points where relevant:

- line-to-line;
- all line conductors conductively joined together and neutral;
- all line conductors conductively joined together and protective earth;
- neutral and protective earth.

b) Transients from a D.C. POWER DISTRIBUTION SYSTEM:

To measure the transient voltage across a CLEARANCE due to transients on a d.c. power distribution system, the impulse test generator reference 2 of table D.1 is used to generate 1,2/50 µs impulses. U_C is equal to the transient voltage determined in 3.6.2.5.

Three to six impulses of alternating polarity, with intervals of at least 1 s between impulses, are applied between each of the following points where relevant:

- the positive and negative supply connection points;
- all supply connection points joined together and protective earth.

c) Transients from an EXTERNAL CIRCUIT

To measure the transient voltage across a CLEARANCE due to transients on an EXTERNAL CIRCUIT, the impulse test generator reference 1 of table D.1 is used to generate 10/700 µs impulses. U_C is equal to the EXTERNAL CIRCUIT transient voltage determined in 3.6.2.6.

Three to six impulses of alternating polarity, with intervals of at least 1 s between impulses, are applied between each of the following EXTERNAL CIRCUIT connection points of a single interface type:

- each pair of terminals (for example, A and B or tip and ring) in an interface;
- all terminals of a single interface type joined together and earth.

Where there are several identical circuits, only one is tested.

3.6.2.9 Determination of the minimum clearance

For equipment to be operated up to 2 000 m above sea level, each CLEARANCE shall comply with the minimum dimensions given in table 3.6.3, using the value of the REQUIRED WITHSTAND VOLTAGE determined according to 3.6.2.7.

For equipment to be operated at more than 2 000 m above sea level, the minimum CLEARANCES shall be multiplied by the factor given in table A.2 of IEC 60664-1. Linear interpolation is permitted between the nearest two points in table A.2. The calculated minimum CLEARANCE using this multiplication factor shall be rounded up to the next higher 0,1 mm increment.

Table 3.9 – Minimum clearances (mm) up to 2 000 m above sea level

REQUIRED WITHSTAND VOLTAGE Volts peak or d.c.	BASIC INSULATION and SUPPLEMENTARY INSULATION			REINFORCED INSULATION		
	PD 1 4)	PD 2	PD 3	PD 1 4)	PD 2	PD 3
Up to 400	0,2 (0,1)	0,2	0,8	0,4 (0,2)	0,4	1,6
800	0,2 (0,1)	0,2	0,8	0,4 (0,2)	0,4	1,6
1 000	0,3 (0,2)		0,8	0,6 (0,4)		1,6
1 200	0,4 (0,3)		0,8	0,8 (0,6)		1,6
1 500	0,8 (0,5)		0,8	1,6 (1)		1,6
2 000	1,3 (1)			2,6 (2)		
2 500	2,0 (1,5)			4 (3)		
3 000	2,6 (2)			5,2 (4)		
4 000	4,0 (3)			6		
6 000	7,5 (5,5)			11		
8 000	11 (8)			16		
10 000	15 (11)			22		
12 000	19 (14)			28		
15 000	24 (18)			36		
25 000	44 (33)			66		
40 000	80 (60)			120		
50 000	100 (75)			150		
60 000	120 (90)			180		
80 000	173 (130)			260		
100 000	227 (170)			340		

1. *Linear interpolation is permitted between the nearest two points, the calculated minimum clearances being rounded up to the next higher 0,1 mm increment.*
2. *The values in parentheses apply only if manufacturing is subjected to a quality control programme. In particular, DOUBLE INSULATION and REINFORCED INSULATION shall be subjected to routine tests for electric strength.*
3. *In a circuit other than directly connected to the a.c. mains, a minimum clearance of 5 mm replaces any higher value, provided that the insulation involved passes a dielectric strength test according to 3.6.14 using:*
   - *an a.c. test voltage whose peak value is equal to 1,5 times the peak working voltage, or*
   - *a d.c. test voltage equal to 1,5 times the peak working voltage.*

   If the clearance path is partly along the surface of insulation that is not Material Group I, the test voltage is applied across the air gap and the Material Group I only. The part of the path along the surface of any other insulating material is bypassed.
4. *It is permitted to use the values for Pollution Degree 1 if one sample passes the tests of 3.6.11.*

3.6.3 Creepage distances

CREEPAGE DISTANCES shall be so dimensioned that, for a given r.m.s. WORKING VOLTAGE, Pollution Degree and Material Group no flashover or breakdown of insulation (e.g. due to tracking) will occur.

3.6.3.1 Test method

Compliance is checked by measurement, taking into account annex Q.

The following conditions apply:

- Movable parts are placed in their most unfavourable positions;
- For equipment incorporating ordinary NON-DETACHABLE POWER SUPPLY CORDS, CREEPAGE DISTANCE measurements are made with supply conductors of the largest cross-sectional area specified in G.9, and also without conductors;
- When measuring CREEPAGE DISTANCES from the outer surface of an ENCLOSURE of insulating material through a slot or opening, the accessible surface is considered to be conductive as if it were covered by metal foil wherever it can be touched by the test finger, test probe B of IEC 61032, applied without appreciable force (see figure Q.13, point B).

3.6.3.1.1 Material group and Comparative tracking index (CTI)

Material Groups are depending on the comparative tracking index (CTI) and are classified 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 $100 \leq CTI < 175$

The Material Group is verified by evaluation of the test data for the material according to IEC 60112 using 50 drops of solution A.

If the Material Group is not known, Material Group IIIb shall be assumed.

If a CTI of 175 or greater is needed, and the data is not available, the Material Group can be established with a test for proof tracking index (PTI) as detailed in IEC 60112. A material may be included in a group if its PTI established by these tests is equal to, or greater than, the lower value of the CTI specified for the group.

3.6.3.2 Compliance criteria

CREEPAGE DISTANCES shall be not less than the appropriate minimum values specified in table 3.10, taking into account the value of the r.m.s. WORKING VOLTAGE, the Pollution Degree and the Material Group.

For REINFORCED INSULATION, the values for CREEPAGE DISTANCE are twice the values for BASIC INSULATION in table 3.10.

If the minimum CREEPAGE DISTANCE derived from table 3.10 is less than the applicable minimum CLEARANCE, that value of minimum CLEARANCE shall be applied as the minimum CREEPAGE DISTANCE.

For glass, mica, glazed ceramic or similar inorganic materials, if the minimum CREEPAGE DISTANCE is greater than the applicable minimum CLEARANCE, it is permitted to apply that value of minimum CLEARANCES as the minimum CREEPAGE DISTANCES.

Table 3.10 – Minimum creepage distance (mm)

r.m.s. working voltage V	Basic insulation and supplementary insulation								
	Pollution Degree 1	Pollution Degree 2	Pollution Degree 1	Pollution Degree 2			Pollution Degree 3		
	Printed Board	Printed Board	Material Group						
	Material Group I, II, IIIa, IIIb	Material Group I, II, IIIa	I, II, III	I	II	IIIa, IIIb	I	II	IIIa, IIIb [2)]
≤ 10	0,025	0,04	0,08	0,4	0,4	0,4	1,0	1,0	1,0
≤ 12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,0	1,05	1,05
≤ 16	0,025	0,04	0,1	0,45	0,45	0,45	1,1	1,1	1,1
≤ 20	0,025	0,04	0,11	0,48	0,48	0,48	1,2	1,2	1,2
≤ 25	0,025	0,04	0,125	0,5	0,5	0,5	1,2	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	0,8	1,1	1,4	1,6	1,8
≤ 50	0,025	0,04	0,18	0,6	0,85	1,2	1,5	1,7	1,9
≤ 63	0,04	0,063	0,2	0,63	0,9	1,25	1,6	1,8	2,0
≤ 80	0,063	0,10	0,22	0,67	0,9	1,3	1,7	1,9	2,1
≤ 100	0,10	0,16	0,25	0,71	1,0	1,4	1,8	2,0	2,2
≤ 125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4
≤ 160	0,25	0,40	0,32	0,8	1,1	1,6	2,0	2,2	2,5
≤ 200	0,40	0,63	0,42	1,0	1,4	2,0	2,5	2,8	3,2
≤ 250	0,56	1,0	0,56	1,25	1,8	2,5	3,2	3,6	4,0
≤ 320	0,75	1,6	0,75	1,6	2,2	3,2	4,0	4,5	5,0
≤ 400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
≤ 500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0
≤ 630	1,8	3,2	1,8	3,2	4,5	6,3	8,0	9,0	10,0
≤ 800	2,4	4,0	2,4	4,0	5,6	8,0	10,0	11	12,5
≤ 1 000	3,2	5,0	3,2	5,0	7,1	10	12,5	14	16
≤ 1 250			4,2	6,3	9	12,5	16	18	20
≤ 1 600			5,6	8,0	11	16	20	22	25
≤ 2 000			7,5	10	14	20	25	28	32
≤ 2 500			10	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			

1) *Linear interpolation is permitted between the nearest two points, the calculated* CREEPAGE DISTANCE *being rounded to the next higher 0,1 mm increment.*

2) *Material Group IIIb is not recommended for applications in Pollution Degree 3 above 630 V.*

3) *It is permitted to use the values for Pollution degree 1 if one sample passes the test of 3.6.11.*

3.6.4 Solid insulation

3.6.4.1 General

Solid insulation shall not break down:

- due to overvoltages, including transients, that enter the equipment, and peak voltages that may be generated within the equipment; and
- due to pinholes in thin layers of insulation.

Solvent-based enamel coatings shall not be used for BASIC INSULATION, SUPPLEMENTARY INSULATION or REINFORCED INSULATION.

Except for printed boards, solid insulation shall comply with 3.6.4.2 to 3.6.4.9 as applicable.

NOTE
For printed boards, see 3.6.5. For antenna terminal, see 3.6.7.

3.6.4.1.1 Test method

Compliance with the requirements of 3.6.4.2 to 3.6.4.9 for the adequacy of solid insulation is verified by inspection and measurement, taking into account annex Q, by the dielectric strength tests of 3.6.14 and the additional tests required in 3.6.4.2 to 3.6.4.9.

3.6.4.2 Minimum distance through insulation

Except where another sub clause of 3.6.4 applies, distances through insulation shall be dimensioned according to the application of the insulation and as follows (see figure Q.12):

- if the PEAK WORKING VOLTAGE does not exceed 71 V, there is no requirement for distance through insulation;
- if the PEAK WORKING VOLTAGE exceeds 71 V, the following rules apply:
  - for BASIC INSULATION there is no minimum distance through insulation;
  - SUPPLEMENTARY INSULATION or REINFORCED INSULATION shall have a minimum distance through insulation of 0,4 mm. It is permitted for the required distance through insulation to be provided by a single layer or by several layers, which can be the same or different materials, provided that one single layer has at least a thickness of 0,4 mm.

The requirements of 3.6.4.2 also apply to gel dielectrics such as are used in some optocouplers.

3.6.4.2.1 Test method

For compliance criteria, see 3.6.4.1.

3.6.4.3 Insulating compound forming solid insulation

NOTE 1
Alternative requirements for semiconductor devices are given in 3.6.4.4.

NOTE 2
For printed boards, see 3.6.5 and for wound components see 3.6.4.7, 3.6.4.8 and 3.6.4.9.

There is no minimum internal CLEARANCE or CREEPAGE DISTANCE if the insulating compound completely fills the casing of a component or subassembly, including a semiconductor device (for example an opto-coupler, see figure Q.17) provided that:

- the component or subassembly meets the minimum distances through insulation of 3.6.4.2; and
- a single sample passes the tests of 3.6.11.

NOTE 3
Some examples of such treatment are variously known as potting, encapsulation and vacuum impregnation.

NOTE 4
Such constructions may contain cemented joints in which case 3.6.4.5 also applies.

3.6.4.3.1 Test method

Compliance is checked according to 3.6.4.1.

3.6.4.4 Semiconductor devices

NOTE 1
Alternative requirements for semiconductor devices are given in 3.6.4.3.

There is no minimum internal CLEARANCE, CREEPAGE DISTANCE or distance through insulation in a semiconductor device (for example an opto-coupler, see figure Q.17) if insulating compound completely fills the casing, provided that the device:

- passes the type tests of 3.6.12; and
- passes routine tests for dielectric strength during manufacture of the semiconductor device, using the appropriate test in 3.6.14.

NOTE 2
Such constructions may contain cemented joints in which case 3.6.4.5 also applies.

3.6.4.4.1 Test method

Compliance is checked according to 3.6.4.1.

3.6.4.5 Cemented joints

Where the path between conductive parts is filled with insulating compound, and the insulating compound forms a cemented joint between two non-conductive parts or between a non-conductive part and itself (see figures Q.14, Q.15 and Q.16) one of the following, a), b) or c) applies.

a) The minimum CLEARANCES and CREEPAGE DISTANCES for Pollution Degree 2 shall be met along the path between the two conductive parts. The requirements for distance through insulation of 3.6.4.2 do not apply along the joint.

b) The minimum CLEARANCES and CREEPAGE DISTANCES for Pollution Degree 1 shall be met. Additionally, one sample shall pass the test of 3.6.11. The requirements for distance through insulation of 3.6.4.2 do not apply along the joint.

c) The requirements for distance through insulation of 3.6.4.2 apply between the conductive parts along the joint. Additionally, 3 samples shall pass the test of 3.6.12.

For a) and b) above, if the insulating materials involved have different Material Groups, the worst case is used. If a Material Group is not known, Material Group IIIb shall be assumed.

For b) and c) above, the tests of 3.6.11 and 3.6.12 are not applied to a printed board made using pre-preg if the temperature of the printed board measured during the heating test of 3.6.1.4 does not exceed 90 °C.

NOTE 1
No actual CLEARANCE or CREEPAGE DISTANCE exists unless the joint comes apart, for example due to ageing. To cover this possibility, the requirements and tests of c) apply if the minimum CLEARANCES and CREEPAGE DISTANCES according to a) or b) are not met.

NOTE 2
Some examples of cemented joints are as follows:
- *two non-conductive parts cemented together, for example two layers of a multilayer board (see figure Q.14) or the split bobbin of a transformer where the centre limb is secured by adhesive (see figure Q.16);*
- *spirally wrapped insulation on winding wire, sealed by adhesive (see figure Q.16);*
- *insulating compound between a non-conductive part (the casing) and the insulating compound itself in an opto-coupler (see figure Q.15).*

3.6.4.5.1 Test method

Compliance is checked according to 3.6.4.1.

3.6.4.6 Thin sheet material

There is no dimensional or constructional requirement for insulation in thin sheet material used as BASIC INSULATION.

Insulation in separable thin sheet materials is permitted for SUPPLEMENTARY INSULATION and REINFORCED INSULATION, irrespective of the distance through insulation, provided that

- at least two layers are used (see figure Q.13);
- they are within the equipment ENCLOSURE; and
- they are not subject to handling or abrasion during servicing.

There is no requirement for all layers of insulation to be of the same material.

Insulation in three or more layers of non-separable thin sheet materials is permitted for use within the equipment enclosure, and shall not be subject to handling or abrasion during servicing. There is no requirement regarding distances through insulation, nor for all layers of insulation to be of the same material.

3.6.4.6.1 Test method

Dielectric strength tests are applied in accordance with 3.6.14 to all the layers together if all the layers are of the same material and have the same thickness, using a test voltage of

- 2 x U_{test} if two layers are used; or
- 1,5 x U_{test} if three or more layers are used,

where U_{test} is the test voltage stated in 3.6.14 for SUPPLEMENTARY INSULATION or REINFORCED INSULATION as appropriate.

3.6.4.6.2 Thin sheet material - alternative test procedure

The following alternative to the dielectric strength test procedure in 3.6.4.6.1 is permitted if layers can be separated for individual testing or where the layers are of different materials or have a different thickness. Dielectric strength tests are applied in accordance with 3.6.14, where U_{test} is the test voltage stated in 3.6.14 for SUPPLEMENTARY INSULATION or REINFORCED INSULATION as appropriate.

If two layers are used, each layer shall pass the test, using a test voltage equal to $U_{test.}$

If three or more layers are used, each combination of two layers together shall pass the test, using a test voltage equal to $U_{test.}$

If three or more layers are used, it is permitted to divide these layers into two or three groups for testing purposes. In the above electric strength tests, these groups are tested instead of two or three layers.

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

3.6.4.6.3 Test on non-separable thin sheet material

Three test samples of thin sheet material are used, each approximately 70 mm wide.

One sample is fixed to the mandrel of the test fixture as shown in figure 3.5. The mandrel is made of steel, nickel plated or brass with smooth surface finish.

A pull of 150 N ± 10 N is applied to the free end of the sample, using an appropriate clamping device. The mandrel is twice rotated forwards and backwards by 230°, and then forwards to the final position.

A sheet of metal foil, 0,035 mm ± 0,005 mm thick, approximately 30 mm wide and at least 200 mm long, is placed across the surface of the sample, hanging down on each side of the mandrel. The surface of the foil in contact with the sample is conductive, not oxidised or otherwise insulated. The foil is tightened by a pull of approximately 1 N at each end, using appropriate clamping devices. The foil is positioned so that its edges are approximately 20 mm from the edges of the sample.

While the mandrel is in its final position, and within the 60 s following the final positioning, a dielectric strength test is applied between the mandrel and the metal foil in accordance with 3.6.14, using a test voltage of 1,5 times the value specified in table 3.6.9.

The test is repeated with the other two samples.

If a sample breaks at the clamping device during rotation, the test is repeated on a fresh sample.

If one or more samples break at any other place, the test has failed.

No flashover or breakdown shall occur during the test; corona effects and similar phenomena being disregarded.

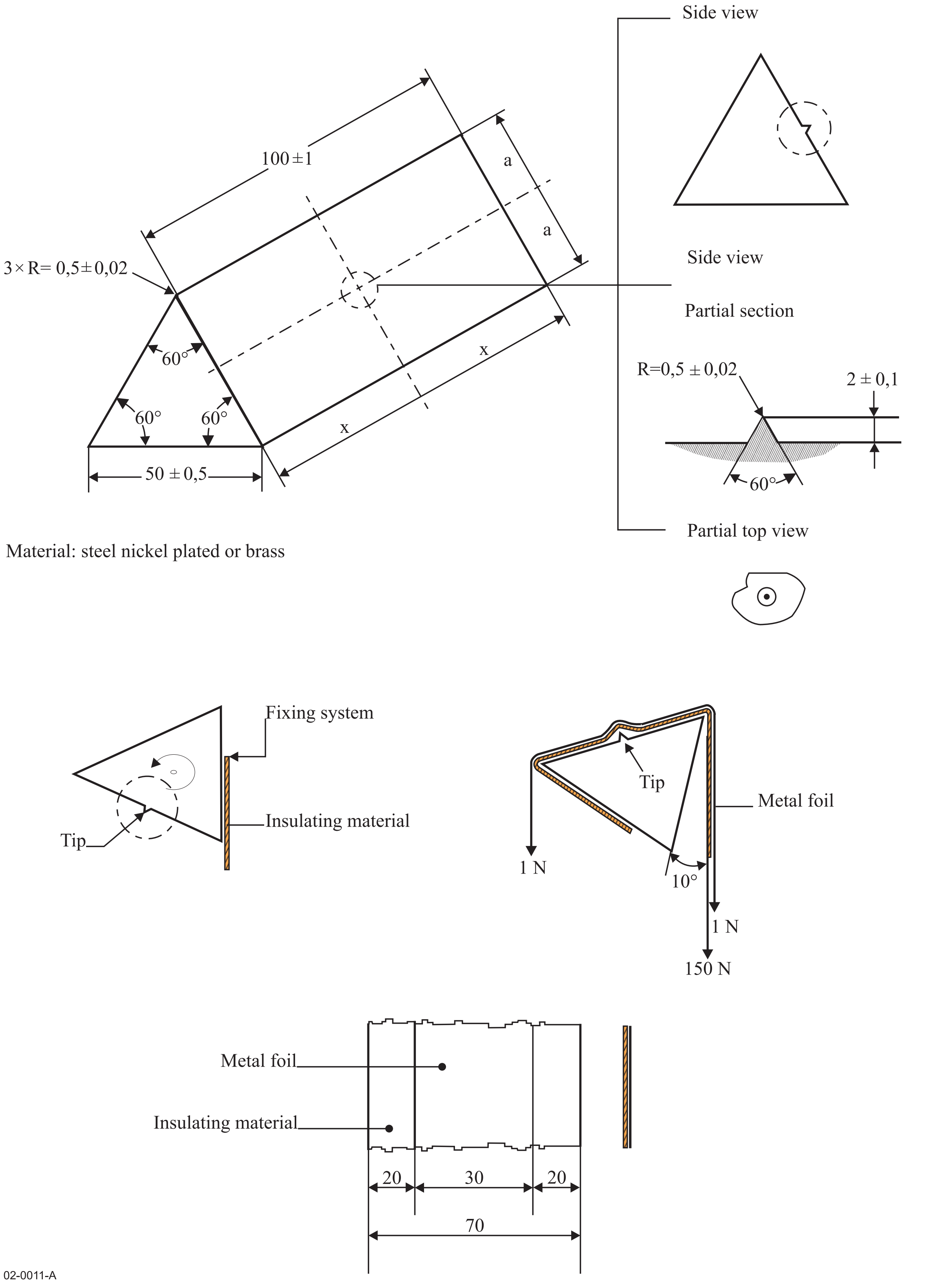

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Figure 3.5 – Test arrangement for checking mechanical withstanding of insulating materials in thin sheet layers

3.6.4.7 Insulation in wound components

Planar transformers are not considered to be wound components.

NOTE 1
Planar transformers are subject to the requirements of 3.6.5.

It is permitted for BASIC INSULATION, SUPPLEMENTARY INSULATION or REINFORCED INSULATION in a wound component to be provided by

- the insulation on winding wire or other wire, see 3.6.4.8; or
- other insulation, see 3.6.4.9; or
- a combination of the two.

NOTE 2
Wound components may contain cemented joints in which case 3.6.4.5 also applies.

For DOUBLE INSULATION between the conductor of a wire and another conductive part, it is permitted for BASIC INSULATION to be provided by insulation complying with 3.6.4.8 on the wire or wires and SUPPLEMENTARY INSULATION by additional insulation complying with 3.6.4.9, or vice versa.

3.6.4.7.1 Test method

Compliance is checked according to 3.6.4.1.

Additionally, BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION in the finished wound component shall pass routine tests for dielectric strength in accordance with 3.6.14.

3.6.4.8 Wire insulation in wound components

The following requirements apply to winding wire and other wire, such as lead-out wires, whose insulation provides BASIC INSULATION, SUPPLEMENTARY INSULATION or REINFORCED INSULATION.

Solvent-based enamel does not provide BASIC INSULATION, SUPPLEMENTARY INSULATION or REINFORCED INSULATION.

If the PEAK WORKING VOLTAGE does not exceed 71 V, there is no dimensional or constructional requirement.

If the PEAK WORKING VOLTAGE exceeds 71 V, one of the following, a), b), c) or d) applies:

a) There is no dimensional or constructional requirement for BASIC INSULATION that is not under stress (for example from winding tension). For BASIC INSULATION that is under such stress, b), c) or d) applies.

NOTE 1
The exception in a) does not apply to SUPPLEMENTARY INSULATION or REINFORCED INSULATION.

b) For basic insulation, supplementary insulation or reinforced insulation, the insulation on the wire shall either have a minimum distance through insulation of 0,4 mm or comply with 3.6.4.6.

c) The winding wire shall comply with annex K. The minimum number of overlapping layers of spirally wrapped tape or extruded layers of insulation shall be as follows:
   - for BASIC INSULATION: one layer;
   - for SUPPLEMENTARY INSULATION: two layers;
   - for REINFORCED INSULATION: three layers.

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

Spirally wrapped tape wound with not more than 50 % overlap is considered to constitute one layer. Spirally wrapped tape wound with more than 50 % overlap is considered to constitute two layers.

Spirally wrapped tape shall be sealed and pass the tests of 3.6.4.5 if the CLEARANCE or the CREEPAGE DISTANCE between layers, as wrapped, is less than the required minimum value for Pollution Degree 2.

NOTE 2
For wires insulated by an extrusion process, sealing is inherent to the process.

d) The wire shall comply with the relevant component standard in accordance with 1.5.

Where two winding wires, or one winding wire and another wire, are in contact inside the wound component, crossing each other at an angle between 45° and 90° and subject to winding tension, one of the following applies:

- protection against mechanical stress shall be provided. This protection can be achieved, for example, by providing physical separation in the form of insulating sleeving or sheet material, or by using double the required number of insulation layers, or
- the wound component passes the endurance tests of 3.6.4.10.

The wound components shall pass a 100 % routine testing for dielectric strength test, using the test as specified in annex K.3.

3.6.4.8.1 Test method

Compliance is checked by 3.6.4.1 and, where required, by 3.6.4.10. If the tests of annex K are required, they are not repeated if the material data sheets confirm compliance.

3.6.4.9 Additional insulation in wound components

The following requirements apply to insulation in a wound component, provided in addition to the insulation on winding wire or other wire. This includes, for example:

- insulation between windings; and
- insulation between a winding wire or other wire and any other conductive part in the wound component.

If the PEAK WORKING VOLTAGE does not exceed 71 V, there is no dimensional or constructional requirement.

If the PEAK WORKING VOLTAGE exceeds 71 V,

- for BASIC INSULATION there is no dimensional or constructional requirement;
- for SUPPLEMENTARY INSULATION or REINFORCED INSULATION, either
  - the additional insulation shall be of such a thickness that the total distance through insulation between the conductive parts is at least 0,4 mm; or
  - the requirements for thin sheet insulation in 3.6.4.6 shall be met.

3.6.4.9.1 Test method

Compliance is checked by inspection and measurement.

3.6.4.10 Endurance test on wound components

Where required by 3.6.4.9, the wound component is subjected to a test cycle consisting of a heat run (see 3.6.4.10.2), a vibration test (see 3.6.4.10.3) and a humidity conditioning (see 3.6.13).

After the heat run the samples are allowed to cool down to ambient temperature before the humidity conditioning is started.

The samples are subjected for two days to the humidity conditioning of 3.6.13.

Three wound components are required. All samples are subjected to 10 test cycles.

The measurements described below are made before the start of the 10 cycles and after each cycle.

The dielectric strength test of 3.6.14 and an insulation resistance test are carried out. The value of the test voltage for the dielectric strength test may be reduced to 35 % of the specified value. However, in this case the testing time has to be doubled.

After the dielectric strength test, the test of 3.6.4.10.4 is made on wound components operated at a.c. MAINS frequency.

3.6.4.10.1 Compliance criteria

If, after the completion of all 10 cycles, one or more samples have failed, the wound component is considered to not comply with the endurance test.

For wound components operated at mains frequency, there shall be no breakdown of the insulation between the turns of a winding, between input and output circuits, between adjacent input and output circuits, or between the windings and any conductive core.

3.6.4.10.2 Heat run

Depending on the type of insulation (thermal classification), the specimens are kept in a heating cabinet for a combination of time and temperature as specified in table 3.11. The 10 cycles are carried out with the same combination.

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

3.6.4.10.3 Vibration test

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

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

3.6.4.10.4 Test for transformers operating at a.c. mains frequency

One input circuit is connected to a voltage equal to a test voltage of at least 1,2 times the RATED VOLTAGE, at double the RATED FREQUENCY for 5 min. No load is connected to the transformer. During the test, polyfilar windings, if any, are connected in series.

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

Table 3.11 – Test temperature and testing time (days) per cycle

Test temperature	Temperature for the insulation system				
	100 °C	115 °C	120 °C	140 °C	165 °C
220 °C					4 days
210 °C					7 days
200 °C					14 days
190 °C				4 days	
180 °C				7 days	
170 °C				14 days	
160 °C			4 days		
150 °C		4 days	7 days		
140 °C		7 days			
130 °C	4 days				
120 °C	7 days				
Corresponding classification according to IEC 60085 and IEC 60216	A	E	B	F	H
Condition: the manufacturer shall specify the testing time per class used.					

3.6.5 Construction of printed boards

This clause also applies to the windings of a planar transformer.

3.6.5.1 Uncoated printed boards

The insulation between conductors on the outer surfaces of an uncoated printed board shall comply with the minimum CLEARANCE requirements of 3.6.2 and the minimum CREEPAGE DISTANCE requirements of 3.6.3.

3.6.5.1.1 Test method

Compliance is checked by inspection and by measurement.

3.6.5.2 Coated printed boards

For printed boards whose outer surfaces are coated with a suitable coating material, the minimum separation distances of table 3.12 apply to conductive parts before they are coated.

Either one or both conductive parts and at least 80 % of the distances over the surface between the conductive parts shall be coated.

The values in table 3.12 shall be used only if manufacturing is subject to a quality control programme. In particular, DOUBLE INSULATION and REINFORCED INSULATION shall pass routine tests for electric strength.

The coating process, the coating material and the base material shall be such that uniform quality is assured and the separation distances under consideration are effectively protected.

The minimum CLEARANCES of 3.6.2 and the minimum CREEPAGE DISTANCES of 3.6.3 shall apply

- if the above conditions are not met;
- between any two uncoated conductive parts; and
- over the outside of the coating.

3.6.5.2.1 Test method

Compliance is checked by inspection and measurement, taking figures Q.11 and Q.12 into account, and by the tests of 3.6.9.

Table 3.12 – Minimum separation distances for coated printed boards

Peak working voltage V peak	Basic insulation or supplementary insulation mm	Reinforced insulation mm
≤ 90	0,1	0,2
> 90 ≤ 180	0,2	0,4
> 180 ≤ 230	0,3	0,6
> 230 ≤ 285	0,4	0,8
> 285 ≤ 355	0,6	1,2
> 355 ≤ 455	0,8	1,6
> 455 ≤ 570	1,0	2,0
> 570 ≤ 710	1,3	2,6
> 710 ≤ 895	1,8	3,6
> 895 ≤ 1 135	2,4	3,8
> 1 135 ≤ 1 450	2,8	4,0
> 1 450 ≤ 1 770	3,4	4,2
> 1 770 ≤ 2 260	4,1	4,6
> 2 260 ≤ 2 830	5,0	5,0
> 2 830 ≤ 3 540	6,3	6,3
> 3 540 ≤ 4 520	8,2	8,2
> 4 520 ≤ 5 660	10	10
> 5 660 ≤ 7 070	13	13
> 7 070 ≤ 8 910	16	16
> 8 910 ≤ 11 310	20	20
> 11 310 ≤ 14 140	26	26
> 14 140 ≤ 17 700	33	33
> 17 700 ≤ 22 600	43	43
> 22 600 ≤ 28 300	55	55
> 28 300 ≤ 35 400	70	70
> 35 400 ≤ 45 200	86	86
Linear interpolation is permitted between the nearest two points, the calculated spacing being rounded up to the next higher 0,1 mm increment.		

3.6.5.3 Insulation between conductors on the same inner surface

On an inner surface of a multi-layer printed board (see figure Q.17), the path between any two conductors shall comply with the requirements for a cemented joint in 3.6.4.5.

3.6.5.4 Insulation between conductors on different surfaces

For BASIC INSULATION there is no thickness requirement.

SUPPLEMENTARY INSULATION or REINFORCED INSULATION between conductive parts on different surfaces in double-sided single-layer printed boards, multi-layer printed boards and metal core printed boards, shall either have a minimum thickness of 0,4 mm or conform with one of the specifications and pass the relevant tests in table 3.13.

3.6.5.4.1 Test method

Compliance is checked by inspection and measurement and by tests where required.

Table 3.13 – Insulation in printed boards

Specification of insulation	Type tests [1]	Routine tests for electric strength [3]
Two layers of sheet insulating material including pre-preg [2]	No	Yes
Three or more layers of sheet insulating material including pre-preg [2]	No	No
An insulation system with ceramic coating over a metallic substrate, cured at ≥ 500 °C	No	Yes
An insulation system, with two or more coatings other than ceramic over a metallic substrate, cured at < 500 °C	Yes	Yes

1) Thermal conditioning of 3.6.9.2 followed by the electric strength test of 3.6.14.

2) Layers are counted before curing.

3) Electric strength testing is carried out on the finished printed board.

NOTE
Pre-preg is the term used for a layer of glass cloth impregnated with a partially cured resin.

3.6.6 Component external terminations

It is permitted to use coatings over external terminations of components to increase effective CLEARANCES and CREEPAGE DISTANCES (see figure Q.11). The minimum separation distances of table 3.11 apply to the component before coating, and the coating shall meet all the requirements of 3.6.5.2, including quality control provisions. The mechanical arrangement and rigidity of the terminations shall be adequate to ensure that, during normal handling, assembly into equipment and subsequent use, the terminations will not be subject to deformation which would crack the coating or reduce the separation distances between conductive parts below the values in table 3.12 (see 3.6.5.2).

3.6.6.1 Test method

Compliance is checked by inspection taking into account figure Q.11 and by applying the sequence of tests covered by 3.6.9.1, 3.6.9.2 and 3.6.9.3. These tests are carried out on a completed assembly including the component(s).

The abrasion resistance test of 3.6.9.4 is carried out on a specially prepared sample printed board as described for sample 3 in 3.6.9.1, except that the separation between the conductive parts shall be representative of the minimum separations and maximum potential gradients used in the assembly.

3.6.7 Antenna terminals

The insulation between accessible parts or parts connected to them and MAINS terminals shall be able to withstand surges due to voltages present at the antenna terminal.

3.6.7.1 Test method

Compliance is checked by the following test.

The insulation between terminals for the connection of an antenna and the MAINS terminals is subjected to 50 discharges at a maximum rate of 12/min, from a test generator reference 3 of table D.1 with U_c = 10 kV.

During the test, the equipment shall not be energized.

After the test the equipment is subjected to the dielectric strength test of 3.6.14.

The test is not required for CLASS I equipment provided the antenna input circuit is connected to the PROTECTIVE BONDING CONDUCTOR.

3.6.8 Insulation on internal wiring

The insulation of internal wiring between a circuit not exceeding the limits of ES 2 and only separated from ES 3 by one safeguard and accessible conductive parts shall meet the following requirements:

a) supplementary insulation detailed in 3.6.4; or

b) all of the following apply:
- the wiring does not need to be handled by the ORDINARY PERSON and is so placed that the ORDINARY PERSON is unlikely to pull on it, or is so fixed that the connecting points are relieved from strain; and
- the wiring is routed and fixed so as not to touch unearthed accessible conductive parts; and
- the insulation passes the electric strength test of 3.6.14 for SUPPLEMENTARY INSULATION; and
- the distance through the insulation is not less than that given in table 3.14.

Table 3.14 – Distance through insulation of internal wiring

Working voltage (in case of failure of basic insulation)		Minimum distance through insulation
V peak or d.c.	V r.m.s. (sinusoidal)	(mm)
> 71 ≤ 350	> 50 ≤ 250	0,17
> 350	> 250	0,31

Insulation of internal wiring between an ES 3 circuit and accessible conductive parts and insulation of internal wiring of an ES 3 circuit where the internal wiring is not routed and fixed to prevent it from touching unearthed accessible conductive parts shall meet the following requirements:

- the minimum distance through insulation is 0,4 mm provided the insulation is made of polyvinyl chloride; or
- the insulation complies with the requirements for DOUBLE INSULATION or REINFORCED INSULATION as detailed in 3.6.4 and is capable of withstanding a dielectric strength test described in 3.6.14.

3.6.8.1 Test method

Compliance is checked by inspection and evaluation of test data showing that the insulation withstands the relevant test voltage.

If such applicable test data is not available, compliance is checked by applying the dielectric strength test using a sample of approximately 1 m in length and by the voltage Test method given in clause 3 of IEC 60885-1, using the relevant test voltage in 3.6.14 in this Standard for the grade of insulation under consideration; and

Where required in 3.6.8 the dielectric strength test of 3.6.14 shall be used.

3.6.9 Tests on coated printed boards

3.6.9.1 Sample preparation and preliminary inspection

Three sample printed boards (or, for coated components in 3.6.6, two components and one board) identified as samples 1, 2 and 3 are required. It is permitted to use either actual boards or specially produced samples with representative coating and minimum separations. Each sample board shall be representative of the minimum separations used, and coated. Each sample is subjected to the full sequence of manufacturing processes, including soldering and cleaning, to which it is normally subjected during equipment assembly.

When visually inspected, the boards shall show no evidence of pinholes or bubbles in the coating or breakthrough of conductive tracks at corners.

3.6.9.2 Thermal conditioning

Sample 1 is subjected to the thermal cycling sequence of 3.6.10.

Sample 2 is aged in a full draught oven at a temperature and for a time duration chosen from the graph of figure 3.6 using the temperature index line that corresponds to the maximum operating temperature of the coated board. The temperature of the oven is maintained at the specified temperature ± 2 °C. The temperature used to determine the temperature index line is the highest temperature on the board where safety is involved.

When using figure 3.6, interpolation is permitted between the nearest two temperature index lines.

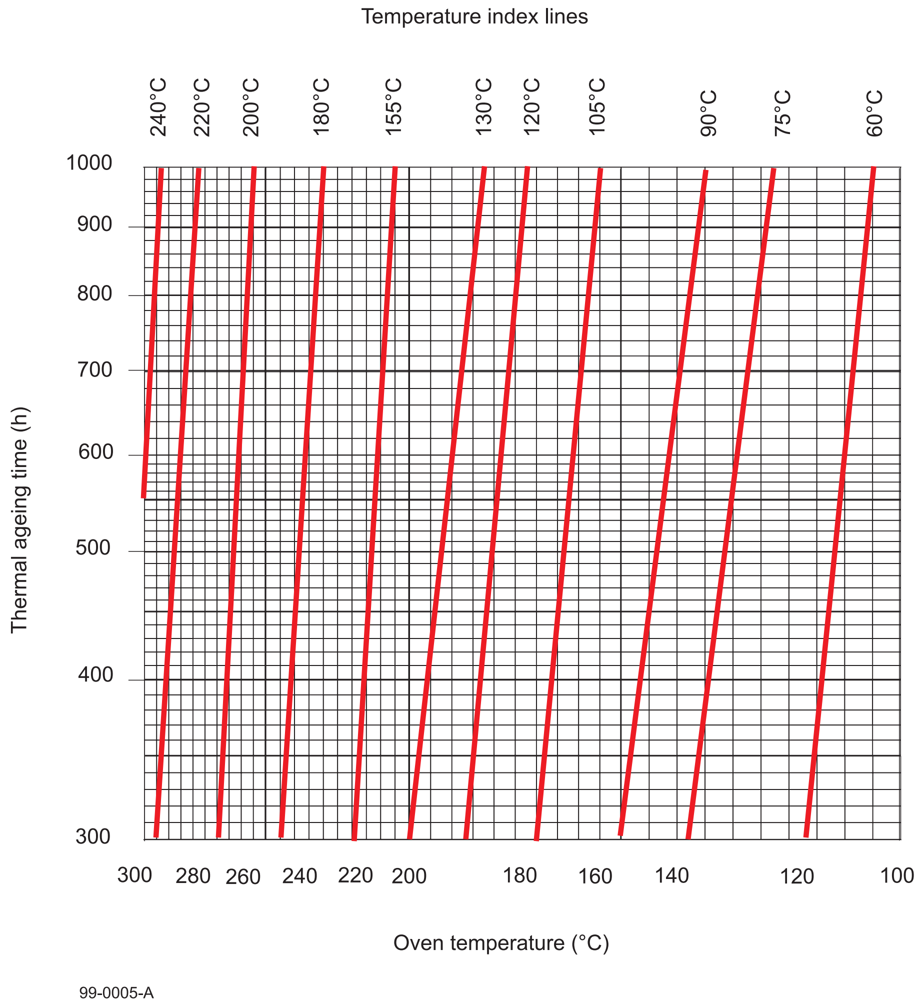


Figure 3.6 – Thermal ageing time

3.6.9.3 Electric strength test

Samples 1 and 2 are then subjected to the humidity conditioning of 3.6.13 and shall withstand the dielectric strength test of 3.6.14 between conductors.

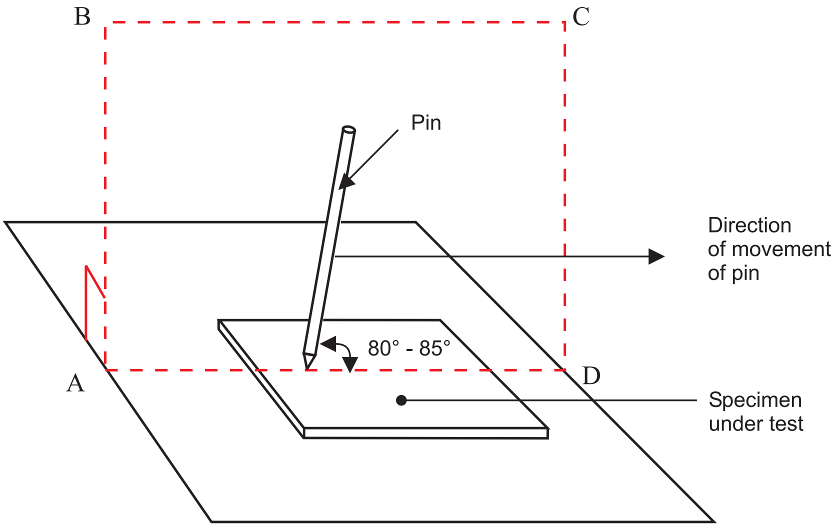
3.6.9.4 Abrasion resistance test

Sample board 3 is subjected to the following test.

Scratches are made across five pairs of conducting parts and the intervening separations at points where the separations will be subject to the maximum potential gradient during the tests.

The scratches are made by means of a hardened steel pin, the end of which has the form of a cone having a tip angle of 40°, its tip being rounded and polished, with a radius of 0,25 mm ± 0,02 mm.

Scratches are made by drawing the pin along the surface in a plane perpendicular to the conductor edges at a speed of 20 mm/s ± 5 mm/s as shown in figure 3.7. The pin is so loaded that the force exerted along its axis is 10 N ± 0,5 N. The scratches shall be at least 5 mm apart and at least 5 mm from the edge of the specimen.



NOTE
The pin is in the plane ABCD which is perpendicular to the specimen under test.

Figure 3.7 – Abrasion resistance test for coating layers

3.6.9.4.1 Compliance criteria

After the test, the coating layer shall neither have loosened nor have been pierced. The coating shall withstand a dielectric strength test as specified in 3.6.14 between conductors. In the case of metal core printed boards, the substrate is one of the conductors.

3.6.10 Thermal cycling

A sample of a component or subassembly is subjected to the following sequence of tests. For transformers, magnetic couplers and similar devices, if insulation is relied upon for safety, a voltage of 500 V r.m.s at 50 Hz to 60 Hz is applied between windings.

The sample is subjected 10 times to the following sequence of thermal cycling:

68 h	at	T_1 ± 2 °C;
1 h	at	25 °C ± 2 °C;
2 h	at	0 °C ± 2 °C;
≥ 1 h	at	25 °C ± 2 °C.

$T_1 = T_2 + T_{ma} - T_{amb} + 10$ K, measured in accordance with B.4 and, where relevant, B.6, or 85 °C, whichever is higher. However, the 10 K margin is not added if the temperature is measured by an embedded thermocouple or by the resistance method.

T_2 is the temperature of the parts measured during the test of 3.6.1.4.

The significance of T_{ma} and T_{amb} are as given in B.5.

The period of time taken for the transition from one temperature to another is not specified, but the transition is permitted to be gradual.

3.6.10.1 Compliance criteria

There shall be no evidence of insulation breakdown during this conditioning.

3.6.11 Test for Pollution Degree 1 environment and for an insulating compound

This test is conducted when it is required to verify a Pollution Degree 1 environment and when required by 3.6.4.3.

A sample is subjected to the thermal cycling sequence of 3.6.10.

It is allowed to cool to room temperature and is then subjected to the humidity conditioning of 3.6.13, followed immediately by the dielectric strength tests of 3.6.14.

The tests are followed by inspection and measurement.

3.6.11.1 Compliance criteria

There shall be no cracks in the insulating material. For compliance with 3.6.4.3, the sample is also sectioned, and there shall be no voids in the insulating material.

3.6.12 Tests for semiconductor components and for cemented joints

Three samples are subjected to the thermal cycling sequence of 3.6.10. Before testing a cemented joint, any winding of solvent-based enamelled wire used in the component is replaced by metal foil or by a few turns of bare wire, placed close to the cemented joint.

The three samples are then tested as follows:

- one of the samples is subjected to the dielectric strength test of 3.6.14, immediately after the last period at T_1 °C during thermal cycling, except that the test voltage is multiplied by 1,6;
- the other samples are subjected to the relevant electric strength test of 3.6.14 after the humidity conditioning of 3.6.13, except that the test voltage is multiplied by 1,6.

The tests are followed by inspection, including sectioning, and measurement.

3.6.12.1 Compliance criteria

There shall be no voids, gaps or cracks in the insulating material. In the case of multilayer printed boards, there shall be no delamination.

3.6.13 Humidity conditioning

The humidity conditioning is carried out for 48 h in a cabinet or room containing air with a relative humidity of 90 % to 95 %. The temperature of the air, at all places where samples can be located, is maintained within 2 °C of any value t between 20 °C and 30 °C such that condensation does not occur. During this conditioning the component or subassembly is not energized.

For tropical conditions the time duration shall be 120 h at a temperature of 40 ± 2 °C and a relative humidity of 90 % to 95 %.

Before the humidity conditioning the sample is brought to a temperature between the specified temperature t and (t + 4) °C.

3.6.14 Dielectric strength test

The insulation is subjected either to a voltage of substantially sine-wave form having a frequency of 50 Hz or 60 Hz, or to a d.c. voltage equal to the peak voltage of the prescribed a.c. test voltage.

Unless otherwise specified elsewhere in this Standard, test voltages for dielectric strength for the appropriate grade of insulation (BASIC INSULATION, SUPPLEMENTARY INSULATION or REINFORCED INSULATION) are specified in table 3.15.

The voltage applied to the insulation under test is gradually raised from zero to the prescribed voltage and held at that value for 60 s.

NOTE 1
For routine tests specified elsewhere in this Standard, it is permitted to reduce the duration of the electric strength test to 1 s.

Insulation breakdown is considered to have occurred when the current, which flows as a result of the application of the test voltage, rapidly increases in an uncontrolled manner that is, the insulation does not restrict the flow of the current. Corona discharge or a single momentary flashover is not regarded as insulation breakdown.

Insulation coatings are tested with metal foil in contact with the insulating surface. This procedure is limited to places where the insulation is likely to be weak, for example, where there are sharp metal edges under the insulation. If practicable, insulating linings are tested separately. Care is taken that the metal foil is so placed that no flashover occurs at the edges of the insulation. Where adhesive metal foil is used, the adhesive shall be conductive.

To avoid damage to components or insulation that are not involved in the test, disconnection of integrated circuits or the like and the use of equipotential bonding are permitted.

For equipment incorporating both REINFORCED INSULATION and lower grades of insulation, care is taken that the voltage applied to the REINFORCED INSULATION does not overstress BASIC INSULATION or SUPPLEMENTARY INSULATION.

NOTE 2
Where there are capacitors across the insulation under test (for example, radio-frequency filter capacitors), it is recommended that d.c. test voltages are used.
NOTE 3
Components providing a d.c. path in parallel with the insulation to be tested, such as discharge resistors for filter capacitors and voltage limiting devices, should be disconnected.

Where insulation of a transformer winding varies along the length of the winding in accordance with 3.6.1.7, an electric strength Test method is used that stresses the insulation accordingly.

NOTE 4
An example of such a Test method is an induced voltage test which is applied at a frequency sufficiently high to avoid saturation of the transformer. The input voltage is raised to a value which would induce an output voltage equal to the required test voltage.

NOTE 5
For consideration of temporary overvoltages see IEC 60664-1.

Table 3.15 – Test voltages for electric strength tests based on required withstand voltages

Required withstand voltage (kV peak)	Test voltage [2] (kV peak a.c. or d.c. [2])
≤ 0,33	0,35
≤ 0,5	0,55
≤ 0,8	0,91
≤ 1,5	1,75
≤ 2,5	2,95
≤ 4,0	4.8
≤ 6,0	7,3
≤ 8,0	9,8
≤ 12,0	14,8
≤ U [1]	1,23 x U

1) *U is any REQUIRED WITHSTAND VOLTAGE higher than 12,0 kV.*
2) *The test voltages in the table apply for BASIC INSULATION or SUPPLEMENTARY INSULATION. For REINFORCED INSULATION, the test voltages are 160 % of the values for BASIC INSULATION.*
3) *Linear Interpolation is permitted between the nearest two points.*
4) *Where routine tests for electric strength are required, the above test voltages are reduced by 20 %.*

3.6.14.1 Compliance criteria

There shall be no insulation breakdown during the test.

3.7 Components as safeguards

3.7.1 Components as principal safeguard and supplementary safeguard

For components used as a PRINCIPAL SAFEGUARD the insulation shall comply with BASIC INSULATION (see 3.5.1.1).

For components used as a SUPPLEMENTARY SAFEGUARD the insulation shall comply with SUPPLEMENTARY INSULATION (see 3.5.2.1).

Components may be used as PRINCIPAL SAFEGUARD or SUPPLEMENTARY SAFEGUARD only, if used within their ratings.

3.7.1.1 Capacitors and RC units as principal safeguard and supplementary safeguard

Capacitors and RC units shall comply with the safety requirements of IEC 60384-14:1993, subclass Y2 or Y4.

For a capacitor used as PRINCIPAL SAFEGUARD, the peak test voltage of the capacitor shall be at least equal to the REQUIRED WITHSTAND VOLTAGE.

Class X capacitors shall be used for functional purposes only and not used as PRINCIPAL SAFEGUARD.

It is permitted to use a higher grade capacitor than the one specified, as follows:

- subclass Y1 if subclass Y2 is specified;
- subclass Y1 or Y2 if subclass Y4 is specified.

3.7.1.2 Transformers as principal safeguard and supplementary safeguard

Insulation of transformers used as PRINCIPAL SAFEGUARD shall comply with BASIC INSULATION requirements (3.5.1.1) or with the safety requirements of the relevant IEC standard. Insulation of transformers used as SUPPLEMENTARY SAFEGUARD shall comply with SUPPLEMENTARY INSULATION requirements (3.5.2.1).

3.7.1.3 Optocouplers as principal safeguard and supplementary safeguard

Insulation of optocouplers used as PRINCIPAL SAFEGUARD shall comply with BASIC INSULATION requirements(3.5.1.1) or with the safety requirements of the relevant IEC standard. Insulation of optocouplers used as SUPPLEMENTARY SAFEGUARD, shall comply with SUPPLEMENTARY INSULATION requirements (3.5.2.1) or with the safety requirements of the relevant IEC standard.

3.7.1.4 Relays as principal safeguard and supplementary safeguard

Insulation of relays used as PRINCIPAL SAFEGUARD shall comply with BASIC INSULATION requirements (3.5.1.1) or with the safety requirements of the relevant IEC standard.

Insulation of relays used as SUPPLEMENTARY SAFEGUARD shall comply with SUPPLEMENTARY INSULATION requirements (3.5.2.1) or with the safety requirements of the relevant IEC standard.

3.7.1.5 Resistors as principal safeguard and supplementary safeguard

Resistors may be used as PRINCIPAL SAFEGUARD. The resistor shall comply with the requirements for BASIC INSULATION (3.5.1.1) between its terminations for the total r.m.s. WORKING VOLTAGE across the insulation.

Resistors may be used as SUPPLEMENTARY SAFEGUARD. The resistor shall comply with the requirements for SUPPLEMENTARY INSULATION (3.5.2.1) between its terminations for the total r.m.s. WORKING VOLTAGE across the insulation.

The resistor shall have an adequate stable resistance value under overload.

3.7.1.5.1 Test method

Compliance is checked by inspection by applying the following test on 10 sample resistors.

Before the test, the resistance of each sample is measured and they are then subjected to the damp heat test according to IEC 60068-2-3, severity 21 days.

Each sample is then subjected to 50 discharges from the impulse test generator reference 3 of table N.1, at not more than 12 discharges per minute, with Uc equal to 10 kV.

3.7.1.5.2 Compliance criteria

After the test, the resistance of each sample shall not have changed by more than 20 %. No failure is allowed.

3.7.1.6 VDR as principal safeguard and supplementary safeguard

It is permitted to use a VDR as a PRINCIPAL SAFEGUARD or as a SUPPLEMENTARY SAFEGUARD provided that one side of the VDR is earthed.

A VDR used as a PRINCIPAL SAFEGUARD or as a SUPPLEMENTARY SAFEGUARD shall comply with the requirements of annex G.10.

A VDR used as a PRINCIPAL SAFEGUARD shall be applied only in one of the following types of equipment:

- PLUGGABLE EQUIPMENT TYPE B; or
- PERMANENTLY CONNECTED EQUIPMENT; or
- equipment that has provision for a permanently connected PROTECTIVE EARTHING CONDUCTOR and is provided with instructions for the installation of that conductor.

3.7.1.7 Other components as principal safeguard between ES 1 and ES 2

It is permitted to use any type of component as PRINCIPAL SAFEGUARD provided that:

- two components are in series if a separation is required, or
- two components are in parallel if bonding (connection) is required

Each component shall be used within its rating.

3.7.2 Components as reinforced safeguard

For components used as a REINFORCED SAFEGUARD the insulation shall comply with REINFORCED INSULATION (see 3.5.3.1).

A component used as a REINFORCED SAFEGUARD shall be used within its rating.

3.7.2.1 Capacitors and RC units as reinforced safeguard

Capacitors and RC units used as REINFORCED INSULATION shall meet one of the following:

- a single capacitor or RC unit complying with IEC 60384-14, subclass Y1, or
- a single capacitor or RC unit complying with IEC 60384-14, subclass Y2 where the equipment rated voltage is less than 150 V with respect to neutral or earth, or
- two capacitors in series each complying with IEC 60384-14, subclass Y2 or Y4

Where two capacitors are used in series, they shall each be rated for the total working voltage across the pair and shall the same nominal capacitance value.

For a single capacitor used as REINFORCED SAFEGUARD or double SAFEGUARD, the peak test voltage of the capacitor shall be at least equal to twice the REQUIRED WITHSTAND VOLTAGE.

Class X capacitors shall be not used as a REINFORCED SAFEGUARD.

3.7.2.2 Transformers as reinforced safeguard

Transformers used as REINFORCED SAFEGUARD shall comply with the requirements of 3.6.4.8 and annex G.7.

3.7.2.3 Optocouplers as reinforced safeguard

Insulation of optocouplers used as REINFORCED SAFEGUARD or double SAFEGUARD shall comply with REINFORCED INSULATION requirements (3.5.3.1) or with the safety requirements of the relevant IEC standard.

3.7.2.4 Relays as reinforced safeguard

Insulation of relays used as REINFORCED SAFEGUARD or double SAFEGUARD shall comply with REINFORCED INSULATION requirements (3.5.3.1) or with the safety requirements of the relevant IEC standard.

3.7.2.5 Resistors as reinforced safeguard

Resistors may be used as REINFORCED SAFEGUARD.

Each resistor shall comply with the requirements for BASIC INSULATION (3.5.1.1) or SUPPLEMENTARY INSULATION (3.5.2.1), as applicable, between their terminations, for the total r.m.s. WORKING VOLTAGE across the insulation.

Additionally,

- if two resistors are used in series, they shall have the same nominal resistance value.
- If a single resistor is used, it shall pass the test given below.

3.7.2.5.1 Test method

Compliance is checked by inspection and, if a single resistor is used, by applying the following test on 10 sample resistors.

Before the test, the resistance of each sample is measured and they are then subjected to the damp heat test according to IEC 60068-2-3, severity 21 days.

Each sample is then subjected to 50 discharges from the impulse test generator reference 3 of table D.1, at not more than 12 discharges per minute, with Uc equal to 10 kV.

3.7.2.5.2 Compliance criteria

After the test, the resistance of each sample shall not have changed by more than 20 %. No failure is allowed.

3.8 Protective conductor

3.8.1 Generic requirements

PROTECTIVE CONDUCTORS and their terminations shall not have excessive resistance.

PROTECTIVE CONDUCTORS shall have sufficient current-carrying capacity. The current carrying capacity shall be adequate for the actual current under NORMAL CONDITION, and under ABNORMAL CONDITION.

PROTECTIVE CONDUCTORS shall not contain switches or overcurrent protective devices.

Protective bonding connections shall be such that disconnection (e.g. for servicing) of a PROTECTIVE CONDUCTOR at one point in a unit or a system does not break the protective bonding connection to other parts or units in a system, unless the relevant hazard is removed at the same time.

Protective bonding connections shall make earlier and break later than the supply connections in each of the following:

- the connector of a part that can be removed by an ORDINARY PERSON;
- a plug on a power supply cord;
- an appliance coupler.

Conductive parts in contact at protective bonding terminals and connections shall not be subject to significant corrosion due to electrochemical action in any working, storage or transport environment conditions as specified in the instructions supplied with the equipment.

3.8.1.1 Test method

Compliance is checked by inspection and, where required, by measurement.

3.8.2 Colour of insulation

The insulation of the PROTECTIVE EARTHING CONDUCTOR shall be green-and-yellow.

If a PROTECTIVE BONDING CONDUCTOR is insulated, the insulation shall be green-and-yellow except in the following two cases:

- for an earthing braid, the insulation may be transparent;
- PROTECTIVE BONDING CONDUCTOR in assemblies such as ribbon cables, bus bars, printed wiring, etc., any colour is permitted provided that no misinterpretation of the use of the conductor is likely to arise.

3.8.2.1 Test method

Compliance is checked by inspection.

3.8.3 Protective conductors as principal safeguard between ES 1 and ES 2

3.8.3.1 Low current carrying protective conductors

PROTECTIVE CONDUCTORS may serve as PRINCIPAL SAFEGUARD:

- for parts receiving its power from an EXTERNAL CIRCUIT,
- to limit transients that might effect insulation provided parts connected to the PROTECTIVE BONDING CONDUCTOR could not reach an ES 3 level during ABNORMAL CONDITION,
- to limit touch current to an EXTERNAL CIRCUIT.

The requirements of 3.8.1 and 3.8.2 apply.

For parts receiving its power from an EXTERNAL CIRCUIT, the test current is 1,5 times the maximum current available from that EXTERNAL CIRCUIT (if known) or 2 A, whichever is greater.

3.8.3.1.1 Test method

Compliance is checked by inspection and if necessary by the following test.

The voltage drop in a PROTECTIVE CONDUCTOR is measured after conducting the test current for the time period specified below. The test current can be either a.c. or d.c. and the test voltage shall not exceed 12 V. The measurement is made between the main protective earthing terminal and the point in the equipment that is required to be earthed.

3.8.3.2 Fault current carrying protective conductors

PROTECTIVE CONDUCTORS may serve as PRINCIPAL SAFEGUARD.

- for accessible conductive parts not assuming an ES 3 level during ABNORMAL CONDITION,
- to maintain the integrity of parts at ES 1 level during NORMAL CONDITION provided that parts do not reach an ES 3 level during ABNORMAL CONDITION,
- to maintain the integrity of parts at ES 2 level during NORMAL CONDITION provided that parts do not reach an ES 3 level during ABNORMAL CONDITION,

The size of the PROTECTIVE EARTHING CONDUCTORS shall comply with 3.8.4.1 and for PROTECTIVE BONDING CONDUCTORS with 3.8.4.2.

3.8.3.2.1 Test method

See Test method of 3.8.4.1; 3.8.4.2 and 3.8.4.3.

3.8.4 Protective conductors as supplementary safeguard

Protective conductors may serve as SUPPLEMENTARY SAFEGUARD:

- for parts that might assume an ES 3 level during ABNORMAL CONDITION, or
- to limit transients that might effect insulation for parts that could not assume an ES 3 level during ABNORMAL CONDITION, or
- to limit touch current to an EXTERNAL CIRCUIT.

3.8.4.1 Size of protective earthing conductors

PROTECTIVE EARTHING CONDUCTORS shall comply with the minimum conductor sizes in table 3.15.

3.8.4.1.1 Test method

Compliance is checked by inspection and measurement.

Table 3.16 – Sizes of conductors

Rated current of equipment A	Minimum conductor sizes: Nominal cross-sectional area mm2	Minimum conductor sizes: AWG or kcmil [cross-sectional area in mm2] see note 2
≤ 6	0,75 1)	18 [0,8]
> 6 ≤ 10	(0,75) 2) 1	16 [1,3]
> 10 ≤ 16	(1,0) 3) 1,5	14 [2]
> 16 ≤ 25	2,5	12 [3]
> 25 ≤ 32	4	10 [5]
> 32 ≤ 40	6	8 [8]
> 40 ≤ 63	10	6 [13]
> 63 ≤ 80	16	4 [21]
> 80 ≤ 100	25	2 [33]
> 100 ≤ 125	35	1 [42]
> 125 ≤ 160	50	0 [53]
> 160 ≤ 190	70	000 [85]
> 190 ≤ 230	95	0000 [107]
> 230 ≤ 260	120	250 kcmil [126]
> 260 ≤ 300	150	300 kcmil [152]
> 300 ≤ 340	185	400 kcmil [202]
> 340 ≤ 400	240	500 kcmil [253]
> 400 ≤ 460	300	600 kcmil [304]

1) For rated current up to 3 A, a nominal cross-sectional area of 0,5 mm^2 is permitted in some countries provided that the length of the cord does not exceed 2 m.

2) The value in parentheses applies to detachable power supply cords fitted with the connectors rated 10 A in accordance with IEC 60320 (types C13, C15, C15A and C17) provided that the length of the cord does not exceed 2 m.

3) The value in parentheses applies to detachable power supply cords fitted with the connectors rated 16 A in accordance with IEC 60320 (types C19, C21 and C23) provided that the length of the cord does not exceed 2 m.

NOTE 1
IEC 60320 specifies acceptable combinations of appliance couplers and flexible cords, including those covered by items 1), 2) and 3). However, a number of countries have indicated that they do not accept all of the values listed in table 3B, particularly those covered by items 1), 2) and 3).

NOTE 2
AWG and kcmil sizes are provided for information only. The associated cross-sectional areas, in square brackets, have been rounded to show significant figures only. AWG refers to the American Wire Gage and the term "cmil" refers to circular mils where one circular mil is equal to the area of a circle having a diameter of one mil (one thousandth of an inch). These terms are commonly used to designate wire sizes in North America.

3.8.4.2 Size of protective bonding conductors

PROTECTIVE BONDING CONDUCTORS shall comply with one of the following:

- the minimum conductor sizes in table 3.16; or
- the requirements of 3.8.4.3 and also, if the current rating of the circuit is more than 16 A, with the minimum conductor sizes in table 3.17; or
- for components only, be not smaller than the conductors supplying power to the component.

The current rating of the circuit used in table 3.17 and in the test of 3.8.4.3 depends on the provision of overcurrent protective devices and shall be taken as the smaller of a) or b) as follows:

a) The rating of an overcurrent protective device specified in the equipment installation instructions to be installed in the building installation wiring to protect the equipment.

b) The rating of an overcurrent protective device in the equipment that protects the circuit or part required to be earthed.

For PLUGGABLE EQUIPMENT TYPE A, and if neither a) nor b) is applicable, the current rating of the circuit shall be taken as the rated current of the equipment or 16 A, whichever is greater.

3.8.4.2.1 Test method

Compliance is checked by inspection and measurement.

Table 3.17 – Minimum size of protective bonding conductors

Current rating of the circuit under consideration A	Minimum conductor sizes cross-sectional area mm^2	AWG or kcmil [cross-sectional area in mm^2]
≤ 16	Size not specified	Size not specified
> 16 ≤ 25	1,5	14 [2]
> 25 ≤ 32	2,5	12 [3]
> 32 ≤ 40	4,0	10 [5]
> 40 ≤ 63	6,0	8 [8]
> 63 ≤ 80	10	6 [13]
> 80 ≤ 100	16	4 [21]
> 100 ≤ 125	25	2 [33]
> 125 ≤ 160	35	1 [42]
> 160 ≤ 190	50	0 [53]
> 190 ≤ 230	70	000 [85]
> 230 ≤ 260	95	0000 [107]
> 260 ≤ 300	120	250 kcmil [126]
> 300 ≤ 340	150	300 kcmil [152]
> 340 ≤ 400	185	400 kcmil [202]
> 400 ≤ 460	240	500 kcmil [253]

NOTE
WG and kcmil sizes are provided for information only. The associated cross-sectional areas have been rounded to show significant figures only. AWG refers to the American Wire Gage and the term "cmil" refers to circular mils where one circular mil is equal to the area of a circle having a diameter of one mil (one thousandth of an inch). These terms are commonly used to designate wire sizes in North America.

3.8.4.3 Resistance of protective conductors and their terminations

PROTECTIVE CONDUCTORS and their terminations shall not have excessive resistance.

PROTECTIVE CONDUCTORS that meet the minimum conductor sizes in table 3.16 or table 3.17 throughout their length and whose terminals all meet the minimum sizes in table 3.18 are considered to comply without test.

Table 3.18 – Sizes of terminals for protective conductors

Rated current of equipment A	Minimum nominal thread diameter (mm) Pillar type or stud type	Screw type 1)
≤ 10	3,0	3,5
> 10 ≤ 16	3,5	4,0
> 16 ≤ 25	4,0	5,0
> 25 ≤ 32	4,0	5,0
> 32 ≤ 40	5,0	5,0
> 40 ≤ 63	6,0	6,0

1) "Screw type" refers to a terminal that clamps the conductor under the head of a screw, with or without a washer.

3.8.4.3.1 Test method

Compliance is checked by inspection, measurement and, for PROTECTIVE BONDING CONDUCTORS that do not meet the minimum conductor sizes in table 3.17 throughout their length or whose terminals do not all meet the minimum sizes in table 3.18 by the following test.

The voltage drop in a PROTECTIVE BONDING CONDUCTOR is measured after conducting the test current for the time period specified below. The test current can be either a.c. or d.c. and the test voltage shall not exceed 12 V. The measurement is made between the main protective earthing terminal and the point in the equipment that is required to be earthed. The resistance of the PROTECTIVE EARTHING CONDUCTOR is not included in the measurement. However, if the PROTECTIVE EARTHING CONDUCTOR is supplied with the equipment, it is permitted to include the conductor in the test circuit but the measurement of the voltage drop is made only from the main protective earthing terminal to the part required to be earthed.

On equipment where the protective earth connection to a subassembly or to a separate unit is by means of one core of a multicore cable which also supplies power to that subassembly or unit, the resistance of the PROTECTIVE BONDING CONDUCTOR in that cable is not included in the measurement. However, this option is only permitted if the cable is protected by a suitably rated protective device that takes into account the size of the conductor.

Care is taken that the contact resistance between the tip of the measuring probe and the conductive part under test does not influence the test results.

The test current, duration of the test and test results are as follows:

- if the current rating of the circuit under test is 16 A or less, the test current is 1,5 times the current rating of the circuit under test, the current is applied for 60 s and the resistance of the PROTECTIVE BONDING CONDUCTOR, calculated from the voltage drop, shall not exceed 0,1 Ω;
- if the current rating of the circuit under test exceeds 16 A:
  - for a.c. powered equipment, the test current is two times the current rating of the circuit under test, the current is applied for 2 min and the voltage drop across the PROTECTIVE BONDING CONDUCTOR shall not exceed 2,5 V;
  - for d.c. powered equipment the test current and duration are as specified by the manufacturer and the voltage drop across the PROTECTIVE BONDING CONDUCTOR shall not exceed 2,5 V.

3.8.5 Protective conductors as reinforced safeguard

PROTECTIVE CONDUCTORS may serve as REINFORCED SAFEGUARD, provided all of the following are met:

- the requirements of 3.8.1 and 3.8.2 apply; and
- the PROTECTIVE CONDUCTOR shall comply with the minimum conductor sizes in table 3.16; and
- the minimum conductor size shall not less than $10mm^2$ to avoid mechanical damage; and
- the PROTECTIVE CONDUCTOR shall be permanently connected.

3.8.5.1 Test method

Compliance is checked by inspection and measurement.

4 Fire hazards

Electrically-caused fire is electrical heating followed by ignition. Such risk of ignition may result from excessive fuel temperature resulting from overload, component failure, loose connection, arcing, etc.

The probability for fire originating from within the equipment and spreading beyond the immediate vicinity of the source of fire, or causing damage to the surroundings of the equipment shall be minimised.

A simplified list of methods related to protection against fire hazards is described in table 4.1 and the relation of the subclauses is given in figure 4.1.

4.1 Power sources and potential ignition sources

4.1.1 Electric power source classification and circuits

For the purposes of this Standard, electric power sources are classified as PS 1, PS 2, or PS 3.

Electric circuits are also classified as PS 1, PS 2, or PS 3 circuits depending on the type of power source feeding electrical power to them.

Arcing components with unenclosed contacts, such as open switch and relay contacts and commutators are subject to the requirements of PS 3 circuits.

NOTE
A power source may be an identifiable power supply, or a functional circuit which serves as a power source to another circuit.

4.1.1.1 Power source class PS 1

Power source class PS 1 is a power source that does not exceed 100 W until 1 s and 15 W thereafter:

- with normal power source, into any value of resistive load, or
- with single fault in the power source, into the load under normal conditions.

4.1.1.1.1 Measurement for power source PS 1 classification

Connect an adjustable resistive load via a switch or similar means to the power source and adjust the load for maximum power dissipation.

After the worst-case resistance is found, change from the resistive load to the nominal load and allow the power source to stabilize.

Connect the worst-case resistive load again to the power source by using the switch or similar means and measure the power dissipation in the resistive load.

Read the maximum power value which occurs before and after 1 s after the worst-case load is applied.

Under normal resistive load introduce faults in the source circuit and read the maximum power value which occurs before and after 1 s.

4.1.1.2 Power source class PS 2

Power source class PS 2 is a power source that does not exceed LPS limits as detailed in annex S.

4.1.1.2.1 Measurement for power source PS 2 classification

For power source class PS 2 see annex S.

4.1.1.3 Power source class PS 3

Power source class PS 3 exceeds LPS limits.

Any power source or circuit may be classified as PS 3 without measurement.

4.1.2 Potential ignition sources

4.1.2.1 Potential ignition source 1

For a POTENTIAL IGNITION SOURCE 1, the open circuit voltage measured across an interruption or faulty contact exceeds 50 V (peak) a.c. or d.c. and the product of the peak of this voltage and the measured r.m.s. current under NORMAL CONDITION exceeds 15 W.

NOTE
An electronic protection circuit or additional constructional measures may be used to prevent such a fault from becoming a potential ignition source 1.

Such a faulty contact or interruption in an electric connection includes those which may occur in conductive patterns on printed boards.

4.1.2.2 Potential ignition source 2

A POTENTIAL IGNITION SOURCE 2 is supplied from a power source above 15 W and:

- under fault condition dissipates 15 W or more and may ignite, or
- ignites when subjected to fault conditions.

Table 4.1 – Fire hazards

Cause of hazard	Clause	Prevention/protection methods
Start of fire under NORMAL CONDITION	4.2	• Limit temperature of combustible materials • Provide distance to arcing components
Fire hazards under ABNORMAL CONDITION	4.3	• Select method 1 or 2
PS 1 circuit; method 1	4.3.2	• Low available power prevents ignition
PS 2 circuit; method 1	4.3.3	• Provide sufficient distance or solid barrier between any combustible material and potential ignition sources 1 and 2 • Use adequate materials • Limit available power
PS 3 circuit; method 1	4.3.4	• Use fire containing enclosures • Use adequate materials
PS 1 circuit; method 2	4.3.5	• Low available power prevents ignition
PS 2 or PS 3 circuit; method 2	4.3.6	• Prevent ignition • Provide sufficient distance or solid barrier between any combustible material and potential ignition source 1 • Use of protection devices
Bad connection in MAINS wiring	4.3.7	• Reliable construction
Bad connection in d.c. power distribution system wiring	4.3.8	• Reliable construction
Fire or explosion due to the presence of flammable liquids, gases, vapours, solids and a source of ignition	4.4	• Use alternate substances that are less flammable • Isolate the flammable substances from sources of ignition • Provide ventilation to reduce vapour concentration • Provide warnings of possible hazards
Fire or explosion due to ABNORMAL CONDITION of batteries	4.5	• Limit charge/discharge currents • Limit short circuit currents • Prevent use of wrong polarity
Fire due to entering of foreign objects and subsequent bridging of poles in PS 2 and PS 3 circuits	4.6	• Prevent entry of foreign objects

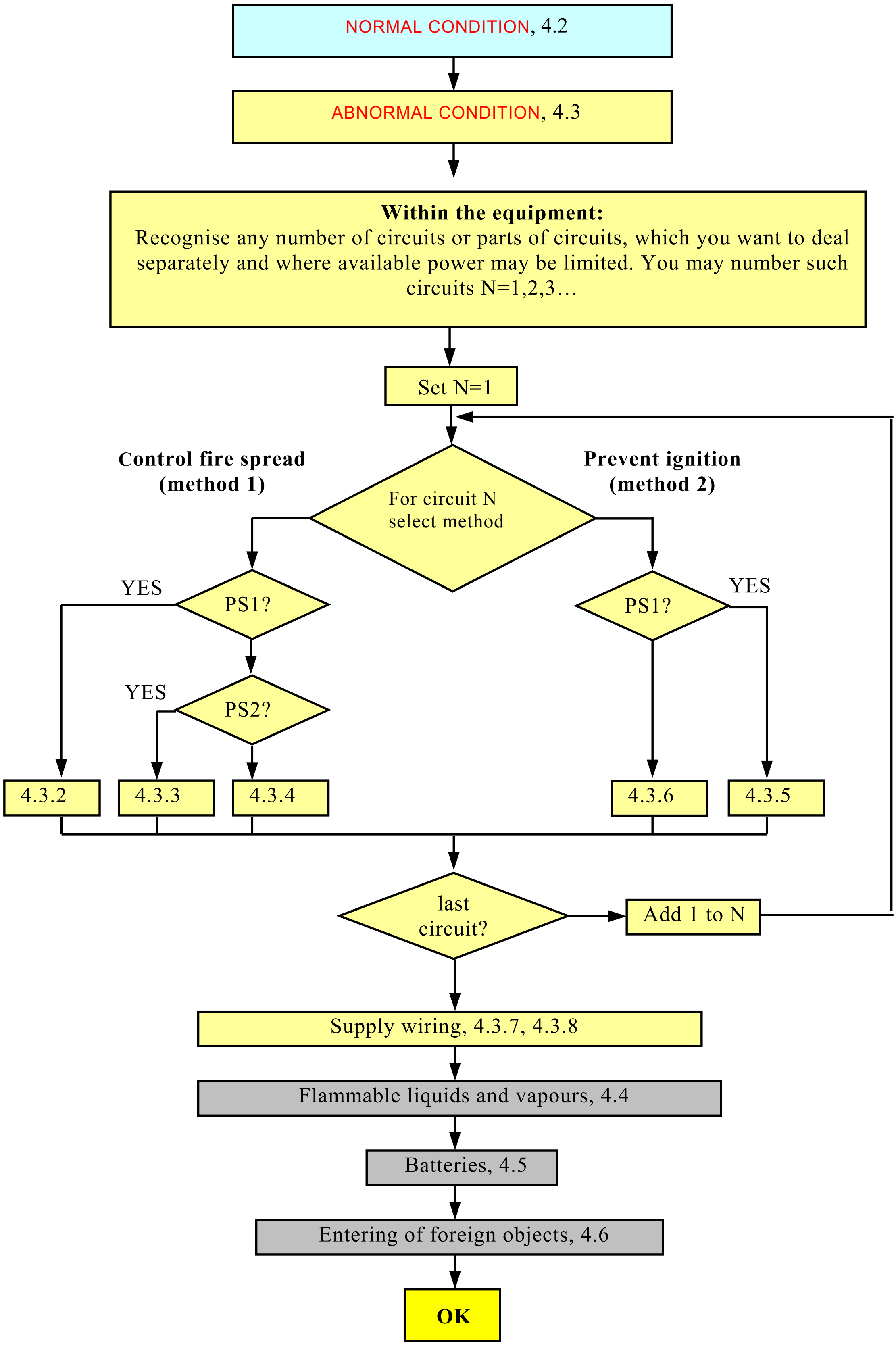


Figure 4.1 – Fire clause flow chart.

4.2 Fire hazards under normal condition

4.2.1 Requirements

Ignition shall not occur under NORMAL CONDITION. Where material is used to prevent ignition, it shall not exceed its rated temperature.

Plastic materials of a FIRE ENCLOSURE shall be located more than 13 mm through air from arcing parts such as unenclosed commutators and unenclosed switch contacts.

Plastic materials of a FIRE ENCLOSURE located less than 13 mm through air from non-arcing parts which, under NORMAL CONDITIONS could attain a temperature sufficient to ignite the material, shall have an average time to ignition, determined according to IEC 60695-2-20, of not less than 15 s.

Safety devices are not bypassed.

4.2.2 Test method

Compliance is checked by test under NORMAL CONDITIONS which result in maximum temperatures. Where materials are used to prevent ignition the material temperature is measured and compared with the allowed limits. Safety devices shall be inspected to determine if they operate during the test.

Compliance is checked by inspection of the equipment, and material data sheets and, if necessary, by the appropriate test or tests in annex U.

4.3 Fire hazards under abnormal conditions

For equipment or part of equipment there are two methods of providing protection against ignition and spread of fire under abnormal conditions.

- **Method 1**: Selection and application of components, wiring and materials which reduce the spread of flame and, where necessary, by the use of a FIRE ENCLOSURE. The appropriate requirements are detailed in 4.3.2, 4.3.3 and 4.3.4.
- **Method 2**: Equipment is so designed that under abnormal conditions no part shall ignite. The appropriate requirements and tests are detailed in 4.3.5 and 4.3.6.

Different circuits of the equipment may employ different methods.

Table 4.2 – Methods of protection against fire

Method 1 Constructional requirements		Method 2 Fault simulation	
PS 1	4.3.2	PS1	4.3.5
PS 2	4.3.3	PS 2 and PS 3	4.3.6
PS 3	4.3.4		

4.3.2 Method 1: prevention of a fire hazard under abnormal condition in PS 1 circuits

A PS 1 circuit does not require a SAFEGUARD.

4.3.3 Method 1: prevention of a fire hazard under abnormal condition in PS 2 circuits

4.3.3.1 Requirements

A PS 2 circuit shall

- be considered as a PS 3 circuit, or
- be subjected to method 2, or
- comply to all the following conditions:
  - All components shall be mounted on material of flammability category V-1 or better;
  - Wiring insulated with flame retardant material complying to IEC 60331 and IEC 60332. Examples are TFE, PTFE, FEP, neoprene, polyamide or flame retardant PVC,
  - Connectors shall comply with one of the following:
    + be made of material of flammability class V-2 or better;

  + comply with the flammability requirements of the relevant IEC component standard;
  + be mounted on material of flammability class V-1 and be of a small size.

- Materials for components and parts shall be of flammability class HB or better. This requirement does not apply to any of the following:
  + materials and components within an enclosure of 0,06 m^3 or less, consisting totally of metal and having no ventilation openings;
  + meter cases, meter faces and indicator lamps or jewels;
  + components meeting the flammability requirements of a relevant IEC component standard which includes such requirements;
  + electronic components, such as integrated circuit packages with a volume not exceeding 1 750 mm^3 if such components are mounted on a material of flammability category V-1 or better;
  + individual clamps (not including helical wraps or other continuous forms), lacing tape, twine and cable ties used with wiring harnesses;
  + gears, cams, belts, bearings and other small parts which would contribute negligible fuel to fire;
  + supplies, consumable materials, media and recording materials;
  + parts which are required to have particular properties in order to perform intended functions, such as synthetic rubber rollers and ink tubes.

- For POTENTIAL IGNITION SOURCES the requirements of annex T apply.

- Motors and transformers shall comply with annex G.

4.3.3.2 Test method

Compliance is checked by inspection of the equipment and material data sheets and, if necessary, by applying annex T and annex U.

4.3.4 Method 1: prevention of a fire hazard under abnormal condition in a PS 3 circuit

A FIRE ENCLOSURE, appropriate use of materials and suitable construction shall be used to limit the risk of ignition and spread of flame both within the PS 3 circuit and to the outside.

4.3.4.1 Parts requiring a fire enclosure

Parts and components in PS 3 circuits shall be provided with a FIRE ENCLOSURE, except as otherwise required by in 4.3.4.2.

4.3.4.2 Parts not requiring a fire enclosure

The following parts in PS 3 circuits do not require a FIRE ENCLOSURE:

- wiring insulated with flame retardant material complying to IEC 60331 and IEC 60332. Examples are TFE, PTFE, PEP, neoprene, polyamide or flame retardant PVC;
- components, including connectors, that meet the requirements of 4.3.4.3, and fill an opening in a FIRE ENCLOSURE;
- plugs and connectors forming part of a power supply cord or interconnecting cable;
- motors and transformers complying with annex G.

4.3.4.3 Fire enclosures and fire barrier material properties

FIRE ENCLOSURE and fire barrier material shall be flame-retardant.

The FIRE ENCLOSURE and fire barrier material properties may be tested, or the FIRE ENCLOSURE and fire barrier material properties shall comply with the constructional requirements.

The material of a FIRE ENCLOSURE in the thinnest significant wall thickness used shall be of a flammability class V-0 or better.

Material for components which fill an opening in a FIRE ENCLOSURE or which are intended to be mounted in such opening shall:

- be of flammability class V-0; or
- comply with the flammability requirements of the relevant IEC component standard.

4.3.4.3.1 Test method

Compliance is checked by inspection of the equipment and material data sheets and, if necessary, by applying annex U.

4.3.4.4 Components and parts inside a fire enclosure

The distance through air from arcing parts to a non-metallic FIRE ENCLOSURE shall be not less than 13 mm.

Plastic materials of a FIRE ENCLOSURE located less than 13 mm through air from non-arcing parts which, under ABNORMAL CONDITION could attain a temperature sufficient to ignite the material, shall have an average time to ignition, determined according to IEC 60695-2-20, of not less than 15 s.

The distance through air from a POTENTIAL IGNITION SOURCE 2, which is inside a non-metallic FIRE ENCLOSURE, to this FIRE ENCLOSURE shall not be less than 5 mm.

Inside a fire enclosure, materials for components and parts shall comply with one of the following:

- be of flammability class V-2 or better;
- pass the flammability test of annex U.2, or
- meet the flammability requirements of a relevant IEC component standard which includes such requirements.

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

- materials and components within an enclosure of 0,06 m^3 or less, consisting totally of metal and having no ventilation openings;
- one or more layers of thin insulating material, such as adhesive tape, used directly on any surface within a fire enclosure, provided that the combination of the thin insulating material and the surface of application complies with the requirements of flammability class V-2;
- meter cases, meter faces and indicator lamps or jewels;
- wiring insulated with flame retardant material complying to IEC 60331 and IEC 60332. Examples are TFE, PTFE, PEP, neoprene, polyamide or flame retardant PVC;
- electronic components, such as integrated circuit packages with a volume not exceeding 1750 mm^3 if such components are mounted on a material of flammability category V-1 or better;
- individual clamps (not including helical wraps or other continuous forms), lacing tape, twine and cable ties used with wiring harnesses;
- the following parts, provided that they are separated from electrical parts (other than insulated wires and cables) which under fault conditions are likely to produce a temperature that could cause ignition, by at least 13 mm of air or by a solid barrier of material of flammability class V-1:
  - gears, cams, belts, bearings and other small parts which would contribute negligible fuel to a fire, including, labels, mounting feet, key caps, knobs and the like;
  - supplies, consumable materials, media and recording materials;
  - parts which are required to have particular properties in order to perform intended functions, such as rubber rollers for paper pick-up and delivery, and ink tubes;
  - tubing for air or any fluid systems, containers for powders or liquids and foamed plastic parts, provided that they are of flammability class HB75 if the thinnest significant thickness of the material is < 3 mm, or flammability class HB40 if the thinnest significant thickness of the material is ≥ 3 mm, or flammability class HBF.

4.3.4.4.1 Test method

Compliance is checked by inspection of the equipment and material data sheets and, if necessary, by applying annex U.

4.3.4.5 Constructional requirements for a fire enclosure and a fire barrier

The safeguard function of the FIRE ENCLOSURE and the fire barrier is to impede the spread of fire through the enclosure or barrier.

NOTE
The FIRE ENCLOSURE may be the overall enclosure, or it may be within the overall enclosure. The FIRE ENCLOSURE need not have an exclusive function, but may provide other functions in addition to that of a FIRE ENCLOSURE.

4.3.4.5.1 Fire enclosure and fire barrier openings

Openings in a FIRE ENCLOSURE or in a fire barrier shall be of such dimensions that fire and products of combustion passing through the openings are not likely to ignite material on the outside of the enclosure or on the side of a fire barrier opposite the potential ignition source.

The openings to which these properties apply are relative to the site or location of the potential ignition source. The locations of openings relative to the flame property are shown in figures 4.2 and 4.3.

Regardless of the equipment orientation, the flame orientation property of the potential ignition source is always vertical. Where the equipment has alternate normal-condition orientations, opening properties apply to each alternate orientation.

4.3.4.5.2 Top openings and top opening properties

Top opening properties of a fire enclosure apply to openings above a potential ignition source and above non-flame-retardant materials. Top opening properties of a fire barrier apply to openings above a potential ignition source.

Top openings are those openings

1. between 0 mm and 50 mm above the horizontal plane of the potential ignition source or highest point of non-flame-retardant material within an inverse conical section of 50 mm diameter at 0 mm tapering to 25 mm diameter at 50 mm.
2. between 50 mm and 100 mm above the horizontal plane of the potential ignition source or highest point of non-flame-retardant material within a cylinder of 25 mm diameter.

Top openings shall comply with one of the following:

- not exceed 3 mm in any dimension, or 1 mm width regardless of length, or .
- pass the following test:
  In a draft-free location, the top openings are located 5 mm ± 1 mm below the tip of a 50 mm non-pre-mixed butane test flame. The position of both the top openings and the flame are fixed. The top openings are covered with a single layer of cheesecloth.

  The flame is applied for a period of 1 min.

  The cheesecloth shall not ignite.

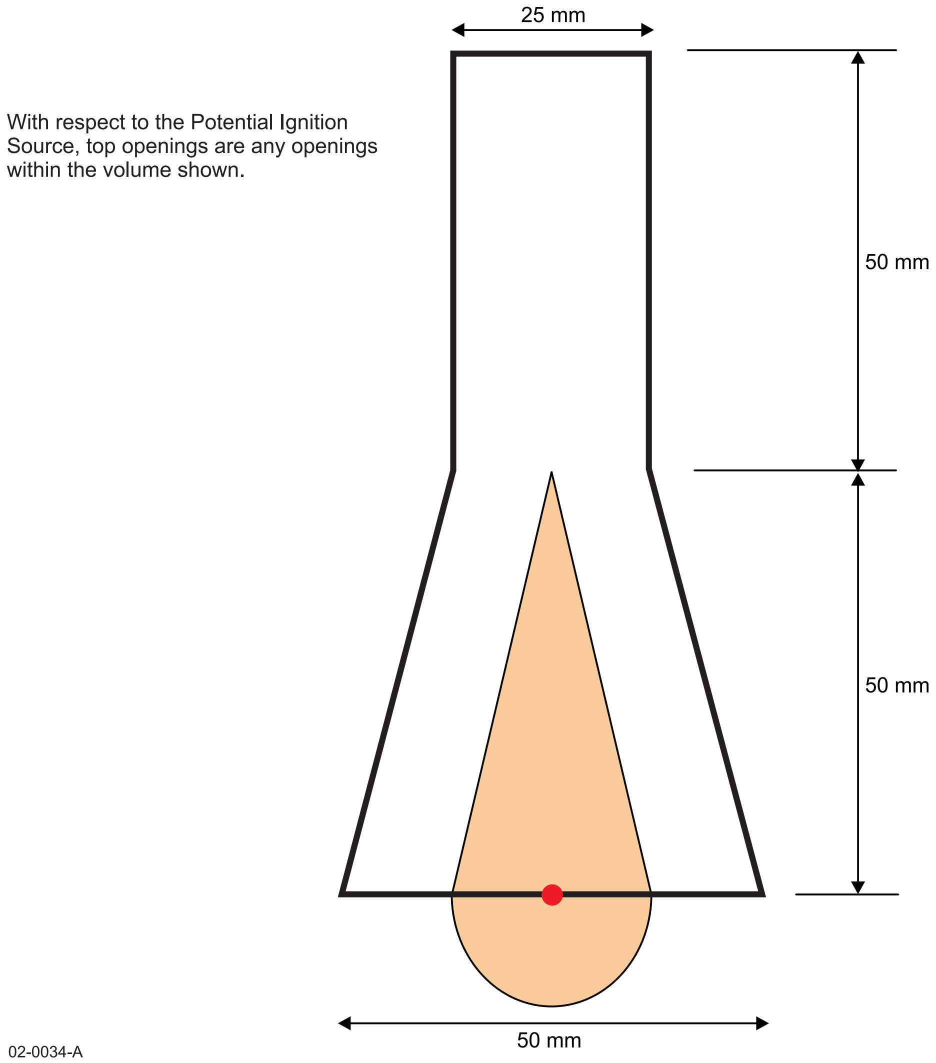


Figure 4.2 – Top Openings

4.3.4.5.3 Bottom openings and bottom opening properties

Bottom openings properties of a FIRE ENCLOSURE apply to openings below both a potential ignition source and non-flame-retardant materials. Bottom opening properties of a fire barrier apply to openings below a potential ignition source.

Bottom openings are those openings below a potential ignition source and within 50 mm diameter cylinder extending indefinitely below the potential ignition source.

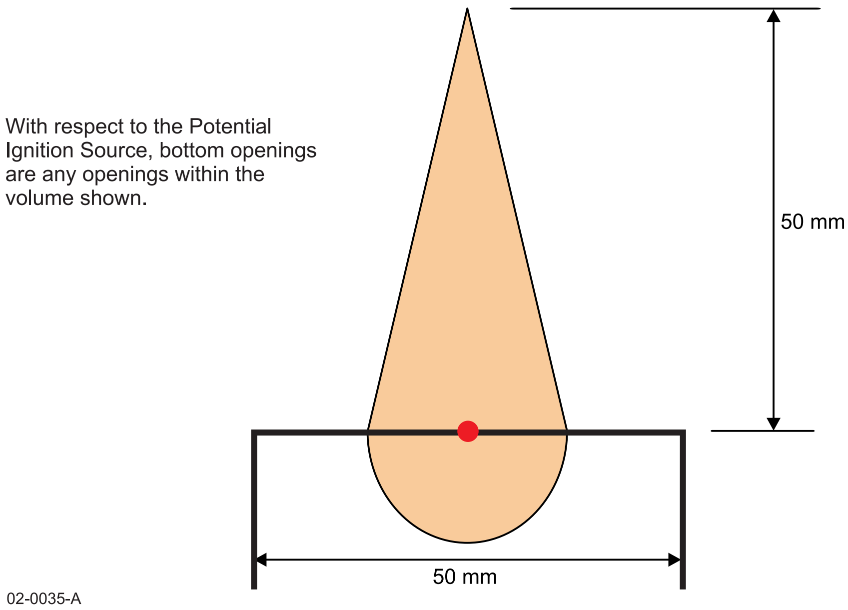


Figure 4.3 – Bottom openings

Bottom openings shall comply with one of the following:

1. Where the products of combustion are low viscosity, bottom openings shall not exceed:
   6 mm in any dimension, or
   2 mm width regardless of length.
2. Where the products of combustion are high viscosity, bottom openings shall not exceed:
   12 mm in any dimension, or
   4 mm width regardless of length.
3. The bottom shall be of metal, where the opening size, distance between openings, and thickness of the metal do not exceed the values in table 4.3.
4. Pass the test of annex U.2.

Table 4.3 – Size and spacing of holes in metal bottoms of fire enclosures

Metal bottom minimum thickness	Circular holes		Other shaped openings	
	Maximum diameter of holes	Minimum spacing of holes centre to centre	Maximum area	Minimum spacing of openings border to border
mm	mm	mm	mm^2	mm
0,66	1,1	1,7	1,1	0,56
0,66	1,2	2,4	1,2	1,1
0,76	1,1	1,7	1,1	0,55
0,76	1,2	2,4	1,2	1,1
0,81	1,9	3,2	2,9	1,1
0,89	1,9	3,2	2,9	1,2
0,91	1,6	2,8	2,1	1,1
0,91	2,0	3,2	3,1	1,2
1,0	1,6	2,8	2,1	1,1
1,0	2,0	3,0	3,2	1,0

Equipment intended only for use in fixed installations and intended to be mounted on a non-combustible surface need not be provided with a FIRE ENCLOSURE bottom. Such equipment shall be marked as follows:

SUITABLE FOR MOUNTING ON CONCRETE
OR OTHER NON-COMBUSTIBLE SURFACE ONLY

4.3.4.5.4 Integrity of the fire enclosure

If part of a FIRE ENCLOSURE consists of a door or cover which can be opened by an ORDINARY PERSON, the door or cover shall comply with requirements a), b), or c):

a) the door or cover shall be interlocked and comply with the interlock requirements in annex L;

b) a door or cover, intended to be routinely opened by the ORDINARY PERSON, shall comply with both of the following conditions:
- it shall not be removable from other parts of the FIRE ENCLOSURE by the ORDINARY PERSON; and
- it shall be provided with a means to keep it closed during normal operation;

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

4.3.4.5.5 Test method

Compliance is checked by inspection of the equipment and material data sheets and, if necessary, by applying annex U.

4.3.5 Method 2: prevention of a fire hazard under abnormal condition in PS 1 circuits

No safeguards are required for PS 1 circuits.

4.3.6 Method 2: prevention of a fire hazard under abnormal condition in PS 2 and PS 3 circuits

4.3.6.1 Requirements

Equipment shall be so designed that under ABNORMAL CONDITION no part shall ignite. For the purpose of this method, ignition is not considered if it does not sustain beyond 3 s and there is no spread of fire to any other part. Spread of fire is considered to exist when the flame of one part ignites another part, regardless of the duration of time.

Ignition is minimized by:

- limiting material temperatures as detailed in table 4.4;
- separation from POTENTIAL IGNITION SOURCES 1;
- reliable protective devices, complying with annex G.2 – G.5;
- components associated with the MAINS, such as the supply cord, appliance couplers, EMC filtering components, switches, shall comply with the relevant IEC component standards and requirements of other parts of this Standard.

Conductors of printed wiring board of flammability rating V-1 or better may open under overload condition and shall not be used as fuses. Bridging of the interrupted conductor shall not create an unsafe situation.

Table 4.4 – Temperature limits

Parts of the equipment	Maximum temperature (T_{max}) °C
a) General	
– natural rubber	135
– thermoplastic materials	[b]
– non-impregnated paper	105
– non-impregnated cardboard	115
– impregnated cotton, silk, paper and textile	125
– laminates based on cellulose or textile, bonded with	
– phenol-formaldehyde, melamine-formaldehyde, phenol-furfural or polyester	145
– epoxy	185
– mouldings of	
– phenol-formaldehyde or phenol-furfural, melamine and melamine phenolic compounds with	
– cellulose fillers	165
– mineral fillers	185
– thermosetting polyester with mineral fillers	185
– alkyd with mineral fillers	185
– composite materials of	
– polyester with glass-fibre reinforcement	185
– epoxy with glass-fibre reinforcement	185
– silicone rubber	225
b) Parts acting as a support or a mechanical barrier including the inside of enclosures	
– Wood and wood-based materials	125
– Thermoplastic materials	[b]
– Other materials	[a]
c) Other parts - These temperature rises apply to parts not covered by items a) and b)	
– Parts of wood and wood-based material	175
– Lithium batteries	85
– Resistors and parts of metal, glass, ceramic, etc.	No limit
– All other parts	335

Conditions applicable to table 4.4

[a] For the purpose of this Standard, the permissible temperatures are based on service experience in relation to the thermal stability of the materials. The materials quoted are examples. For materials for which higher temperature limits are claimed, and for materials other than those listed, the maximum temperatures shall not exceed those which have been proved to be satisfactory, for example in accordance with IEC 60085.

[b] Due to their wide variety, it is not possible to specify a generic permissible temperature rise for thermoplastic materials. In order to determine the softening temperature of a specific thermoplastic material, the softening temperature as determined by the test B50 of ISO 306 shall be used. If the material is not known or if the actual temperature of the parts exceeds the softening temperature, the test described below shall be used.

The softening temperature of the material is determined on a separate specimen, under the conditions specified in ISO 306 with a heating rate of 50 °C/h and modified as follows:

- the depth of penetration is 0,1 mm;
- the total thrust of 10 N is applied before the dial gauge is set to zero or its initial reading noted.

The temperature limit to be considered is the softening temperature itself.

If the required softening temperature exceeds 120 °C, the nature of the plastic material is the governing factor.

4.3.6.2 Test method

The conditions of annex B.7, which are possible causes for ignition, are applied in turn. A consequential fault may either interrupt or short-circuit a component. In case of doubt, the test shall be repeated up to two more times with replacement components in order to check that the same result is always obtained. Should this not be the case, the most unfavourable consequential fault shall be applied together with the specific fault.

The equipment is operated under abnormal conditions and the temperatures of materials in table 4.4 are measured after a steady state has been attained. Where an applied fault condition results in interruption of the current before steady state has been reached, the temperatures are measured immediately after the interruption.

If the temperature is limited by using a fuse complying with IEC 60127 the temperature is measured as follows:

- The fuse-link is short-circuited and the current passing through the fuse-link under the relevant fault condition, is measured.
- If the fuse-link current remains less than 2,1 times the rated current of the fuse-link, the temperatures are measured after a steady state has been attained.
- If the current reaches either immediately 2,1 times the rated current of the fuse-link or more, or reaches this value after a period of time equal to the maximum pre-arcing time for the current through the fuse-link, both the fuse-link and the short-circuit link are removed after an additional time corresponding to the maximum pre-arcing time of the fuse-link and the temperatures are measured immediately thereafter.
- If the fuse resistance influences the current of the relevant circuit, the maximum resistance value of the fuse-link shall be taken into account when establishing the value of the current.

Printed wiring board conductors are tested by applying the single fault conditions of annex B.7.2 in turn to circuits on printed wiring board.

4.3.6.3 Compliance criteria

Equipment complies with the requirements if:

- ignition does not occur, or
- ignition occurs and does not sustain beyond 3 s and there is no spread of fire to any other part;
- temperature of materials comply to values in table 4.4.

If the test results would lead to other hazards in this Standard the equipment does not comply.

If conductors on printed boards are interrupted, peeled or loosened during the test, the equipment is still deemed to be satisfactory if all of the following conditions are met:

- the printed board complies with flammability class V-1 or better; and
- the interrupted conductors have not peeled by more than 2 mm on each side; and
- the interruption is not a POTENTIAL IGNITION SOURCE 1; and
- the equipment complies with the requirements of this clause with the interrupted conductors bridged.

4.3.6.4 Use of protection devices to limit heating under abnormal conditions

If protection devices such as THERMAL CUT-OUTS, thermal links, PTC-resistors and fuses are used to limit heating under abnormal conditions, the requirements of annex G apply.

4.3.6.5 Separation from potential ignition sources 1

Flammable material shall be separated from POTENTIAL IGNITION SOURCE 1. See annex T.

A POTENTIAL IGNITION SOURCE 1 is considered not to become a risk for ignition if:

- an electronic protection circuit is used to reduce the power source of a circuit to PS 1; or
- for circuits associated with the MAINS the following requirements are fulfilled:
  1. Solder joints shall either have
     - two solder joints (solder tags or pads) be connected electrically in parallel, or
     - the holes of solder pads on a printed board be through-metallized, or
     - tubular rivets/eyelets be riveted in the solder holes of a printed wiring board.
  2. Riveted joints shall either have
     - at least two rivets be connected electrically in parallel, or
     - a single rivet be additionally soldered with the riveted parts.
  3. Crimp or wire-wrap connections shall either
     - two independent connections be connected electrically in parallel, or

- the connection be additionally soldered.

4. Welded joints shall have two welding points connected electrically in parallel.
5. Insulation-displacement connections shall have two clampings with independent contact pressure connected electrically in parallel.
6. Plugs and connectors shall either have
   - two contacts connected electrically in parallel, each of which is capable to be loaded with the total current of the concerned circuit, or
   - at least two contact points independent of each other with regard to their contact pressure be provided for each contact.
7. Conductors on printed boards, the interruption of which, e.g. by hair crack, could be a POTENTIAL IGNITION SOURCE 1, shall either have
   - a width of at least 0,3 mm and be tinned for at least 50 %, but not less than 0,3 mm of its width by a process as used for soldering the components, or
   - two independent conductors, if possible not abreast leaded, be connected electrically in parallel.

   Moreover, sharp corners shall be avoided in the lay-out of the conductors on a printed board.
8. Thermal fatigue phenomena shall be prevented by selection of components with a coefficient of thermal expansion similar to that of the printed board material, or by flexible terminals. Attention should be paid to the location of the component with respect to the fibre direction of the board material.

4.3.6.5.1 Test method

Compliance is checked by inspection and measuring. The flammability class is checked in accordance with IEC 60707 for the smallest thickness used. For printed boards a preconditioning of 24 h at a temperature of 125 °C ± 2 °C in an air circulating oven and a subsequent cooling period of 4 h at room temperature in a desiccator over anhydrous calcium chloride.

4.3.6.6 High voltage circuit fire enclosures

4.3.6.6.1 Requirements

A POTENTIAL IGNITION SOURCE 1 with open circuit voltage exceeding 4 kV peak a.c. or d.c. shall be inside a FIRE ENCLOSURE.

A FIRE ENCLOSURE is not required in case the open circuit voltage of the POTENTIAL IGNITION SOURCE 1:

- is limited to a value < 4 kV by means of an electronic protective circuit; or
- does not exceed 4 kV at the moment the faulty connection or interruption occurs.

4.3.6.6.2 Test method

Compliance is checked by inspection and measurement. The voltage is measured over the smallest distance across a faulty connection or interruption where arcing will start.

4.3.7 Mains cord and mains wiring

For safe connection to the MAINS, equipment shall be provided with one of the following:

- terminals for permanent connection to the supply;
- a NON-DETACHABLE POWER SUPPLY CORD for permanent connection to the supply, or for connection to the supply by means of a plug;
- an appliance inlet for connection of a detachable power supply cord;
- a MAINS plug that is part of direct plug-in equipment.

Requirements for the MAINS cord, cord anchorage, terminals for MAINS cord and appliance inlet are given in annex G.9.

4.4 Flammable liquids and vapours

If a flammable liquid is used in equipment, the liquid shall be kept in a closed reservoir, except for the amount needed for the functioning of the equipment. The maximum quantity of flammable liquid stored in equipment shall be not more than 5 l. If, however, the usage of liquid is such that more than 5 l is consumed in 8 h, the quantity stored is permitted to be increased to that required for an 8 h operation.

Oil or equivalent fluids used for lubrication or in a hydraulic system shall have a flash point of 149 °C or higher, and the reservoir shall be of sealed construction. The system shall have provision for expansion of the fluid and shall incorporate means for pressure relief. This requirement is not applicable to lubricating oils which are applied to points of friction in quantities which would contribute negligible fuel to a fire.

Except under conditions given below, replenishable liquids such as printing inks shall have a flash point of 60 °C or higher, and shall not be under sufficient pressure to cause atomisation.

Replenishable flammable liquids which have a flash point of less than 60 °C or which are under sufficient pressure to cause atomisation are permitted provided inspection shows that there is no likelihood of liquid sprays or build-up of flammable vapour-air mixtures which could cause explosion or fire hazard. Under NORMAL CONDITIONS, equipment using a flammable liquid shall not generate a mixture with a concentration exceeding one quarter of the explosion limit if the mixture is in proximity to an ignition source, or exceeding half the explosion limit if the mixture is not in proximity to an ignition source. The investigation shall also take into account the integrity of the liquid handling system. The liquid handling system shall be suitably housed or constructed so as to avoid the risk of fire or explosion.

Manuals shall provide warnings concerning the selection and flash point of flammable liquids.

4.4.1 Test method

Compliance is checked by inspection and, where necessary, by the following test:

The equipment is operated in accordance with B.4 until its temperature stabilizes. Samples of the atmosphere in the vicinity of the electrical components and around the equipment are taken to determine the concentration of flammable vapours present.

The samples of the atmosphere are taken at 4 min intervals: four samples to be taken during normal operation, then seven samples after the equipment has stopped.

If, after the equipment has stopped, the concentration of flammable vapours appears to be increasing, samples shall continue to be taken at 4 min intervals until the concentration is shown to be decreasing.

If operation of the equipment is possible with any of its fans not running, this condition is simulated during this compliance test.

4.4.2 Compliance criteria

The vapour-air concentrations do not exceed the specified explosion limits.

4.5 Batteries

The risk of fire associated with the use of batteries in equipment is evaluated according to annex N.

4.6 Fire hazard due to entering of foreign objects

4.6.1 Requirements

Equipment shall be so designed that the risk of bridging adjacent poles of circuits and components at PS 3 level due to entering of conductive foreign objects such as paper clips etc. is minimised to reduce the risk of fire due to heating of metal.

Openings exceeding 5 mm in any direction or 1 mm in width regardless of length shall be such that they are provided with louvers that are shaped to deflect an external vertically falling object. See figures 4.4, 4.5 and 4.6.

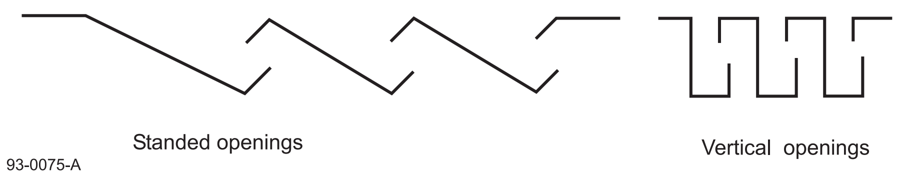


Figure 4.4 – Examples of cross-sections of designs of openings preventing vertical access

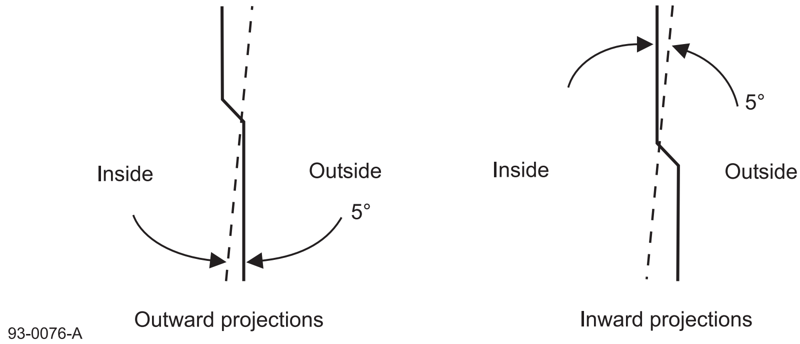
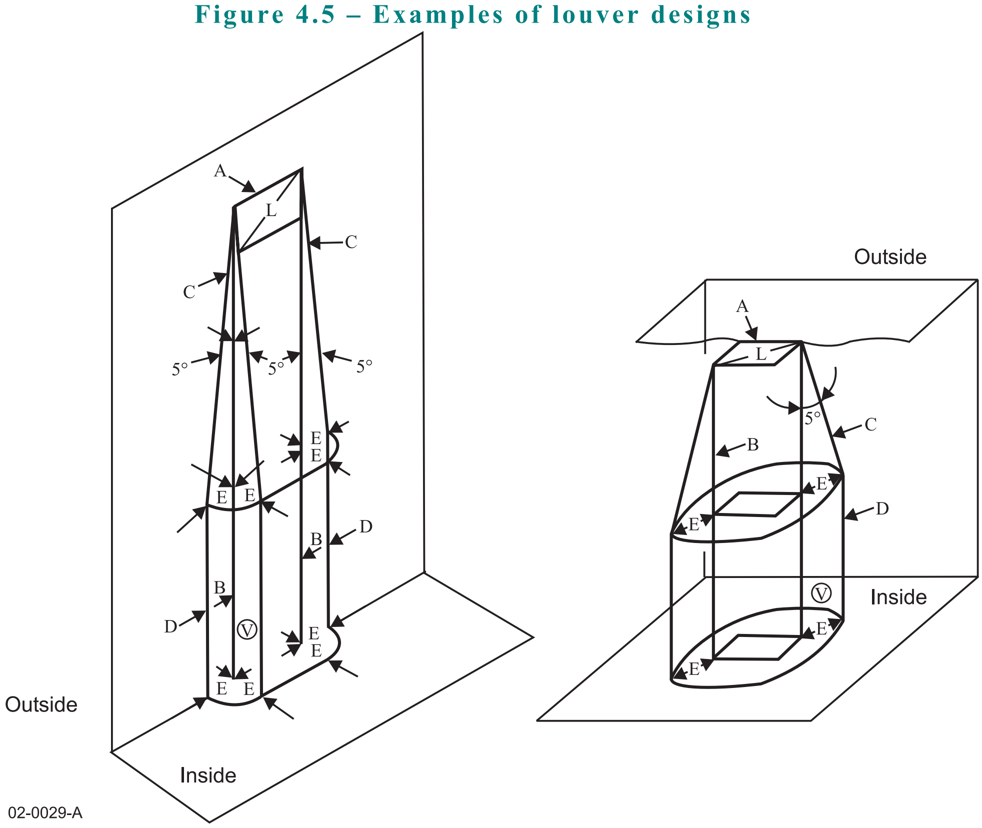


Figure 4.5 – Examples of louver designs



A ENCLOSURE opening.
B Vertical projection of the outer edges of the opening.
C Inclined lines that project at a 5° angle from the edges of the opening to points located E distance from B.
D Line which is projected straight downward in the same plane as the ENCLOSURE side wall.
E Projection of the opening (not to be greater than L).
L Maximum dimension of the ENCLOSURE opening.
V Volume in which bare parts at PS 2 or PS 3 level are not located.

Figure 4.6 – Enclosure openings

For TRANSPORTABLE EQUIPMENT the risk of ignition caused by small conducting objects moving around inside the equipment during transportation shall be reduced by means minimising the likelihood of such objects entering the equipment and bridging adjacent poles of circuits or components at PS 3 level. Acceptable measures include:

- providing openings that do not exceed 1 mm in width regardless of length; or
- providing openings with a screen having a mesh with nominal openings not greater than 2 mm between centre lines and constructed with a thread or wire diameter of not less than 0,45 mm; or
- providing internal barriers.

4.6.2 Test method

Compliance is checked by inspection.

5 Burn Hazard

Burns hazards or undesirable reactions may result from high temperatures on accessible surfaces.

A simplified list of requirements related to protection against burn hazards is described in table 5.1.

Table 5.1 – Protection against burn hazards.

Cause of hazard	Clause	Protection requirements
Hot surfaces accessible to an ORDINARY PERSON	5.1	• Temperature limits for accessible surfaces or • Provide warning if high temperature is unavoidable for functional reason or due to high ambient temperature
Hot surfaces accessible only to a SKILLED PERSON or an INSTRUCTED PERSON		• Temperature limits for any surface which can be inadvertently touched, or • Hot surfaces shall be identifiable as being hot or be identified by a warning
Bridging of conductive parts at PS 2 and PS 3 level	5.2	• Prevent access to adjacent parts at PS 2 and PS 3 level, except for battery poles and audio amplifiers output terminals • Limit possibility of bridging • Provide a warning

NOTE
For PS levels see 4.1.1.

5.1 Access to hot surfaces

5.1.1 Requirements

- Equipment shall be so designed, that temperatures of hot surfaces accessible to ORDINARY PERSONS are limited to the temperatures as shown in table 5.2.
- Where the limits of the table 5.2 are exceeded for functional reasons or due to ambient temperatures above 40 °C, warning according to IEC 60417-4051 shall be provided. It shall be clear, located in a prominent position and be reliably affixed. Handheld equipment with a non-metallic surface shall not require the warning label.
- Equipment shall be so designed that any surface which can be inadvertently touched by a SKILLED PERSON shall meet the temperature limits of table 5.2.
- Surfaces exceeding the temperature limits of table 5.2 shall, by their shape or function, be identifiable as being hot, or be identified by a warning.

Table 5.2 – Temperature limits

Part	Contact period	Material	Temperature
handles, knobs, grips, etc.	continuously held	all	43 °C
	held or touched for short periods only	metallic	55 °C
		non-metallic	65 °C
external surface of equipment	may be touched	metallic	65 °C
		non-metallic	85 °C

NOTE 1

- *Continuous holding is assumed to be below 8 hrs. Less than 10 % of the entire skin surface of body is assumed to touch the hot surface. Limit temperature derived from EN 563.*
- *Short period holding is assumed to be below 10 s.*
- *"May be touched" contact time is assumed to be below 1 s.*

NOTE 2
For outside parts of metal which are covered by plastic material, the thickness of which is at least 0,3 mm, a temperature which corresponds to the permissible temperature of the non-metallic material is allowed.

NOTE 3
For heatsinks, ENCLOSURES directly covering a heatsink, or areas on the external surface of equipment and having no dimension exceeding 50 mm and which are not likely to be touched in normal use, temperatures up to 100 °C are permitted.

5.1.2 Test method

Compliance is checked by inspection and where appropriate, by measuring the temperature of accessible surfaces in accordance with the conditions in annex B.5.

The equipment is operated under normal and abnormal conditions and the temperatures are measured after a steady state has been attained, but not later than after 4 hours.

In deciding whether or not inadvertent contact or bridging is likely, account is taken of the way a SKILLED PERSON needs to gain access to parts, or near to parts, in order to service other parts.

For warnings compliance with requirements is checked by inspection.

5.1.3 Compliance criteria

Requirements of 5.1.1 are fulfilled.

5.2 Bridging of conductive parts

5.2.1 Requirements

Equipment shall be so designed that the risk of bridging of adjacent poles of circuits and components at PS 2 and PS 3 level by conductive objects such as rings, bracelets, tools etc. is minimised to reduce the risk of burn due to heating of metal.

- An ORDINARY PERSON shall have no access to both poles of a PS 2 and PS 3 circuits.
- Bare parts in areas accessible only to a SKILLED PERSON or an INSTRUCTED PERSON shall be so located or guarded that unintentional bridging by conductive materials is unlikely during service operations. Where this is not possible, appropriate warning shall be included in the service documentation.

5.2.2 Test method

In order to verify that a part is accessible the jointed test finger and test pin, see test probe B and test probe 13 of IEC 61032 respectively, are applied without appreciable force, in any possible position. Equipment preventing the entry of the jointed test finger are further tested by means of a straight unjointed version of the test finger applied with a force of 30 N. If the unjointed test finger enters the equipment, the application of the jointed test finger is repeated, the test finger being pushed through the aperture.

The test is repeated using the small finger probes 18 and 19 of IEC 61032. This does not apply if the intended conditions of use prevent the equipment from being accessed by children.

Openings in the top of enclosure are checked with a metal pin having a diameter of 4 mm +0 mm -0,1 mm and a length of 100 mm ± 0,3 mm. The pin is suspended freely from one end and the penetration is limited to the length of the pin.

Floor standing equipment having a mass exceeding 40 kg are not tilted during the test.

5.2.3 Compliance criteria

Requirements of 5.2.1 are fulfilled.

6 Mechanical hazards

Table 6.1 – Mechanical hazards

Cause of hazard	Clause	Prevention/protection methods
Sharp edges and corners	6.1	• Design without sharp edges and corners • Restricting access • Warning
Hazardous rotating or otherwise moving parts	6.2	• Restrict/Prevent access • SAFETY INTERLOCK systems • Stopping means • Warning
Loosening, exploding or imploding parts	6.3	• Shielding / Enclosing • Design
Equipment instability	6.4	• Stabilising means • Design

6.1 Sharp edges and corners

The equipment shall be so designed that the risk of injury by sharp edges and corners is minimised. This can be achieved by deburring of edges and grinding of corners or by restricting access.

Where sharp edges are needed for functional purposes and access is unavoidable, guarding means shall be used to minimise the risk of unintentional contact with such edges.

If none of the prevention methods is practical, a clear warning shall be reliably affixed in a prominent position.

6.1.1 Test method

Compliance is checked by inspection and where applicable by the following test.

The guarding means is subjected to a steady force of 30 N ± 3 N for a period of 5 s applied by means of the rigid test finger, test probe 11 of IEC 61032.

6.2 Hazardous rotating or otherwise moving parts

The equipment shall be so constructed that the risk of personal injury by moving or rotating parts is minimised.

Where an ORDINARY PERSON has access, MECHANICAL ENCLOSURES and/or barriers shall have adequate mechanical strength and shall not be displaceable by hand.

MECHANICAL ENCLOSURES of moulded or formed thermoplastic materials shall be so constructed that any shrinkage or distortion of the material due to release of internal stresses caused by the moulding or forming operation does not result in the exposure of hazardous moving or rotating parts. SAFETY INTERLOCKS shall be provided so that the hazard will be removed before access can be gained. Detailed requirements for SAFETY INTERLOCKS are given in annex L.

For a hazardous moving or rotating part which will continue to move or rotate through momentum, the removal, opening or withdrawal of a cover, door, etc. shall necessitate previous reduction of movement or rotation to a safe level.

A stopping means shall be provided to stop rotating or moving parts where the possibility exists that fingers, jewellery, clothing, hair, etc. can be drawn into those parts (e.g. gears or shredder blades). Such devices shall be placed in a prominent position and shall be accessible from the point where the risk of injury is highest.

If none of the prevention methods are practicable, a clear warning shall be affixed in a prominent position.

6.2.1 Test method

Where access to hazardous rotating or moving parts is prevented by MECHANICAL ENCLOSURES and/or barriers, compliance is checked by:

- the examination of the construction and available data, or
- the tests of annex V as appropriate.

Upon completion of the tests, access to hazardous moving or rotating parts is checked with the rigid test finger, test probe 11 of IEC 61032, in every possible position.

Where SAFETY INTERLOCKS are used, compliance is checked by inspection and by the tests in accordance with annex L.

For warnings, if any, compliance is checked by visual inspection.

6.3 Loosening, exploding or imploding parts

Hazards described in this clause are:

- Parts which may become loose, separated or thrown from a rotating or moving part;
  A mechanical enclosure shall be sufficiently complete to contain or deflect parts which, because of failure or for other reasons, might become loose, separated or thrown from a moving part.
- Particles from an exploding part (e.g. high pressure lamp);
  Protection shall be provided against particles from exploding parts by mechanical enclosures.
  In this Standard, a high pressure lamp, a lamp in which the pressure exceeds a certain pressure limit (0,2 MPa when cold or 0,4 MPa when operating), is regarded as a potentially exploding part. A mechanical enclosure of a high pressure lamp shall have adequate strength to contain all glass particles in the event of an explosion.
- Particles from an imploding cathode ray tube (CRT).
  Protection shall be provided against particles from an imploding CRT by design or by shielding. Detailed requirements are given in annex W.

6.3.1 Test method

- For loosening parts, compliance is checked by visual inspection.
- High pressure lamps are tested in their lamp assembly or in the MECHANICAL ENCLOSURE of the equipment or both for the protection against the effects of the explosion by the following test:
  An explosion of the lamp is stimulated by mechanical impact, circuit component failure or similar method.
- For CRTs having a maximum face dimension exceeding 160 mm compliance is checked by inspection, by measurement and by the tests of annex W.

6.4 Instability of equipment

The equipment shall not become physically unstable, i.e. overbalance, to a degree that it results in a hazard.

Where a means is provided to improve stability when drawers, doors, etc. are opened, it shall be permanently in operation when associated with usage by ORDINARY PERSONS.

Where such means is not permanently provided but has to be used during service, warnings shall be provided for SKILLED PERSONS.

These requirements do not apply to:

- individual units which are designed to be mechanically fixed together on site and are not used individually, and
- equipment to be secured to the building structure before operation, in accordance with the installation instructions.

6.4.1 Test method

Compliance is checked by inspection and by the following tests, where relevant.

Each test is carried out separately. During the test, containers are to contain the amount of substance within their rated capacity producing the most disadvantageous condition. All castors and jacks, if used under NORMAL CONDITION, are placed in their most unfavourable position, with wheels and the like locked or blocked.

a) Overbalance test (1)

This test is applied to units having a mass of 5 kg or more. The unit is tilted to an angle of 15° from its normal upright positions. Doors, drawers, etc. are closed during this test.

b) Overbalance test (2)
For floor standing units having a mass of 5 kg or more but less than 30 kg, a force equal to 20 % of the weight of the unit but not more than 40 N, is applied in any horizontal direction at a height not exceeding 1,5 m from the floor.

Doors, drawers, etc. which may be moved are placed in their most unfavourable position, consistent with the manufacturer's instructions.

c) Overbalance test (3)
For floor standing units having a mass of 30 kg or more, a force equal to 20 % of the weight of the unit but not more than 250 N, is applied in any direction except upwards at a height not exceeding 1,5 m from the floor.

Doors, drawers, etc. which may be moved are placed in their most unfavourable position, consistent with the manufacturer's instructions.

6.4.2 Compliance criteria

- Equipment having a mass of 5 kg to 30 kg shall not fall over when applying the test of a) **or** b).
- Equipment exceeding a mass of 30 kg shall not fall over when applying the test of a) **or** c).

7 Radiation

Table 7.1 – Protection against radiation hazards.

Cause of hazard	Clause	Prevention/protection methods
Laser radiation	7.1	ensure optical design
Ionising radiation	7.2	limit radiation

7.1 Laser radiation

Equipment containing a laser system shall be so constructed that personal protection against laser radiation is provided under NORMAL CONDITION and under ABNORMAL CONDITION.

Equipment containing an LED shall met the same requirements.

7.1.1 Test method

Compliance is checked according to IEC 60825-1 and IEC 60825-2 where appropriate.

7.2 Ionising radiation

Equipment that can generate ionising radiation shall be so designed that harmful effects to persons and damage to materials affecting safety are prevented.

At any point 10 cm from the outer surface of the equipment, the dose-rate shall not exceed 1 µS/hr. Account is taken of the background level.

7.2.1 Test method

Equipment which might produce ionising radiation is checked by measuring the amount of radiation.

The amount of radiation is determined by means of a radiation monitor of the ionising chamber type with an effective area of 10 cm^2, or by measuring equipment of other types giving equivalent results.

Measurements are made with the equipment under test at the most unfavourable supply voltage (see B.4.2) and with controls adjusted so as to give maximum radiation whilst maintaining NORMAL CONDITION. Internal pre-set controls, not intended to be adjusted during the lifetime of the equipment, are not adjusted.

8 Chemical hazards

Consumable materials necessary for the operation of products may present potential chemical hazards. Hazards may arise from the inhalation of vapors or fumes, from ingestion of these substances, or from physical contact with these materials. Products that generate high voltage may produce ozone. It is essential to:

- determine what substances are present;
- understand what potential hazards their use may present and;
- minimize the risk of a hazard to a person due to interaction with these materials.

NOTE
In addition to their potential toxicity, loss of containment of chemical consumables may cause or contribute to other hazards such as fire, electric shock, personal injury due to slippery surfaces.

Table 8.1 – Chemical hazards

Cause of hazard	Clause	Prevention/protection methods
Ingestion, inhalation, skin contact, or other exposure to potentially hazardous chemicals	8.1	• Where possible, avoid the use of potentially hazardous chemicals. • Minimize accessibility by providing guarding, ventilation, or containment. • Provide warnings. • Minimize emissions.
Exposure to excessive concentrations of ozone	8.2	• Where possible, minimize the use of functions that produce ozone. • Provide adequate room ventilation. • Provide filtration to remove ozone.
Explosion due to an explosive mixture of fine particles suspended in air and the presence of a source of ignition	8.3	• Reduce the presence of fine particles available for suspension in air. • Avoid the use of air movement near sources of fine particles. • Warn against the possible hazards of using common vacuum cleaners for picking up spills. • Isolate sources of ignition.

8.1 Hazardous chemicals

Equipment using consumable materials shall be so constructed that exposure to a person of chemicals which are hazardous to health, their vapours, or emissions is minimised or eliminated.

Where potentially hazardous fumes or vapours are generated during the normal operation of the equipment, adequate ventilation shall be provided to reduce their concentration to a level not exceeding the recommended threshold value for any of the hazardous substances in the fumes.

NOTE 1
Recommended threshold values may vary from country to country.

Contact with hazardous materials shall be minimised by the use of guards, MECHANICAL ENCLOSURES, or containers which reduce the need for handling.

The above mentioned consumables shall be identified in the installation, operating, and service manuals. These manuals shall contain instructions for the safe handling, storage and disposal of the materials.

NOTE 1
Some countries may have regulations governing the storage and disposal of hazardous materials.

8.1.1 Test method

Compliance is checked by inspection.

Barriers, guards or MECHANICAL ENCLOSURES used to minimise access to materials are evaluated by:

- the examination of the construction and available data, or
- the test of annex V.1.

8.2 Ozone

For equipment that may produce ozone, the installation and instructions shall refer to the need to provide adequate room ventilation or adequate filtering to ensure that the concentration of ozone resulting from the equipment operation is kept below applicable exposure limits.

When filters are used maintenance instructions shall be provided.

NOTE
The present recommended long term exposure limit for ozone is 0,1 ppm (0,2 mg/m^3) calculated as an 8 hour time-weighted average concentration. It should be noted that ozone is heavier than air.

8.2.1 Test method

Compliance is checked by inspection and, where necessary, by the Test method of ECMA-328.

8.3 Dust, particulates, liquids, or gases

Equipment producing dust (e.g., paper dust) or employing powders, liquids, or gases shall be constructed such that no concentration of these materials can exist which create a hazard within the meaning of this Standard (e.g. by movement, condensation, vaporization, leakage, spillage, or corrosion during normal operation, storage, filling or emptying).

If equipment uses or generates fine powders or particulates and the possibility exists that a person may attempt to clean up spills with an electric vacuum cleaner, appropriate instructions and warnings shall be provided if the use of an unsuitable device could result in a potential dust-air explosion hazard.

8.3.1 Test method

Compliance is checked by inspection of the equipment and of the instructions for handling and disposal of the consumable materials.

For flammable liquids, compliance is checked by the tests of 4.4.

Where spillage of liquid during replenishment could affect electrical insulation, compliance is checked by inspection and by the following test.

The equipment shall be ready to use according to its installation instructions, but not energised.

The liquid container of the equipment is completely filled with the liquid specified by the manufacturer and a further quantity, equal to 15 % of the capacity of the container is poured in steadily over a period of 1 min. For liquid containers having a capacity not exceeding 250 ml, and for containers without drainage and for which the filling cannot be observed from outside, a further quantity of liquid, equal to the capacity of the container, is poured in steadily over a period of 1 min.

Immediately after this treatment, the equipment shall withstand an electric strength test as specified in 3.6.14 on any insulation on which spillage could have occurred.

8.3.2 Compliance criteria

The excess liquid does not create an hazard either by reducing the integrity of electrical insulation, as demonstrated by the results of electric strength tests.

Annexes

Annex A
(informative)

Examples of equipment within the scope of this Standard

Some examples of equipment within the scope of this Standard are:

Office equipment

Calculators, cash registers, copying machines, data and text processing equipment, data preparation equipment, dictation equipment, document shredding machines, duplicators, electrically operated drawing machines (plotters), erasers, facsimile equipment, magnetic tape handlers, mail processing machines, micrographic office equipment, monetary processing machines, motor-operated files, personal computers, point of sale terminals, postage machines, staplers, telephone answering machines, typewriters, visual display units.

Consumer electronic equipment

Antenna positioners, antenna signal converters and amplifiers, apparatus for imagery, audio and/or video equipment, electronic gaming and scoring machines, electronic musical instruments and electronic accessories such as rhythm generators, flipper games, independent load transducers and source transducers, juke boxes, light effect apparatus, music tuners and the like for use with electronic or non-electronic musical instruments, receiving apparatus and amplifiers for sound and/or vision, record and optical disc players, self-contained tone generators, tape and optical disc recorders, teletext equipment, video cameras and video monitors, video games, video projectors.

Communication terminal equipment

Data circuit terminating equipment (e.g. modems), data terminal equipment, intercommunication apparatus using low voltage mains as the transmission medium, key telephone systems, PABXs.

This list is not intended to be comprehensive, and equipment that is not listed is not necessarily excluded from the scope.

Annex B
(normative)

General conditions for tests

B.1 Applicability of requirements

The requirements and tests detailed in this Standard shall be applied only if safety is involved. If it is evident that a particular test is not applicable, the test shall not be made.

In order to establish whether or not safety is involved, the circuits and construction shall be carefully investigated to take into account the consequences of possible failures.

B.2 Type of tests

Except where otherwise stated, tests specified in this Standard are type tests.

B.3 Test samples

Unless otherwise specified, the sample under test shall be representative of the equipment the user would receive, or shall be the actual equipment ready for shipment to the user.

As an alternative to carrying out tests on the complete equipment, tests may be carried out separately on circuits, components or sub-assemblies outside the equipment, provided that inspection of the equipment and circuit arrangements ensures that such testing will indicate that the assembled equipment would conform to the requirements of the Standard. If any such test indicates the likelihood of non-conformance in the complete equipment, the test shall be repeated in the equipment.

If a test specified in this Standard could be destructive, it is permitted to use a model to represent the condition to be evaluated.

NOTE
In view of the amount of resource involved in testing and in order to minimise waste, it is recommended that all parties concerned jointly consider the test programme, the test samples and the test sequence. Tests which may result in the destruction of the sample are recommended to be carried out last.

B.4 Conditions for tests

B.4.1 General

Except where specific test conditions are stated elsewhere in the Standard and, where it is clear that there is a significant impact on the results of the test, the tests shall be carried out under NORMAL CONDITION taking into account the following parameters:

- supply voltage,
- supply frequency,
- physical location of equipment and position of movable parts,
- operating mode,
- adjustment of THERMOSTATS, regulating devices or similar controls to which an ORDINARY PERSON has access and are:
  - adjustable without the use of a TOOL, or
  - adjustable using a means, such as a key or a TOOL, deliberately provided for the ORDINARY PERSON.

B.4.2 Supply voltage

In determining the most unfavourable supply voltage for a test, the following variables shall be taken into account:

- multiple RATED VOLTAGES,
- extremes of RATED VOLTAGE ranges,
- tolerance on RATED VOLTAGE as declared by the manufacturer.

If the manufacturer has not declared a tolerance, it shall be taken as +10 % and -10 %.

When testing equipment designed for d.c. only, the possible influence of polarity shall be taken into account.

B.4.3 Supply frequency

In determining the most unfavourable supply frequency for a test, different frequencies within the RATED FREQUENCY range shall be taken into account (e.g. 50 Hz and 60 Hz) but consideration of the tolerance on a RATED FREQUENCY (e.g. 50 Hz ± 0,5 Hz) is not necessary.

B.4.4 Input current

In determination of the input current, and where other test results could be affected, the following variables shall be considered and adjusted to give the most unfavourable results:

- loads due to optional features, offered or provided for by the manufacturer for inclusion in or with the equipment under test;
- loads due to other units of equipment intended by the manufacturer to draw power from the equipment under test;
- loads that could be connected to any standard supply outlet on the equipment which is accessible to an ORDINARY PERSON, up to the value specified by the manufacturer.

It is permitted to use artificial loads to simulate such loads during testing.

B.4.5 Conditions for audio amplifiers

Under NORMAL CONDITION:

a) The equipment shall be operated in such a way as to deliver 1/8 of the non-clipped output power to the rated load impedance using a sine wave of one 1 kHz, or where applicable, another frequency corresponding to the geometric mean of the upper and lower –3dB response points of the relevant part of the equipment. Alternatively, a band-limited pink noise signal may be used. The noise bandwidth of the test signal shall be limited by a filter of a characteristic as shown in figure B.1.

b) The most unfavourable rated load impedance of any output circuit may be connected or not.

c) Organs or similar instruments that have a tone-generator unit shall be operated with any combination of two bass pedal keys, if present, and ten manual keys depressed. All stops and tabs that can increase the output power shall be activated.

For audio amplifiers used in an electronic musical instrument that cannot generate a continuous tone, the signal described in a) shall be applied to the signal input terminals or to the appropriate input stage of the audio amplifier.

d) Where the intended amplifier function depends on phase difference between two channels, there shall be a phase difference of 90 degrees between signals applied to the two channels. For surround-sound amplifiers, the rear channel shall be loaded to 1/16 of the non-clipped power.

e) When determining whether a part or terminal contact is above ES 2 level, the equipment shall be operated with the signal described in a), sufficient in amplitude for the equipment to deliver maximum non-clipped output power into it's rated load impedance. Open circuit output voltage shall be determined after the load is removed.

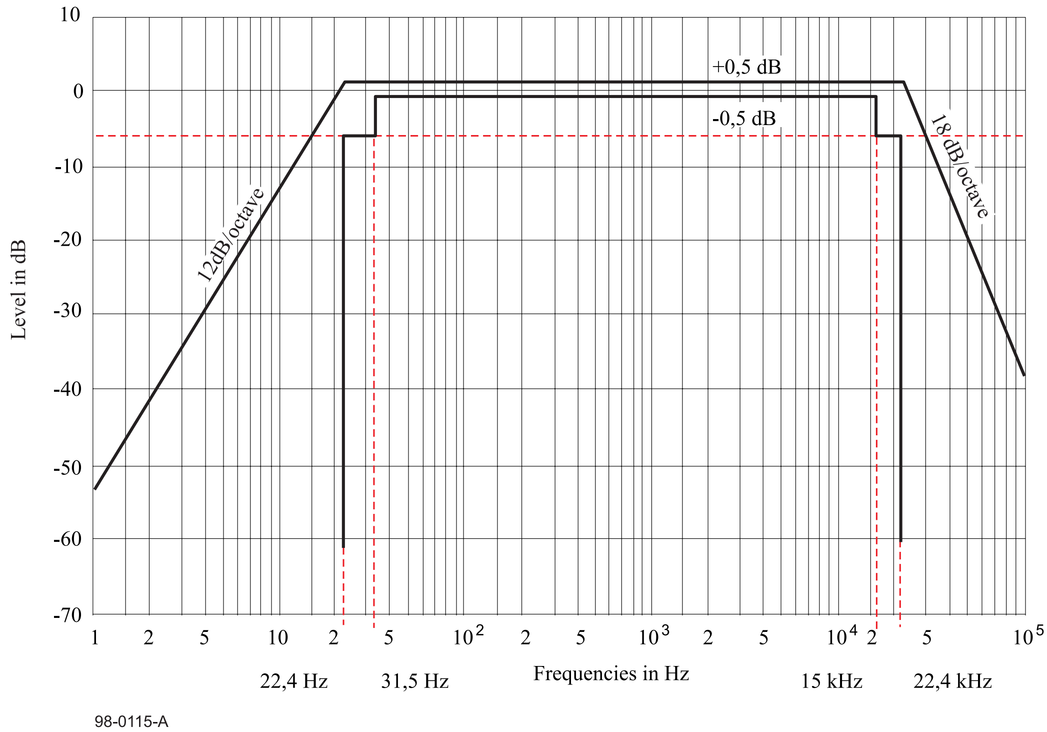


Figure B.1 – Band-pass filter for wide-band noise measurement (Extract of IEC 60268-1)

B.4.6. Conditions for video displays

Under NORMAL CONDITION the settings of the picture shall conform to IEC 60107.

B.4.7 Malfunction of the equipment

Under NORMAL CONDITION a possible malfunction of the equipment which can be corrected by an ORDINARY PERSON shall be taken into consideration.

An example of such a malfunction is a paper jam of paper handling equipment.

B.5 Temperature measurement conditions

The test measurement set-up shall reproduce the most severe installation conditions. Where a maximum temperature (T_{max}) is specified for compliance with tests, it is based on the assumption that the room ambient air temperature will be 25 °C when the equipment is operating. However, the manufacturer may specify a different maximum ambient air temperature.

It is not necessary to maintain the ambient temperature (T_{amb}) at a specific value during tests, but it shall be monitored and recorded.

If the manufacturer has given no specific requirement of temperature measurement duration, a maximum of 4 h is assumed to allow temperature stabilization.

Temperatures (T) measured on the equipment shall conform with one of the following conditions, all temperatures being in °C:

if T_{max} is specified $(T - T_{amb}) \leq (T_{max} - T_{mra})$

if ΔT_{max} is specified $(T - T_{amb}) \leq (\Delta T_{max} + 25 - T_{mra})$

where T_{mra} is the maximum room ambient temperature permitted by the manufacturer's specification or 25 °C, whichever is greater.

The classification of insulating materials (classes A, E, B, F and H) is in accordance with IEC 60085.

Under NORMAL CONDITION temperatures shall not be controlled by protective devices, such as fuses or THERMAL CUT-OUTS.

B.6 Temperature measurement methods

Unless a particular method is specified, temperatures of windings shall be determined either by the thermocouple method or by the resistance method. If temperatures are determined by thermocouples, the measured values are increased by 10 K.

B.7 Simulated abnormal conditions

When applying ABNORMAL CONDITIONS, parts, supplies, and media shall be in place if they are likely to have an affect on the outcome of the test.

The introduction of any ABNORMAL CONDITION shall be applied in turn one at a time. Faults, which are the direct consequence of the ABNORMAL CONDITION, are considered to be part of that ABNORMAL CONDITION.

The equipment, circuit diagrams and component specifications are examined to determine those ABNORMAL CONDITIONS that might reasonably be expected to occur.

The following groups of ABNORMAL CONDITIONS have to be considered:

- ABNORMAL CONDITION introduced by an ORDINARY PERSON,
- single fault condition (component failure),
- overload conditions.

B.7.1 Abnormal conditions introduced by an ordinary person

After applying an ABNORMAL CONDITION introduced by an ORDINARY PERSON, one SAFEGUARD shall be maintained.

During the tests, the temperature limits of table 4.4 for ABNORMAL CONDITIONS shall not be exceeded.

B.7.1.1 Covering of ventilation openings

The top, sides and the back of equipment, if such surfaces have ventilation openings, shall be covered one at a time with a piece of card of 200 g/m^2 density, with dimensions not less than each tested surface, covering all openings.

Openings on different surfaces on top of the equipment (if any) are covered simultaneously by separate pieces of card.

Openings on top of the equipment, on a surface inclined at an angle greater than 30 degrees to the horizontal, from which an obstruction is free to slide, are excluded.

On the back and the sides of the equipment, the card is attached to the upper edge and allowed to hang freely.

NOTE
There is no test for the bottom surface.

B.7.1.2 Setting of voltage selector

Portable equipment to be supplied from the MAINS and provided with a voltage setting device to be set by the ORDINARY PERSON, is connected to a supply voltage of 250 V a.c., with the MAINS voltage setting device at the most unfavourable position.

B.7.1.3 Maximum load at output terminals

Output terminals of equipment supplying power to other equipment, except socket-outlets directly connected to the MAINS, are connected to the most unfavourable load impedance, including short circuit.

B.7.1.4 Step-up of supply voltage

Equipment which can be supplied by supply equipment for general use (adapters) shall be tested by using a test power supply as specified in table B.1 step by step upwards, starting with the value one step above the value specified for the RATED VOLTAGE of the equipment under test. This test is not applied to equipment having a RATED VOLTAGE higher than 12 V d.c.

Table B.1 – Test power supply

Rated voltage	Nominal no-load voltage	Internal resistance
1,5 V d.c.	2,25 V d.c.	0,75 Ω
3,0 V d.c.	4,50 V d.c.	1,50 Ω
4,5 V d.c.	6,75 V d.c.	2,25 Ω
6,0 V d.c.	9,00 V d.c.	3,00 Ω
7,5 V d.c.	11,25 V d.c.	3,75 Ω
9,0 V d.c.	13,50 V d.c.	4,50 Ω
12,0 V d.c.	18,00 V d.c.	6,00 Ω
NOTE *The rated output current is 1 A.*		

B.7.1.5 Reverse battery polarity

If it is possible for an ORDINARY PERSON to insert replaceable batteries with reversed polarity, the equipment is tested with one or more batteries reversed. See also annex N.

B.7.1.6 Blocking of motors

Motors are stalled, if this is possible during the use of the equipment by internal or external influences.

NOTE
See also annex B.7.3.2 and annex G.

B.7.1.7 Maximum power to audio amplifier

The equipment shall be operated so as to deliver the most unfavourable output power from zero up to the maximum attainable output power to the rated load impedance or, if applicable, to the most unfavourable load impedance connected to the output terminals including a short-circuit and an open circuit.

B.7.2 Single fault conditions

After applying a single fault condition, no hazardous condition shall exist. Where more than one SAFEGUARD is required, at least one SAFEGUARD shall be maintained.

During the tests, the temperatures shall not exceed the limits given for ABNORMAL CONDITIONS.

B.7.2.1 Short circuit of functional insulation on coated and uncoated printed circuit boards

Short circuit across separation distances if they are less that the values specified in table B.2.

Table B.2 – Minimum separation distance for functional insulation on printed circuit boards (mm)

Working voltage V peak or d.c.	Coated (see 3.6.5.2)	Uncoated
≤ 40	0,1	0,2
≤ 90	0,1	0,4
≤ 180	0,2	0,7
≤ 230	0,3	0,8
≤ 285	0,4	0,9
≤ 355	0,6	1,1
≤ 455	0,8	1,4
≤ 570	1,0	1,9
≤ 710	1,3	1,9
≤ 895	1,8	2,3
≤ 1135	2,4	2,8
≤ 1 450	2,8	3,3
≤ 1 770	3,4	4,0
≤ 2 260	4,1	
≤ 2 830	5,0	
≤ 3 540	6,3	
≤ 4 520	8,2	
≤ 5 660	10	
≤ 7 070	13	
≤ 8 910	16	
≤ 11 310	20	
≤ 14 140	26	
≤ 17 700	33	
≤ 22 600	43	
≤ 28 300	55	
≤ 35 400	70	
≤ 45 200	86	

Linear interpolation is permitted between the nearest two points, the calculated spacing being rounded up to the next higher 0,1 mm increment.

B.7.2.2 Short circuit of functional insulation of clearances

Short circuit across CLEARANCES if they are less than the values specified in table B.3.

Table B.3 – Minimum clearances (mm) up to 2 000 m above sea level

Required withstand voltage V peak or d.c.	Functional insulation
≤ 400	0,1
800	0,1
1 000	0,2
1 200	0,3
1 500	0,5
2 000	1,0
2 500	1,5
3 000	2,0
4 000	3,0
6 000	5,5
8 000	8,0
10 000	11
12 000	14
15 000	18
25 000	33
40 000	60
50 000	75
60 000	90
80 000	130
100 000	170

- *Linear interpolation is permitted between the nearest two points, the calculated spacing being rounded up to the next higher 0,1 mm increment.*
- *The REQUIRED WITHSTAND VOLTAGE is calculated according to 3.6.2 for BASIC INSULATION.*

B.7.2.3 Short circuit of electrodes in tubes and semiconductors

Short-circuit, or if applicable, interruption of electrodes in electronic tubes and semiconductors. One lead at a time is interrupted or any two leads connected together in turn.

B.7.2.4 Short circuit or disconnect of passive components

Short-circuit or disconnection, whichever is more unfavourable, of resistors, capacitors, windings, loudspeakers, VDR and other passive components.

These fault conditions do not apply to:

- PTC-S thermistors complying with IEC 60730-1, clause 15, 17, J15 and J17;
- short-circuit between the input and output terminations of optocouplers, which comply with the relevant CLEARANCES and CREEPAGE DISTANCES;
- short-circuit between the input and output of transformers, which comply with the relevant CLEARANCES and CREEPAGE DISTANCES;
- Resistors complying with the test of 3.7.1.5;
- Capacitors complying with IEC 60384-14 and tested according to 3.7.2.1.

B.7.2.5 Earth faults of heating elements

Earth faults are simulated by:

- short circuiting of line to earth;
- interruption of the protective earth path.

B.7.2.6 Continuous operation of components

Motors, relay coils or the like, intended for SHORT–TIME OPERATION or INTERMITTENT OPERATION, are operated continuously if this can occur during operation of the equipment.

For equipment rated for only SHORT–TIME OPERATION, the duration of the test is equal to the RATED OPERATING TIME.

For equipment rated for SHORT–TIME OPERATION or INTERMITTENT OPERATION, the test is repeated until steady state conditions are reached, irrespective of the operating time. For this test the THERMOSTATS, TEMPERATURE LIMITERS and THERMAL CUT-OUTS are not short-circuited.

In circuits not directly connected to the MAINS and in circuits supplied by a d.c. power distribution system where a hazard is likely to occur, electromechanical components normally energized intermittently, except for motors, a fault shall be simulated in the drive circuit to cause continuous energizing of the component.

The duration of the test shall be as follows:

- for equipment or components whose failure to operate is not evident to the ORDINARY PERSON, as long as necessary to establish steady conditions or up to the interruption of the circuit due to other consequences of the simulated fault condition, whichever is the shorter; and
- for other equipment and components: 5 min or up to interruption of the circuit due to a failure of the component (e.g. burn-out) or to other consequences of the simulated fault condition, whichever is shorter.

B.7.3 Overload conditions

B.7.3.1 Overload test on transformers

If the tests are carried out under simulated conditions on the bench, these conditions shall include any protection device which would protect the transformer in the complete equipment.

Transformers for switch mode power supply units are tested in the complete power supply unit or in the complete equipment. Test loads are applied to the output of the power supply unit.

A linear transformer or a ferro-resonant transformer has each secondary winding loaded in turn, with any other secondary winding loaded between zero and its specified maximum to result in the maximum heating effect.

The output of a switch mode power supply is loaded to result in the maximum heating effect in the transformer.

Where an overload cannot occur, the tests are not made.

Maximum temperatures of windings shall not exceed the values in table G.2 when measured as specified in B.5 and B.6, and determined as specified below:

- with external overcurrent protection: at the moment of operation, for determination of the time until the overcurrent protection operates, it is permitted to refer to a data sheet of the overcurrent protection device showing the trip time versus the current characteristics;
- with an automatic reset THERMAL CUT-OUT: after 4 h;
- with a manual reset THERMAL CUT-OUT: at the moment of operation;
- for current-limiting transformers: after the temperature has stabilized.

Secondary windings, which exceed the temperature limits but which become open circuit or otherwise require replacement of the transformer, do not constitute a failure of this test provided that no hazard is created in the meaning of this Standard.

For compliance criteria see annex G.

B.7.3.2 Overload tests on motors

B.7.3.2.1 Test conditions

Unless otherwise specified, during the test the equipment is operated at RATED VOLTAGE, or at the highest voltage of the RATED VOLTAGE range.

The tests are carried out either in the equipment or under simulated conditions on the bench. It is permitted to use separate samples for bench tests. Simulated conditions include:

- any protection device which would protect the motor in the complete equipment, and

- use of any mounting means which may serve as a heat sink to the motor frame.

Temperatures of windings are measured as specified in B.5. Where thermocouples are used they are applied to the surface of the motor windings. Temperatures are determined at the end of the test period where specified, otherwise when the temperature has stabilised, or at the instant of operation of fuses, THERMAL CUT-OUTS, motor protection devices and the like.

For totally enclosed, impedance-protected motors, the temperatures are measured by thermocouples applied to the motor case.

When motors without inherent thermal protection are tested under simulated conditions on the bench, the measured winding temperature is adjusted to take into account the ambient temperature in which the motor is normally located within the equipment.

B.7.3.2.2 Running overload test

A running overload protection test is carried out by operating the motor under NORMAL CONDITION. The load is then increased so that the current is increased in appropriate gradual steps, the motor supply voltage being maintained at its original value. When steady conditions are established, the load is again increased. The load is thus progressively increased in appropriate steps but without reaching locked-rotor condition (see B.7.3.2.3) until the overload protection device operates.

The motor winding temperatures are determined during each steady period.

B.7.3.2.3 Locked-rotor overload test

A locked-rotor test is carried out starting at room temperature.

The duration of the test is as follows:

- a motor protected by inherent or external impedance is operated on locked-rotor for 15 days except that testing is discontinued when the windings of the motor reach a constant temperature;
- a motor with an automatic reset protection device is cycled on locked-rotor for 18 days;
- a motor with a manual reset protection device is cycled on locked-rotor for 60 cycles, the protection device being reset after each operation as soon as possible for it to remain closed, but after not less than 30 s;
- a motor with a non-resettable protection device is operated until the device operates.

Temperatures are recorded at regular intervals during the first three days for a motor with inherent or external impedance protection or with an automatic reset protection device, or during the first ten cycles for a motor with a manual reset protection device, or at the time of operation of a non-resettable protection device.

During the test, protection devices shall operate reliably without permanent damage to the motor including:

- severe or prolonged smoking or flaming;
- electrical or mechanical breakdown of any associated component part such as a capacitor or starting relay;
- flaking, embrittlement or charring of insulation;
- deterioration of the insulation.

Discoloration of the insulation is permitted but charring or embrittlement to the extent that insulation flakes off or material is removed when the winding is rubbed with the thumb is not permitted.

NOTE
Continuation of the test of an automatic reset protection device beyond 72 h, and of a manual reset protection device beyond 10 cycles, is only for the purpose of demonstrating the capability of the device to make and break locked-rotor current for an extended period of time.

B.7.3.2.4 Running overload test for d.c. motors

The running overload test is carried out only if a possibility of an overload occurring is determined by inspection or by review of the design. The test need not be carried out, for example, where electronic drive circuits maintain a substantially constant drive current.

The test is carried out by operating the motor under NORMAL CONDITION. The load is then increased so that the current is increased in appropriate gradual steps, the motor supply voltage being maintained at its original value. When steady conditions are established the load is again increased. The load is thus progressively increased in appropriate steps until either the overload protection device operates or the winding becomes an open circuit.

The motor winding temperatures are determined during each steady period and the maximum temperature recorded shall not exceed the value in table G.4 except that, where difficulty is experienced in obtaining accurate temperature measurements, due to the small size or unconventional design of the motor, it is permitted to use the following test instead of temperature measurement.

During the running overload test, the motor is covered with a single layer of bleached cotton cheesecloth of approximately 40 g/m^2. There shall be no ignition of the cheesecloth during the test or at its conclusion.

Compliance with either method is acceptable; it is not necessary to comply with both methods.

B.7.3.2.5 Locked-rotor overload test for d.c. motors

Motors shall pass the test in a), except that, where difficulty is experienced in obtaining accurate temperature measurements, because of the small size or unconventional design of the motor, the method b) can be used instead. Compliance may be established by either method.

Following the test a) or b), as applicable, if the motor voltage exceeds 42,4 V peak, or 70 V d.c., and after the motor has cooled to room temperature, the motor shall withstand the dielectric strength test in 3.6.14 and with test voltages reduced to 0,6 times the specified values.

a) The motor is operated with its rotor locked for 7 h or until steady conditions are established.

b) The motor is placed on a wooden board which is covered with a single layer of wrapping tissue, and the motor in turn covered with a single layer of bleached cotton cheesecloth of approximately 40 g/m^2.

   NOTE
   Wrapping tissue is defined in ISO 4046: a soft and strong lightweight wrapping paper of a density generally between 12 g/m^2 and 30 g/m^2.

The motor is then operated with the rotor locked for 7 h or until steady conditions are established.

B.7.3.2.6 Test for motors with capacitors

Motors having phase-shifting capacitors are tested under locked-rotor conditions with the capacitor short-circuited or open-circuited (whichever is the more unfavourable).

The short-circuit test is not made if the capacitor is so designed that, upon failure, it will not remain short-circuited.

NOTE
Locked-rotor is specified because some motors may not start and variable results could be obtained.

B.7.3.2.7 Test for three-phase motors

Three-phase motors are tested under NORMAL CONDITION, with one phase disconnected, unless circuit controls prevent the application of voltage to the motor when one or more supply phases are missing.

The effect of other loads and circuits within the equipment may necessitate that the motor be tested within the equipment and with the three supply phases disconnected one at a time.

B.7.3.2.8 Test for series motors

Series motors are operated at a voltage equal to 1,3 times the voltage rating of the motor for 1 min with the lowest possible load.

Annex C
(informative)

Bibliography

IEC 60052 (1960-01)	Recommendations for voltage measurement by means of sphere-gaps (one sphere earthed)
IEC 60065 (2001-12)	Audio, video and similar electronic apparatus - Safety requirements
IEC 60364 series	Electrical installations of buildings
IEC 60454 series	Specifications for pressure-sensitive adhesive tapes for electrical purposes
IEC 60950-1 (2001-10)	Safety of information technology equipment
IEC Guide 105	Safety of equipment electrically connected to a telecommunication network
ISO 261:1998	ISO general-purpose metric screw threads -- General plan
ISO 262:1998	ISO general-purpose metric screw threads -- Selected sizes for screws, bolts and nuts
ISO 1043 series	Plastics -- Symbols and abbreviated terms
ISO 9772:1994	Cellular plastics - Determination of horizontal burning characteristics of small specimens subjected to a small flame
ISO 9773:1998	Plastics - Determination of burning behaviour of flexible vertical specimens in contact with a small-flame ignition source

Annex D
(normative)

Test generators

D.1 General

This annex describes the characteristics of two impulse test generators. These circuits produce test pulses as referenced in table D.1. In this table:

- the reference 1 surge is typical of voltages induced into telephone wires and coaxial cables in long outdoor cable runs due to lightning strikes to their earthing shield;
- the reference 2 surge is typical of earth potential rises due to either lightning strikes to power lines or power line faults;
- the reference 3 surge is typical of voltages induced into antenna system wiring due to nearby lightning strikes to earth.

NOTE
Extreme care is necessary when using these test generators due to the high electric charge stored in the capacitor C_1.

D.2 ITU-T test generators

The circuit in figure D.1, using the component values in references 1 and 2 of table D.1, is used to generate impulses, the C_1 capacitor being charged initially to a voltage U_c.

The impulse test circuit reference 1 of table D.1 for the 10/700 µs impulse (10 µs virtual front time, 700 µs virtual time to half value) is that specified in ITU-T Recommendation K.17 to simulate lightning interference in the EXTERNAL CIRCUIT.

The impulse test circuit reference 2 of table D.1 for the 1,2/50 µs impulse (1,2 µs virtual front time, 50 µs virtual time to half value) is that specified in IEC 60060 to simulate transients in power distribution systems.

The impulse wave shapes are under open-circuit conditions and can be different under load conditions.

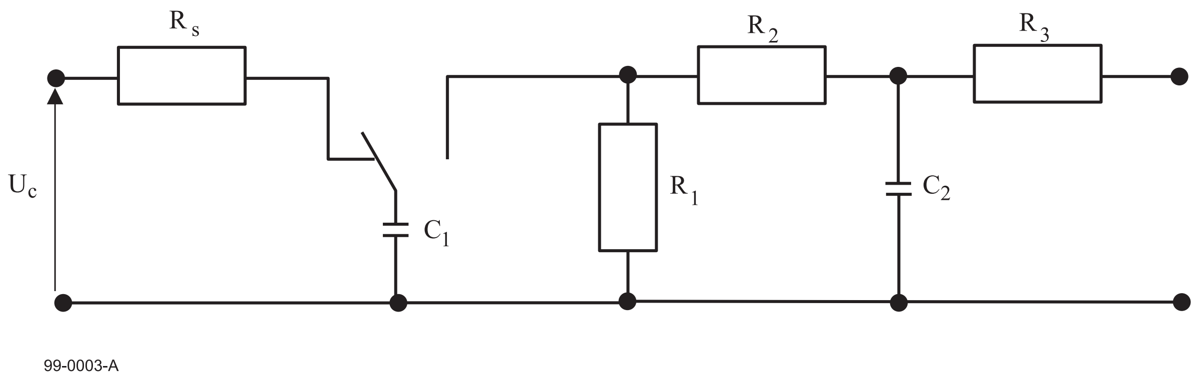


Figure D.1 – ITU-T Impulse generating circuit

D.3 Antenna interface test generator

The circuit in figure D.2, using the component values reference 3 in table D.1, is used to generate impulses, the C_1 capacitor being charged initially to a voltage U_c. The switch used in figure D.2 is a critical part of the circuit, see figure D.3.

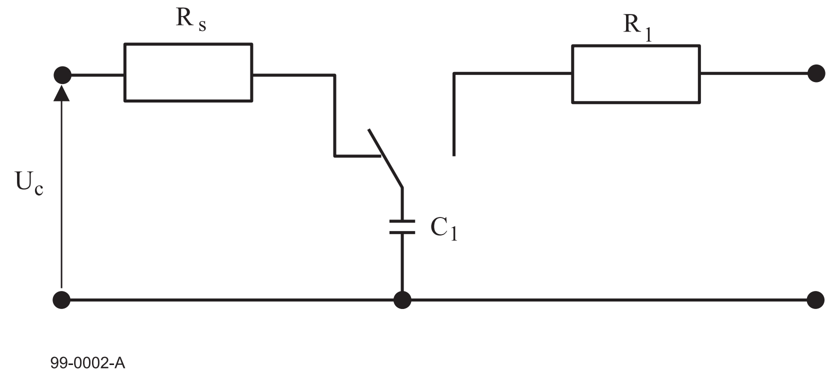


Figure D.2 – Antenna interface test generator circuit

Table D.1 – Component values for figures D.1 and D.2

Reference	Test Impulse	Figure	R_S	C_1	C_2	R_1	R_2	R_3
1	10/700 µF	D.1	-	20 µF	0,2 µF	50 Ω	15 Ω	25 Ω
2	1,2/50 µs	D.1	-	1 µF	33 nF	76 Ω	13 Ω	25 Ω
3	-	D.2	15 MΩ	1 nF	-	1 KΩ	-	-

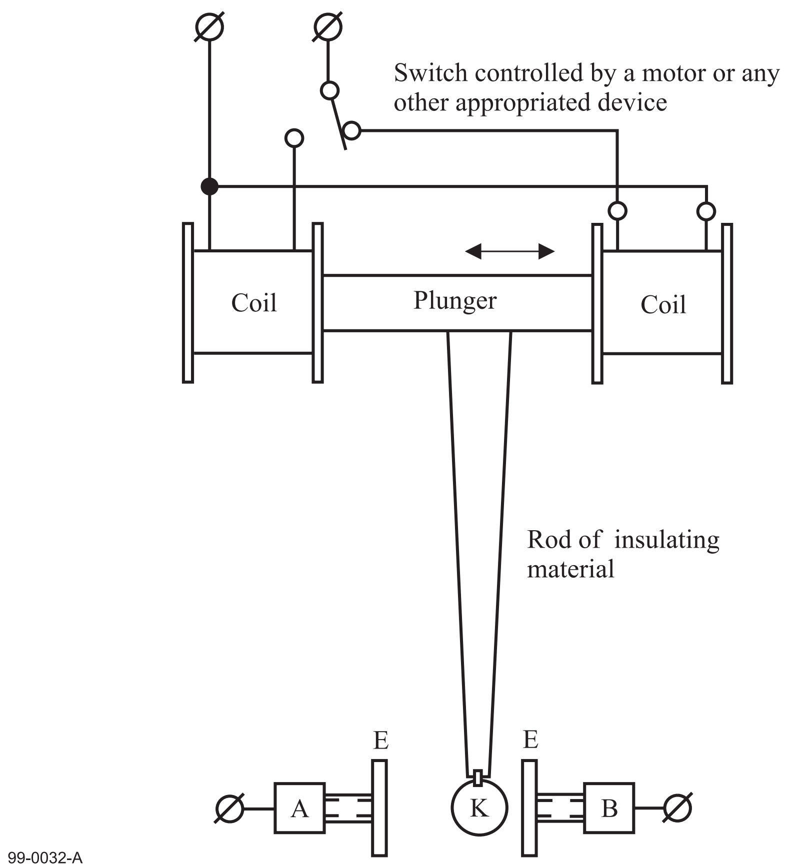
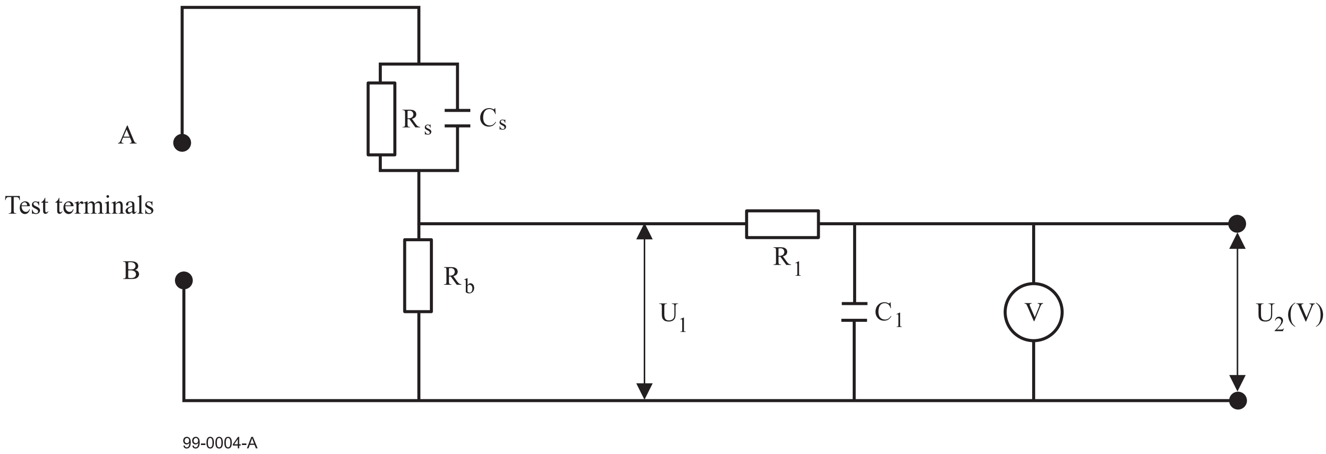


Figure D.3 – Example of a switch to be used in the test circuit

Annex E
(normative)

Measuring network for touch currents



R_1 =	10	kΩ
R_S =	1500	Ω
R_b =	500	Ω
C_S =	0,22	µF
C_1 =	0,022	µF

V: Voltmeter or oscilloscope
(r.m.s. or peak reading)

Input resistance: =	1	MΩ
Input capacitance: =	200	pF
Frequency range: and d.c. respectively	15 Hz to 1 MHz	

touch current = U_2/500 (peak value).

Figure E.1 – Measuring network for touch currents according to IEC 60990

The measuring instrument is calibrated by comparing the frequency factor of U2 with the solid line in figure F.2 of IEC 60990 at various frequencies. A calibration curve is constructed showing the deviation of U2 from the ideal curve as a function of frequency.

NOTE
Appropriate measures should be taken to obtain the correct value in case of non-sinusoidal waveforms.

Annex F
(normative)

Marking and instructions

F.1 Introduction

Equipment marking, on the outside as well as inside, might be needed for proper connection, use and servicing.

Safety instructions might be needed to ensure proper installation, interconnection, operation, maintenance and servicing.

Safety markings and instructions are required by this Standard for protection against hazards that remain when other means to eliminate or reduce them are not practical. Where safety markings need to be on the equipment, preference should be given to graphical symbols in accordance with IEC 60417 and ISO 3864. This may be a combination of marking signs and information signs. In the absence of suitable symbols in IEC 60417-1 the manufacturer may design specific graphical symbols. Other markings are permitted, provided they do not conflict with required markings or instructions. Where written warnings are given they should be in a language acceptable to the country where the equipment is intended to be used.

NOTE 1
For marking of components the relevant component standards apply.

NOTE 2
Other applicable standards and regulations may require additional marking or instructions for the ORDINARY PERSON, INSTRUCTED PERSON or SKILLED PERSON.

F.2 Marking

Equipment shall bear markings in accordance with F.2.1 to F.2.1.4.

F.2.1 General

Unless specifically permitted to be temporary, markings shall be permanent and comprehensible.

Except for marking of internal parts, markings shall be easily discernible on the equipment when ready for use.

The marking should preferably be on the exterior of the equipment, excluding the bottom. It is, however, permitted to have it in an area that is easily accessible by hand, for example under a lid, or on the exterior of the bottom of a portable equipment or an equipment with a mass not exceeding 7 kg, provided that the location of the marking is given in the instructions for use.

For PERMANENTLY CONNECTED EQUIPMENT, installation instructions shall be provided either as markings on the equipment or in a separate installation instruction document.

Markings applying to the equipment as a whole shall not be put on parts which can be removed by a ORDINARY PERSON without the use of a TOOL.

For rack or panel mounted equipment, markings are permitted to be on any 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.

Graphical symbols shall be in accordance with IEC 60417 and ISO 7000, as appropriate.

Markings which are printed or screened on the equipment shall contrast with the background.

Markings which are moulded or engraved shall have a depth or be raised to a height of minimum 0,5 mm, unless contrasting colours are used.

In all cases the meaning of the markings shall be explained in the relevant documentation.

F.2.1.1 Identification

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

- manufacturer’s or responsible vendor's name, trade mark or identification mark;
- model number, name or other means to identify the equipment.

F.2.1.2 Supply ratings

The equipment shall be marked with the following information.

a) Nature of supply:

- d.c. only with the symbol:  (IEC 60417-2; -5031)
- three-phase a.c. systems with the symbol: 02-0030-A
- RATED VOLTAGE or RATED VOLTAGE range which can be applied without operating a voltage setting device.

  Equipment which can be set to different RATED VOLTAGES or RATED VOLTAGE ranges shall be so constructed that the RATED VOLTAGE or RATED VOLTAGE ranges to which the equipment is set, is discernible on the equipment when ready for use;

  A solidus shall be used for ORDINARY PERSON selectable RATED VOLTAGES as well as RATED VOLTAGE ranges, for example “110/230 V” and a hyphen shall be used for a RATED VOLTAGE range, for example “110-230 V”;

b) RATED FREQUENCY or RATED FREQUENCY range in Hertz, if safety is dependent on the use of the correct frequency;

c) RATED CURRENT for equipment which can be supplied by supply equipment for general use.

d) RATED CURRENT for equipment intended for connection to the MAINS other than single phase, for PERMANENTLY CONNECTED EQUIPMENT and for equipment for professional use.

F.2.1.3 Terminals and operating devices

Terminals and operating devices shall be marked as follows:

a) The wiring terminal intended for connection of the PROTECTIVE EARTHING CONDUCTOR associated with the supply wiring:

 02-0031-A (IEC 60417-2; -5019)

This symbol shall not be used for other earthing terminals.

It is not a requirement to mark terminals for PROTECTIVE BONDING CONDUCTORS, but where such terminals are marked, the symbol (IEC-60417-2; -5017) shall be used.

The following situations are exempt from the above requirements:

- where terminals for the connection of a supply are provided on a component (e.g., terminal block) or subassembly (e.g. power supply), the symbol is permitted for the protective earthing terminal instead of (IEC 60417-2; -5019);
- on subassemblies or components, the symbol (IEC 60417-2; -5019) is permitted in place of the symbol (IEC 60417-2; -5017) provided that it does not give rise to confusion.

A wiring terminal intended exclusively for connection of the MAINS neutral conductor, if any, shall be indicated by the capital letter “N”.

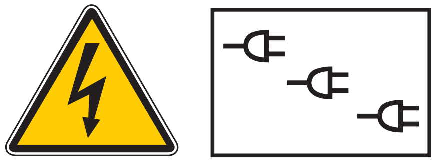
These indications shall not be placed on screws, removable washers or other parts which can be removed when conductors are being connected.

These requirements are applicable to terminals for connection of a PROTECTIVE EARTHING CONDUCTOR whether provided as an integral part of a power supply cord or with separate supply conductors.

b) Terminals which are at ES 3 level under NORMAL CONDITION, except terminals for MAINS:

99-0010-A (IEC 60417-1; 5036)

c) Stationary equipment for multiple supply shall be marked with the following symbols, the number of power plugs indicating the number of supply circuits:



99-0009-A

In case of a written warning, it shall have the following or similar wording:

Warning:
Before obtaining access to terminals, all supply circuits must be disconnected.

This warning shall be placed in the vicinity of the terminal cover.

d) Output terminals of equipment supplying power to other equipment, except socket-outlets directly connected to the MAINS, shall be marked with the nominal output voltage and, in addition, the maximum output current, if with the most unfavourable load higher temperature rises than allowed can occur, unless the terminals are marked with the type references of the equipment which are permitted to be connected.

Socket-outlets providing MAINS power to other equipment shall be marked with the power or current which may be drawn.

If there is only one terminal provided for supply of other equipment, the marking may be put on the equipment at any place, taking into account the first paragraphs of F.2.1.

e) If symbols are used on or near MAINS switches or circuit-breakers to indicate the on-position, the off-position or the stand by position of the equipment, the following applies:

ON symbol:	(IEC 60417-2; -5007)
OFF symbol:	(IEC 60417-2; -5008)
STAND-BY symbol:	(IEC 60417-2; -5009)

It is permitted to use the symbols to indicate the position of any primary or secondary power switches, including isolating switches.

f) Fuses replaceable by an ORDINARY PERSON shall be marked, close to the fuse holder, with the fuse symbol (IEC 60417; 5016), current rating and type, such as indication of rupturing speed, for example by the codes of IEC 60127. Where fuses of different voltage rating value could be fitted, the fuse voltage rating shall be indicated.
Where fuses are intended to be replaced only by an INSTRUCTED PERSON or a SKILLED PERSON, it is permitted to provide the information in the service instructions.
Where fuses are not intended to be replaced no marking is required.

g) Where a plug on the power supply cord is used as the DISCONNECT DEVICE, the installation and service instructions shall state that the power supply cord plug is the DISCONNECT DEVICE. For pluggable equipment intended for installation by an ORDINARY PERSON, the installation instructions shall be made available to the ORDINARY PERSON. Where servicing of pluggable equipment is necessary by an ORDINARY PERSON, in addition to other means of protection, the operating instructions shall direct the ORDINARY PERSON to disconnect the power supply cord from the MAINS.

h) Suitable marking shall be provided on the equipment or a statement shall be provided in the servicing instructions to alert a SKILLED PERSON to a possible hazard where both of the following conditions exist:

- Where a fuse is used in the neutral of single phase equipment either permanently connected or provided with a non-reversible plug; and
- Where, after operation of the fuse, parts of the equipment that remain energized might represent a hazard during servicing.

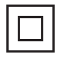
The following or similar working is regarded as suitable:

CAUTION
DOUBLE POLE/NEUTRAL FUSING

F.2.1.4 Equipment classification

The equipment shall be marked with the following information:

- the symbol for Class II equipment, if applicable:

 02-0022-A (IEC 60417-2; -5172)

  This symbol shall not be used on equipment which is partly of Class I construction, or is provided with a protective earth terminal.

- IP number according to degree of protection against ingress of water, if other than IP X0.

F.2.2 Test method

Compliance is checked by inspection, by the test of F.2.2.1 and by measurement according to F.2.2.2.

F.2.2.1 Test on the permanence of the marking

In order to verify whether the marking is permanent, the following test is carried out.

The marking is rubbed by hand for 15 s with a piece of cloth soaked with water and, at a different place or on a second sample, for 15 s with a piece of cloth soaked with petroleum spirit.

NOTE
Petroleum spirit, to be used for reference purposes is defined as follows: The petroleum spirit is an aliphatic solvent hexane having a maximum aromatics content of 0,1 % by volume, a kauri-butanol value of 29, an initial boiling point of approximately 65 °C, a dry-point of approximately 69 °C and a specific mass of approximately 0,7 kg/l.

F.2.2.2 Measurement of power or current

The measurement of input power or input current is made under NORMAL CONDITION (annex B.4), except that the equipment is connected to its RATED VOLTAGE.

F.2.3 Compliance criteria

The markings shall be complete and applied correctly.

F.2.3.1 Rubbing test

After this test the marking shall be legible; it shall not be easily possible to remove marking plates and they shall show no curling.

F.2.3.2 Measurement of power or current

The measured value shall not exceed the marked value by more than 10 %.

F.3 Instructions

F.3.1 General

For ORDINARY PERSONS, when information with regard to safety is required according to this Standard, this information shall be given in an instruction for installation or use or be made available. This information shall be given in a language acceptable to the country where the equipment is intended to be used and shall be accessible prior to the installation of the equipment.

NOTE
Reference is made to ISO/IEC Guide 37.

The instructions shall include the following as far as applicable.

a) For MAINS powered equipment and for equipment producing internal voltages greater than ES 1 level, having no protection against splashing water according to IEC 60529, IP X4, the instructions for use shall state that the equipment shall not be exposed to dripping or splashing and that no objects filled with liquids, such as vases, shall be placed on the equipment.

b) A statement in case equipment is intended exclusively for use in a restricted access location.

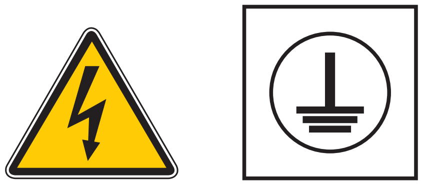
c) A warning that terminals marked with the symbol according to F.2.1.3 b) are at ES 3 level and that the external wiring connected to these terminals requires installation by an INSTRUCTED PERSON or the use of ready-made leads or cords.

d) A warning that equipment with Class I construction shall be connected to the protective earth connection (e.g. wall socket outlet).

e) A warning for equipment which is provided with or connected to a main protective earth terminal, in case the touch current through a PROTECTIVE EARTHING CONDUCTOR exceeds 3,5 mA r.m.s., or in case connection ports allow the connection of multiple items of other equipment. In case of verbal warning it shall have the following or similar wording:

Warning
High leakage current possible
Earth connection essential before connecting supply

The graphical symbols are:



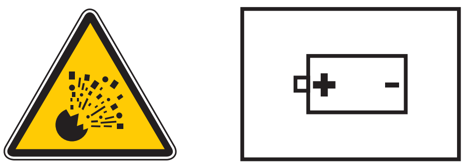
99-0011-A

f) Instructions to ensure correct and safe installation and interconnection of the equipment in multimedia systems.

g) If an equipment is provided with a replaceable lithium battery, the following applies:

- if the battery is intended to be replaced by an ORDINARY PERSON, there shall be a warning close to the battery or in both the instructions for use and the service instructions;
- if the battery is not intended to be replaced by an ORDINARY PERSON, there shall be a warning close to the battery or in the service instructions.

The graphical symbols are:



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In case of a verbal warning it shall include the following or similar text:

CAUTION
Danger of explosion if battery is incorrectly replaced.
Replace only with the same or equivalent type.

h) Explanation of symbols used.

i) If a PERMANENTLY CONNECTED EQUIPMENT is not provided with an all-pole MAINS switch, the instructions shall state that an all-pole MAINS switch with a contact separation of at least 3 mm in each pole shall be incorporated in the electrical installation of the building.

NOTE
The following information with regard to safety is recommended to be included as far as applicable:

- *minimum distances around the equipment for sufficient ventilation;*
- *the ventilation should not be impeded by covering the ventilation openings with items, such as newspapers, table-cloths, curtains, etc.;*
- *no naked flame sources, such as lighted candles, should be placed on or near to the equipment;*
- *attention should be drawn to the environmental aspects of battery disposal;*
- *attention should be drawn to the correct replacements and disposal of hazardous chemical consumables*
- *the use of equipment in tropical and/or moderate climates.*
- *an instruction not to position the equipment so that it is difficult to operate the disconnecting device.*

F.3.1.1 Other information

Where in a manufacturer's service documentation, for example in circuit diagrams or lists of components, a symbol is used to indicate that a specific component shall be replaced only by the component specified in that documentation for safety reasons, the following symbol shall be used:


02-0023-A (ISO 7000-0434)

The colour of the symbol is optional, the printing can be as shown or with opposite colour setting.

The symbol may also be put adjacent to the relevant component, but shall not be placed on components.

F.3.2 Test method

Compliance is checked by inspection.

F.3.3 Compliance criteria

Instructions for installation or use or other documentation shall give the necessary safety information to the user and to service personnel.

Annex G
(normative)

Components

G.1 Switches

Mechanical switches controlling currents exceeding 0,2 A a.c or d.c. shall meet the following requirements if the voltage across the open switch contacts exceeds 35 V peak a.c. or 24 V d.c.:

- Comply with the flammability category V-0 according to IEC 60707;
- Comply with the requirements of IEC 61058-1, whereby the following applies:
  - 10.000 operating cycles (see IEC 61058-1, 7.1.4.4);
  - the switch shall be suitable for use in a normal pollution situation;
  - the switch shall be of level 3 regarding the resistance to heat and fire;
  - for MAINS switches the speed of contact making and breaking shall be independent of the speed of actuation;
  - The characteristics of the switch with regard to the ratings and classification (see IEC 61058-1) shall be appropriate for the function of the switch under NORMAL CONDITION. Compliance is checked according to IEC 61058-1.
- The switch shall be so constructed that it does not attain excessive temperatures during intended use. Compliance is checked in the on-position according to IEC 61058-1, 16.2.2 d, l and m, taking into account the total rated current of MAINS socket-outlets, if any, including peak surge current according to table G.1.
- A MAINS switch controlling MAINS socket-outlets shall withstand the endurance test with an additional load according to IEC 61058-1, figure 9 and 10. The total current rating of the additional load shall correspond to the marking of the socket-outlets. The peak surge current of the additional load shall have a value as shown in table G.1.

Table G.1 – Peak surge current

Total rated current of the switch controlled socket-outlets	Peak surge current
≤ 0,5 A	20 A
> 0,5 A ≤ 1,0 A	50 A
>1,0 A ≤ 2,5 A	100 A
> 2,5 A	150 A

G.1.1 Test method

For MAINS switches the tests of IEC 61058-1 shall be applied with the modifications shown in G.1.

G.1.2 Compliance criteria

After the tests, the switch shall show no damage in the sense of this Standard. In particular, it shall show no deterioration of its enclosure, no reduction of CLEARANCES and CREEPAGE DISTANCES and no loosening of electrical connections or mechanical fixings.

G.2 Thermal cut-outs

A THERMAL CUT-OUT shall meet either requirements a) or b) below.

a) The THERMAL CUT-OUT when tested as a separate component, shall comply with the requirements and tests of IEC 60730 series as far as applicable

- the THERMAL CUT-OUT shall be of type 2 action (see IEC 60730-1, 6.4.2);

- the THERMAL CUT-OUT shall have at least micro-disconnection (type 2B) (see IEC 60730-1, 6.4.3.2 and 6.9.2);
- the THERMAL CUT-OUT shall have a trip-free mechanism in which contacts cannot be prevented from opening against a continuation of a fault (type 2E) (see IEC 60730-1, 6.4.3.5);
- the number of cycles of automatic action shall be at least
  - 3000 cycles for a THERMAL CUT-OUT with automatic reset used in circuits which are not switched-off when the equipment is switched-off (see IEC 60730-1, 6.11.8),
  - 300 cycles for a THERMAL CUT-OUT with no automatic reset which can be reset by hand from the outside of the equipment (see IEC 60730-1, 6.11.10),
  - 30 cycles for a THERMAL CUT-OUT with no automatic reset and which cannot be reset by hand from the outside of the equipment (see IEC 60730-1, 6.11.11);
- the THERMAL CUT-OUT shall be tested as designed for a long period of electrical stress across insulating parts (see IEC 60730-1, 6.14.2);
- the THERMAL CUT-OUT shall meet the ageing requirements for an intended use of at least 10 000 h (see IEC 60730-1, 6.16.3).
- The characteristics of the THERMAL CUT-OUT with regard to:
  - the ratings of the THERMAL CUT-OUT (IEC 60730-1, clause 5);
  - the classification of the THERMAL CUT-OUT according to
    + nature of supply (IEC 60730-1, 6.1),
    + type of load to be controlled (IEC 60730-1, 6.2),
    + degree of protection provided by ENCLOSURES against ingress of solid objects and dust (IEC 60730-1, 6.5.1),
    + degree of protection provided by ENCLOSURES against harmful ingress of water (IEC 60730-1, 6.5.2),
    + pollution situation for which the THERMAL CUT-OUT is suitable (IEC 60730-1, 6.5.3),
    + maximum ambient temperature limit (IEC 60730-1, 6.7);

  shall be appropriate for the application in the equipment under NORMAL CONDITIONS and under fault conditions.

b) The THERMAL CUT-OUT when tested as a part of the equipment shall:

- have a trip-free mechanism in which contacts cannot be prevented from opening against a continuation of a fault, and;
- be aged for 300 h at a temperature corresponding to the ambient temperature of the THERMAL CUT-OUT when the equipment is operated under NORMAL CONDITION at an ambient temperature of 30 °C or higher if specified by the manufacturer, and;
- be subjected to a number of cycles of automatic action as specified under a) for a THERMAL CUT-OUT tested as a separate component, by estimating the relevant fault conditions.

The test is made on three specimens.

G.2.1 Test method

Compliance is checked according to the test specifications of IEC 60730 series by inspection and by measurement.

G.2.2 Compliance

Requirements of G.2 are fulfilled.

No sustained arcing shall occur during the test. After the test, the THERMAL CUT-OUT shall show no damage in the sense of this Standard. In particular, it shall show no deterioration of its ENCLOSURE, no reduction of CLEARANCES and CREEPAGE DISTANCES and no loosening of electrical connections or mechanical fixings.

G.3 Thermal links

A thermal link shall meet either requirements **a)** or **b)** below.

a) The thermal link when tested as a separate component, shall comply with the requirements of IEC 60691. The characteristics of the thermal link with regard to:

- the ambient conditions (see IEC 60691, 6.1);
- the circuit conditions (see IEC 60691, 6.2);
- the rating of the thermal link (see IEC 60691, 8 b);
- the suitability for sealing in or use with impregnating fluids or cleaning solvents (see IEC 60691, 8 c).

shall be appropriate for the application in the equipment under NORMAL CONDITION and under fault conditions.

b) The thermal link when tested as a part of the equipment shall be:

- aged for 300 h at a temperature corresponding to the ambient temperature of the thermal link when the equipment is operated under NORMAL CONDITION at an ambient temperature of 30°C or higher if specified by the manufacturer, and
- subjected to such fault conditions of the equipment which cause the thermal link to operate. During the test no sustained arcing and no damage in sense of this Standard shall occur, and
- capable of withstanding two times the voltage across the disconnection and have an insulation resistance of at least 0,2 MΩ, when measured with a voltage equal to two times the voltage across the disconnection.

G.3.1 Test method

If a thermal link is tested as a separate component, see a) above, compliance is checked according to the test specifications of IEC 60691, by inspection and measurement.

If a thermal link is tested as a part of the equipment, see b) above, compliance is checked by inspection and by the specified tests in the given order. The test is made 10 times. No failure is allowed. The thermal link is replaced after each test.

G.4 PTC-S thermistors

PTC-S thermistors used in order to prevent the equipment from becoming unsafe within the meaning of this Standard shall comply with IEC 60738.

For PTC-S thermistors whose power dissipation exceeds 15 W for the rated zero-power resistance at an ambient temperature of 25 °C, the encapsulation or tubing shall comply with the flammability category V-1 or better according to IEC 60707.

G.4.1 Test method

Compliance is checked by inspection and where applicable by the tests of IEC 60738.

G.5 Protective devices not mentioned in G.2 to G.4

Such protective devices, for example fusing resistors, fuse-links not standardized in IEC 60127 or miniature circuit breakers, shall have adequate rating including breaking capacity.

For non-resettable protective devices, such as fuse-links, a marking shall be located close to the protective device, so that correct replacement is possible.

G.5.1 Test method

Compliance is checked by inspection and during the tests under ABNORMAL CONDITION (see 4.3).

The test under fault condition is carried out three times.

G.5.2 Compliance criteria

No failure is allowed.

G.6 High voltage components and assemblies

Components operating at voltages exceeding 4 kV peak and spark gaps provided to protect against overvoltages, if not otherwise covered by 4.3.6.6, shall not give rise to danger of fire to the surroundings of the equipment, or to any other hazard within the sense of this Standard.

The components shall be of flammability category V-1 according to IEC 60707, or better or pass the test of G.6.1.

Wiring working at voltages exceeding 4 kV peak a.c. or d.c. shall pass the test of U.3.

G.6.1 Test method

Compliance is checked by inspection or by the following test for high voltage transformers and multipliers.

Three specimens of the transformer with one or more high-voltage windings or of the high-voltage multipliers are subjected to the treatment specified under a), followed by the test specified under b).

a) Preconditioning

For transformers, a power of 10 W (a.c. at RATED FREQUENCY or d.c.) is initially supplied to the high-voltage winding. This power is sustained for 2 min, after which it is increased by successive steps of 10 W at 2 min intervals to 40 W.

The treatment lasts 8 min or is terminated as soon as interruption of the winding or appreciable splitting of the protective covering occurs.

NOTE 1
Certain transformers are so designed that this preconditioning cannot be carried out. In such cases, only the test of item b) below is applied.

For high-voltage multipliers, a voltage taken from an appropriate high-voltage transformer, is supplied to each specimen, its output circuit being short-circuited.

The input voltage is adjusted so that the short-circuit current is initially 25 mA ± 5 mA. This is maintained for 30 min or is terminated as soon as any interruption of the circuit or appreciable splitting of the protective covering occurs.

NOTE 2
Where the design of a high-voltage multiplier is such that a short-circuit current of 25 mA cannot be obtained, a preconditioning current is used, which represents the maximum attainable current, determined either by the design of the multiplier or by its conditions of use in a particular equipment.

b) Flame test

The specimen is subjected to the flammability test of U.2.

G.7 Transformers

Inductors and windings shall comply with either the requirements of IEC 61558-1 and the relevant parts of IEC 61558-2, with the following additions and limitations:

- insulating material of inductors and windings, except in thin sheet form, shall comply with flammability class V-1,
- the limit values for ES 1of this Standard apply (see 3.1),
- for working voltages above 1000 V (see IEC 61558-1, sub-clause 18.3), the test voltages according to table 3.14 have to be applied.
- the overload test according to B.7.3.1.

or with the requirements given in G.7.1 to G.7.3.

NOTE
Examples of relevant parts of IEC 61558-2 are:

- *IEC 61558-2-1: Separating transformers*
- *IEC 61558-2-4: Isolating transformers*
- *IEC 61558-2-6: Safety isolating transformers*
- *IEC 61558-2-17: Transformers for switch mode power supplies*

G.7.1 General

Transformers shall comply with the relevant requirements of this Standard, including G.7.2 and G.7.3.

G.7.2 Insulation

Insulation in transformers shall comply with the following requirements.

Windings and conductive parts of transformers shall be treated as parts of the circuits to which they are connected, if any. The insulation between them shall comply with the relevant requirements of clause 3 and pass the relevant dielectric strength tests, according to the application of the insulation in the equipment.

Precautions shall be taken to prevent the reduction below the required minimum values of CLEARANCES and CREEPAGE DISTANCE that provide BASIC INSULATION, SUPPLEMENTARY INSULATION or REINFORCED INSULATION by:

- displacement of windings, or their turns;
- displacement of internal wiring or wires for external connections;
- undue displacement of parts of windings or internal wiring, in the event of rupture of wires adjacent to connections or loosening of the connections;
- bridging of insulation by wires, screws, washers and the like should they loosen or become free.

It is not expected that two independent fixings will loosen at the same time.

All windings shall have the end turns retained by positive means.

NOTE
Examples of acceptable forms of construction are the following (there are other acceptable forms of construction):

- *windings isolated from each other by placing them on separate limbs of the core, with or without spools;*
- *windings on a single spool with a partition wall, where either the spool and partition wall are pressed or moulded in one piece, or a pushed-on partition wall has an intermediate sheath or covering over the joint between the spool and the partition wall;*
- *concentric windings on a spool of insulating material without flanges, or on insulation applied in thin sheet form to the transformer core;*
- *insulation is provided between windings consisting of sheet insulation extending beyond the end turns of each layer;*
- *concentric windings, separated by an earthed conductive screen which consists of metal foil extending the full width of the windings, with suitable insulation between each winding and the screen. The conductive screen and its lead-out wire have a cross section sufficient to ensure that on breakdown of the insulation an overload device will open the circuit before the screen is destroyed. The overload device may be a part of the transformer.*

G.7.2.1 Test method

Compliance is checked by inspection and measurement.

If a transformer is fitted with an earthed screen for protective purposes, the transformer shall pass the test of 3.8.4.2 between the earthed screen and the earthing terminal of the transformer.

No dielectric strength test applies to insulation between any winding and the core or screen, provided that the core or screen is totally enclosed or encapsulated and there is no electrical connection to the core or screen. However, the tests between windings which have terminations continue to apply.

G.7.3 Requirements after overload test

NOTE
See also B.7.3.1.

Maximum temperatures of windings shall not exceed the values in table G.2 when measured as specified in B.5 and B.6, and determined as specified below:

- with external overcurrent protection: at the moment of operation, for determination of the time until the overcurrent protection operates, it is permitted to refer to a data sheet of the overcurrent protection device showing the trip time versus the current characteristics;
- with an automatic reset THERMAL CUT-OUT: after 4 h;
- with a manual reset THERMAL CUT-OUT: at the moment of operation;
- for current-limiting transformers: after temperature has stabilized.

Secondary windings which exceed the temperature limits but which become open circuit or otherwise require replacement of the transformer do not constitute a failure of this test, provided that no hazard is created in the meaning of this Standard.

Table G.2 – Permitted temperature limits for transformer windings

	Maximum temperature				
	Class A	Class E	Class B	Class F	Class H
Protection by inherent or external impedance	150 °C	165 °C	175 °C	190 °C	210 °C
Protection by a protective device which operates during the first hour	200 °C	215 °C	225 °C	240 °C	260 °C
Protection by any protective device: • maximum after the first hour • arithmetic average during the 2nd hour and during the 72nd hour	175 °C 150 °C	190 °C 165 °C	200 °C 175 °C	215 °C 190 °C	235 °C 210 °C

The arithmetic average temperature is determined as follows:

The graph of temperature against time (see figure G.1), while the power to the transformer is cycling on and off, is plotted for the period of test under consideration. The arithmetic average temperature (t_A) is determined by the formula:

$$t_A = \frac{t_{max} + t_{min}}{2}$$

where:

- t_{max} *is the average of the maxima*
- t_{min} *is the average of the minima*

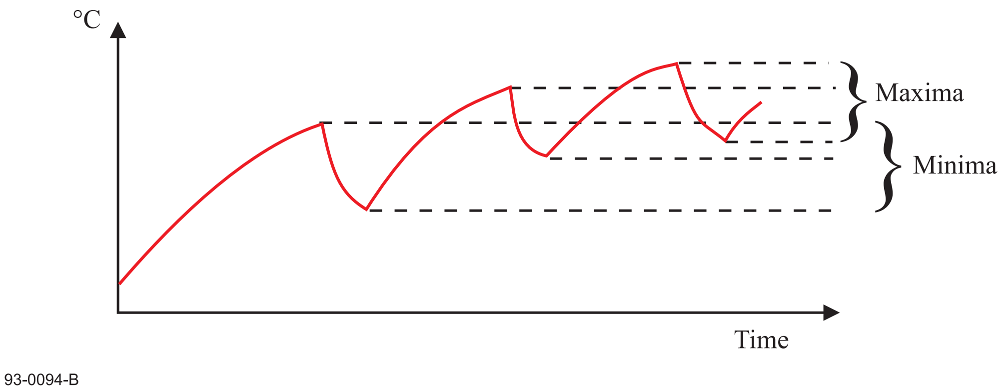


Figure G.1 – Determination of arithmetic average temperature

G.8 Motors

G.8.1 General requirements

Motors, other than d.c. motors, shall pass the overload tests of B.7.3.2.2 and B.7.3.2.3 and, where applicable, B.7.3.2.6, B.7.3.2.7 and B.7.3.2.8.

However, the following motors are not required to pass the test of B.7.3.2.2:

- motors which are used for air-handling only and where the air-propelling component is directly coupled to the motor shaft, and
- shaded pole motors whose values of locked-rotor current and no-load current do not differ by more than 1 A and have a ratio of not more than 2/1.

DC motors shall pass the tests of B.7.3.2.4, B.7.3.2.5 and B.7.3.2.8. Motors which by their intrinsic operation normally operate under locked-rotor conditions, such as stepper motors, are exempted from testing.

G.8.2 Compliance criteria

G.8.2.1 Maximum temperatures

For the tests according to B.7.3.2.3, B.7.3.2.5, B.7.3.2.6 and B.7.3.2.7 the temperature limits, as specified in table G.3, shall not be exceeded.

Table G.3 – Permitted temperature limits for motor windings (except for running overload test)

	Maximum temperature				
	Class A	Class E	Class B	Class F	Class H
Protection by inherent or external impedance	150 °C	165 °C	175 °C	190 °C	210 °C
Protection by a protective device which operates during the first hour	200 °C	215 °C	225 °C	240 °C	260 °C
Protection by any protective device: • maximum after the first hour • arithmetic average during the 2nd hour and during the 72nd hour	 175 °C 150 °C	 190 °C 165 °C	 200 °C 175 °C	 215 °C 190 °C	 235 °C 210 °C

The arithmetic average temperature is determined as follows:

The graph of temperature against time (see figure G.1), while the power to the motor is cycling on and off, is plotted for the period of test under consideration. The arithmetic average temperature (t_A) is determined by the formula:

$$t_A = \frac{t_{max} + t_{min}}{2}$$

where:

- *t_{max} is the average of the maxima*
- *t_{min} is the average of the minima*

For the tests according to B.7.3.2.2 and B.7.3.2.4 the temperature limits, as specified in table G.4, shall not be exceeded for each class of insulating material.

Table G.4 – Permitted temperature limits for running overload tests

Maximum temperature (°C)				
Class A	Class E	Class B	Class F	Class H
140	155	165	180	200

G.8.2.2 Locked-rotor overload test

After the period specified for temperature measurement in B.7.3.2.3, the motor shall withstand the dielectric strength test in 3.6.14 after the insulation has cooled to room temperature and with test voltages reduced to 0,6 times the specified values. No further dielectric strength test is required.

G.8.2.3 Running overload test for d.c. motors

The motor winding temperatures are determined during each steady period and the maximum temperature recorded shall not exceed the value in table G.4, except that, where difficulty is experienced in obtaining accurate temperature measurements, due to the small size or unconventional design of the motor, it is permitted to use the following test instead of temperature measurement.

During the running overload test B.7.2.3.4, the motor is covered with a single layer of bleached cotton cheesecloth of approximately 40 g/m^2. There shall be no ignition of the cheesecloth during the test or at its conclusion.

Compliance with either method is acceptable; it is not necessary to comply with both methods.

G.8.2.4 Locked-rotor overload test for d.c. motors

At the conclusion of B.7.3.2.5, test b), there shall be no ignition of the wrapping tissue or cheesecloth.

G.8.2.5 Test for series motors

After the test of B.7.3.2.8, windings and connections shall not have worked loose and no hazard shall be present within the meaning of this Standard.

G.9 Mains supply cords

A MAINS supply cord for connection to the MAINS shall be of the sheathed type and comply with the following as appropriate:

- if rubber sheathed, be of synthetic rubber and not lighter than ordinary tough rubber-sheathed flexible cord according to IEC 60245 (designation 60245 IEC 53);
- if PVC sheathed:
  - for equipment provided with a NON-DETACHABLE POWER SUPPLY CORD and having a mass not exceeding 3 kg, be not lighter than light PVC sheathed flexible cord according to IEC 60227 (designation 60227 IEC 52);
  - for equipment provided with a NON-DETACHABLE POWER SUPPLY CORD and having a mass exceeding 3 kg, be not lighter than ordinary PVC sheathed flexible cord (designation 60227 IEC 53);
  - for equipment provided with a detachable power supply cord, be not lighter than light PVC sheathed flexible cord according to IEC 60227 (designation 60227 IEC 52).

  NOTE
  There is no limit on the mass of the equipment if the equipment is intended for use with a detachable power supply cord.
- include, for equipment required to have protective earthing, a PROTECTIVE EARTHING CONDUCTOR having green-and-yellow insulation.
- MAINS supply cords shall have conductors with cross-sectional areas not less than those specified in table G.5.

Table G.5 - Sizes of conductors in mains supply cords

Rated current of the equipment 1) A	Nominal cross-sectional area mm^2	AWG [cross-sectional area in mm^2] see note 2
≤ 3	0,50 2)	20 [0,5]
> 3 ≤ 6	0,75	18 [0,8]
> 6 ≤ 10	(0,75) 3) 1,00	16 [1,3]
> 10 ≤ 16	(1,0) 4) 1,5	14 [2]
> 16 ≤ 25	2,5	12 [3]
> 25 ≤ 32	4	10 [5]
> 32 ≤ 40	6	8 [8]
> 40 ≤ 63	10	6 [13]
> 63 ≤ 80	16	4 [21]
> 80 ≤ 100	25	2 [33]
> 100 ≤ 125	35	1 [42]
> 125 ≤ 160	50	0 [53]

1) The RATED CURRENT includes currents which can be drawn from the socket-outlet providing MAINS power for other equipment.

2) This nominal cross-sectional area is allowed only for Class II equipment and provided that the length of the supply cord, measured between the point where the cord, or the cord guard, enters the equipment, and the entry to the plug, does not exceed 2 m.

3) The value in parentheses applies to detachable power supply cords fitted with the connectors rated 10 A in accordance with IEC 60320 (types C13, C15, C15A and C17), provided that the length of the cord does not exceed 2 m.

4) The value in parentheses applies to detachable power supply cords fitted with the connectors rated 16 A in accordance with IEC 60320 (types C19, C21 and C23), provided that the length of the cord does not exceed 2 m.

NOTE 1
IEC 60320 specifies acceptable combinations of appliance couplers and flexible cords, including those covered by conditions 1), 2) and 3). However, a number of countries have indicated that they do not accept all of the values listed in Table 11, particularly those covered by conditions 2), 3) and 4).

NOTE 2
AWG sizes are provided for information only. The associated cross-sectional areas, in square brackets, have been rounded to show significant figures only. AWG refers to the American Wire Gage. This term is commonly used to designate wire sizes in North America.

G.9.1 Test method

Compliance is checked by inspection.

In addition, for screened cords, compliance is checked by the tests of IEC 60227.

NOTE
Although screened cords are not covered in the scope of IEC 60227, the relevant tests of IEC 60227 are used.

G.9.2 Compliance criteria

The appropriate cord shall be used. For screened cords damage to the screen is acceptable provided that:

- during the flexing test the screen does not make contact with any conductor, and
- after the flexing test, the sample withstands the dielectric strength test between the screen and all other conductors.

G.10 Voltage dependent resistors (VDRs)

G.10.1 General

It is permitted to use VDRs to reduce transient voltages for the protection of components and insulation.

G.10.2 Component properties

A VDR shall comply with IEC 61051-2, with the following details.

a) Preferred climatic categories (IEC 61051-2, subclause 2.1.1)

- lower category temperature : - 10 °C
- upper category temperature: + 85 °C
- duration of damp heat, steady state test: 21 days

b) Maximum continuous voltage (IEC 61051-2, subclause 2.1.2)

- at least 1,25 times the RATED VOLTAGE of the equipment or
- at least 1,25 times the upper voltage of the RATED VOLTAGE range.

c) Pulse current (IEC 61051-2, table I group 1)

For the test, combination pulses 6 kV/3 kA of alternating polarity are used, having a combination pulse shape of 1,2/50 µs for voltage and 8/20 µs for current.

In addition to the performance requirements of IEC 61051-2, table I group 1, the VDR voltage after the test shall not have changed by more than 10 % when measured with the manufacturer's specified current.

G.10.3 Protection of VDRs

For protection against:

- temporary overvoltages above the maximum continuous voltage;
- thermal overload due to leakage current within the VDR;
- burning and bursting of the VDR in the event of a short-circuit fault;

an interrupting means having an adequate breaking capacity shall be connected in series with the VDR.

NOTE 1
For temporary overvoltages from the MAINS, see IEC 60664-1.

NOTE 2
During the life-time of a VDR the leakage current increases with the number of switching cycles in the VDR. This leakage current causes a permanent and continuously increasing temperature stress, which can cause the VDR to burn or burst.

Annex H
(normative)

Criteria for telephone ringing signals

H.1 Introduction

The two alternative methods described in this annex reflect satisfactory experience in different parts of the world. Method A is typical of analogue telephone networks in Europe, and Method B of those in North America. The two methods result in standards of electrical safety which are broadly equivalent.

H.2 Method A

This method requires that the currents I_{TS1} and I_{TS2} flowing through a 5 000 Ω resistor, between any two conductors or between one conductor and earth do not exceed the limits specified, as follows.

a) For normal operation, I_{TS1}, the current determined from the calculated or measured current for any single active ringing period t_1 (as defined in figure H.1), does not exceed:

1) for cadenced ringing ($t_1 < \infty$), the current given by the curve of figure H.2 at t_1;

2) for continuous ringing ($t_1 = \infty$), 16 mA.

I_{TS1}, in mA, is as given by

$$I_{TS1} = \frac{I_p}{\sqrt{2}} \qquad \text{for } (t_1 \leq 600\ ms)$$

$$I_{TS1} = \frac{t_1 - 600}{600} \times \frac{I_{pp}}{2\sqrt{2}} + \frac{1\,200 - t_1}{600} \times \frac{I_p}{\sqrt{2}} \qquad \text{for } (600\ ms < t_1 < 1\,200\ ms)$$

$$I_{TS1} = \frac{I_{pp}}{2\sqrt{2}} \qquad \text{for } (t_1 \geq 1\,200\ ms)$$

where

I_p is the peak current, in mA, of the relevant waveform given in figure H.3;

I_{pp} is the peak-to-peak current, in mA, of the relevant waveform given in figure H.3;

t_1 is expressed in ms.

b) For normal operation, I_{TS2}, the average current for repeated bursts of a cadenced ringing signal calculated for one ringing cadence cycle t_2 (as defined in figure H.1), does not exceed 16 mA r.m.s.

I_{TS2} in mA is as given by

$$I_{TS2} = \left[\frac{t_1}{t_2} \times I_{TS1}^2 + \frac{t_2 - t_1}{t_2} \times \frac{I_{dc}^2}{3{,}75^2} \right]^{1/2}$$

where

I_{TS1} in mA, is as given by H.2 a);

I_{dc} is the d.c. current in mA flowing through the 5 000 Ω resistor during the non-active period of the cadence cycle;

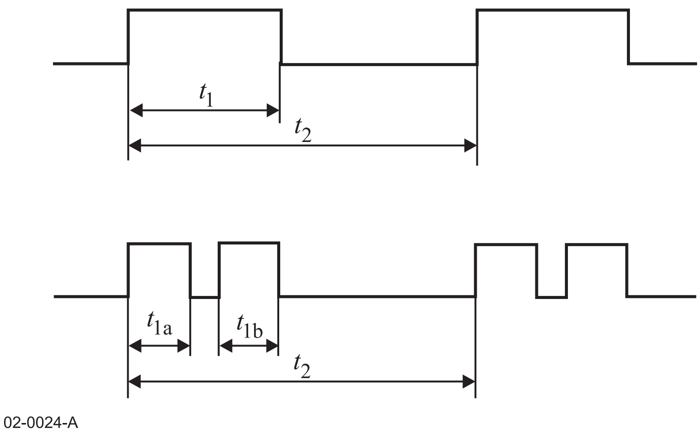
t_1 and t_2 are expressed in milliseconds.

NOTE
The frequencies of telephone ringing voltages are normally within the range of 14 Hz to 50 Hz.

c) Under single fault conditions, including where cadenced ringing becomes continuous:

1) I_{TS1} shall not exceed the current given by the curve of figure H.2, or 20 mA, whichever is greater; and

2) I_{TS2} shall not exceed a limit of 20 mA.



t_1 is:

- the duration of a single ringing period, where the ringing is active for the whole of the single ringing period;
- the sum of the active periods of ringing within the single ringing period, where the single ringing period contains two or more discrete active periods of ringing, as in the example shown, for which $t_1 = t_{1a} + t_{1b}$.

t_2 is:

- is the duration of one complete cadence cycle.

Figure H.1 – Definition of ringing period and cadence cycle

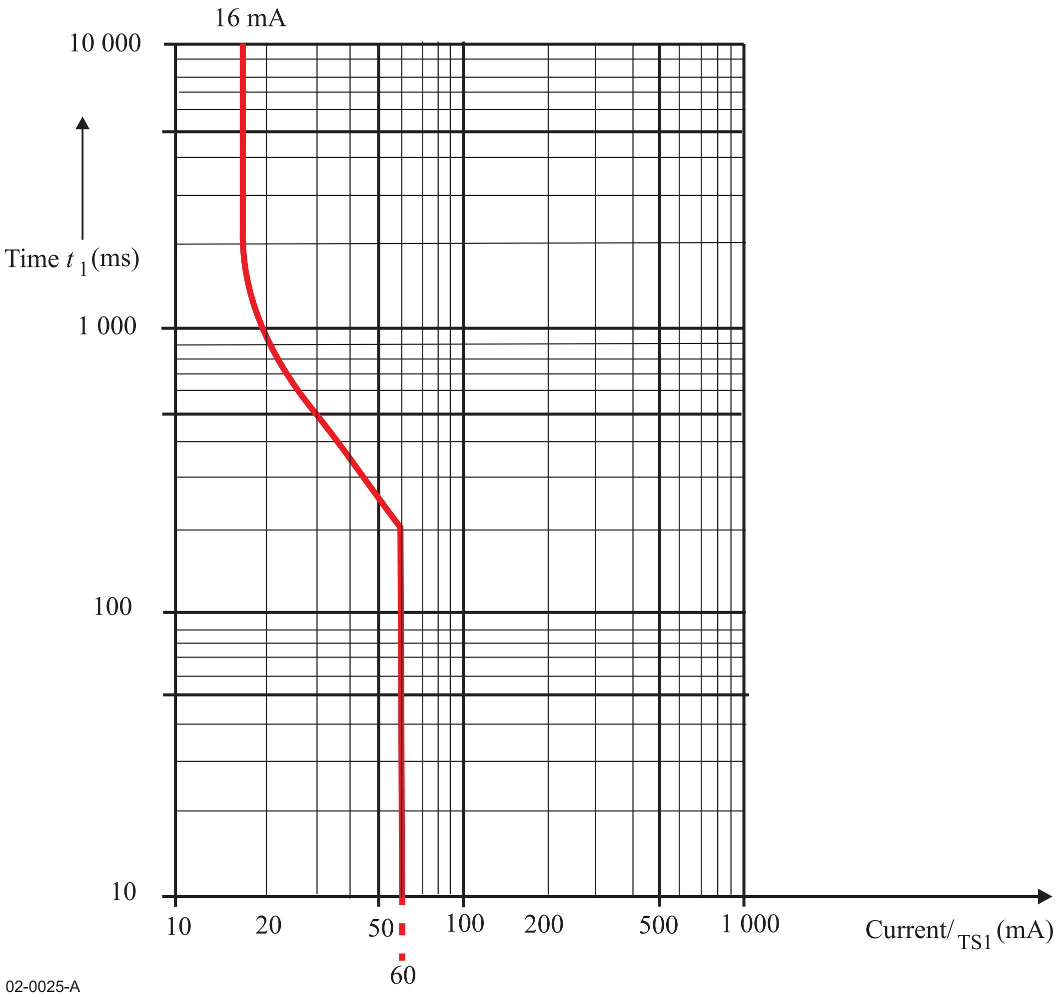


Figure H.2 – I_{TS1} limit curve for cadenced ringing signal

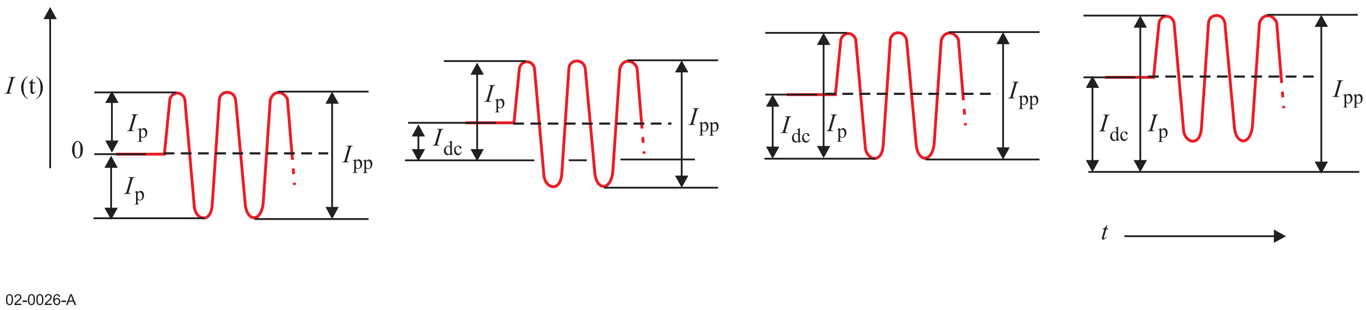


Figure H.3 – Peak and peak-to-peak currents

H.3 Method B

NOTE
This method is based on USA CFR 47 ("FCC Rules") Part 68, Sub-part D, with additional requirements that apply under fault conditions.

H.3.1 Ringing signal

H.3.1.1 Frequency

The ringing signal shall use only frequencies whose fundamental component is equal to or less than 70 Hz.

H.3.1.2 Voltage

The ringing voltage shall be less than 300 V peak-to-peak and less than 200 V peak with respect to earth, measured across a resistance of at least 1 MΩ.

H.3.1.3 Cadence

The ringing voltage shall be interrupted to create quiet intervals of at least 1 s duration separated by no more than 5 s. During the quiet intervals, the voltage to earth shall not exceed 56,5 V d.c.

H.3.1.4 Single fault current

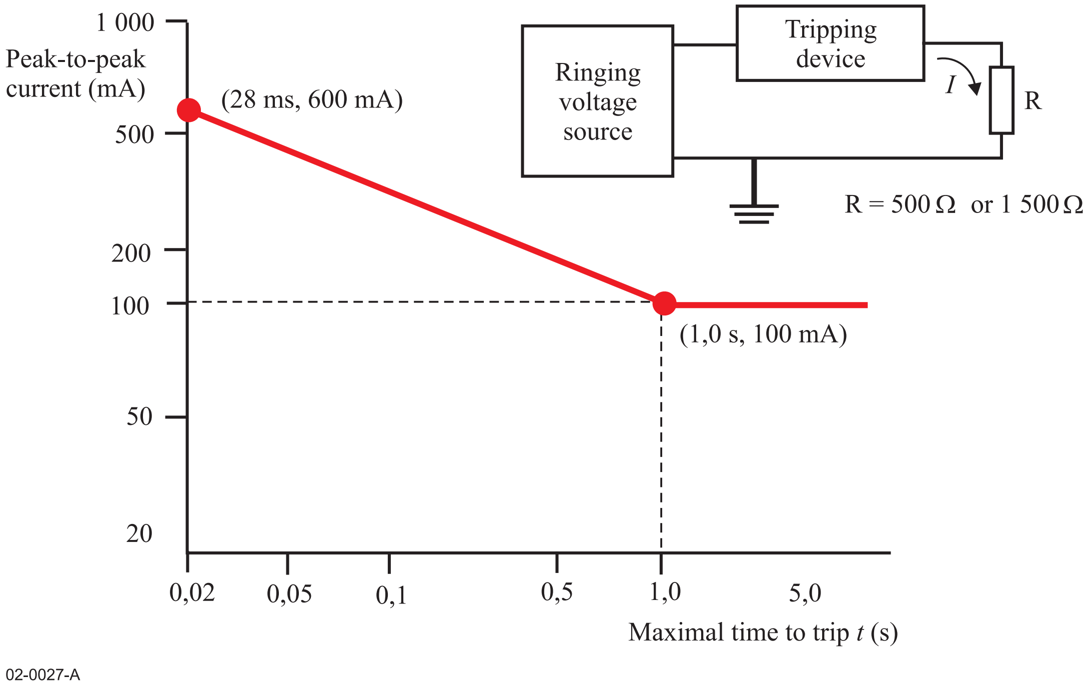
Where cadenced ringing becomes continuous as a consequence of a single fault, the current through a 5 000 Ω resistor connected between any two output conductors or between one output conductor and earth shall not exceed 56,5 mA peak-to-peak, as shown in figure H.3.

H.3.2 Tripping device and monitoring voltage

H.3.2.1 Conditions for use of a tripping device or a monitoring voltage

A ringing signal circuit shall include a tripping device as specified in H.3.2.2, or provide a monitoring voltage as specified in H.3.2.3, or both, depending on the current through a specified resistance connected between the ringing signal generator and earth, as follows:

- if the current through a 500 Ω resistor does not exceed 100 mA peak-to-peak, neither a tripping device nor a monitoring voltage is required;
- if the current through a 1 500 Ω resistor exceeds 100 mA peak-to-peak, a tripping device shall be included. If the tripping device meets the trip criteria specified in figure M.4 with R = 500 Ω no monitoring voltage is required. If, however, the tripping device only meets the trip criteria with R = 1 500 Ω, a monitoring voltage shall also be provided;
- if the current through a 500 Ω resistor exceeds 100 mA peak-to-peak, but the current through a 1 500 Ω resistor does not exceed this value, either:
  - a tripping device shall be provided, meeting the trip criteria specified in figure M.4 with R = 500 Ω, or
  - a monitoring voltage shall be provided.



NOTE 1
t is measured from the time of connection of the resistor R to the circuit.

NOTE 2
The sloping part of the curve is defined as I = 100/$\sqrt{t}$.

Figure H.4 – Ringing voltage trip criteria

H.3.2.2 Tripping device

A series current-sensitive tripping device in the ringlead which will trip ringing as specified in figure H.4.

H.3.2.3 Monitoring voltage

A voltage to earth on the tip or ring conductor with a magnitude of at least 19 V peak, but not exceeding 56,5 V d.c., whenever the ringing voltage is not present (idle state).

Annex J
(informative)

Overvoltage Categories
(see 3.6.2)

The largest transient overvoltage likely to be experienced at the power input interface of equipment connected to the MAINS is known as the MAINS transient voltage. In this Standard, minimum CLEARANCES for insulation in circuits connected to the mains are based on the MAINS transient voltage.

According to IEC 60664-1, the value of the MAINS transient voltage depends on the MAINS voltage and the Overvoltage Category, I to IV. See table 3.8.

The Overvoltage Category therefore has to be identified for each equipment intended to be connected to the MAINS.

The Overvoltage Category depends on the manner of connection of the equipment to the building power supply arrangements. It is normally considered to be as shown in table J.1. When transient limiting measures such as external filters in the MAINS are used, the equipment can be used in a higher Overvoltage Category.

The term Overvoltage Category is not used in connection with d.c. power distribution systems.

Table J.1 – Overvoltage categories

Overvoltage Category	Equipment and its point of connection to the AC MAINS	Examples of equipment
IV	Equipment which will be connected to the point where the MAINS supply enters the building	• Electricity meters • Communications ITE for remote electricity metering
III	Equipment which will be an integral part of the building wiring	• Socket outlets, fuse panels and switch panels • Power monitoring equipment
II	Pluggable or permanently connected equipment which will be supplied from the building wiring	• Household appliances, portable tools, home electronics • Most ITE used in the building
I	Equipment which will be connected to a special MAINS in which measures have been taken to reduce transients	• ITE supplied via an external filter or a motor driven generator

Annex K
(normative)

Insulated winding wires for use without interleaved insulation

K.1 General

This annex specifies winding wires whose insulation may be used to provide BASIC INSULATION, SUPPLEMENTARY INSULATION, DOUBLE INSULATION or REINFORCED INSULATION in wound components without interleaved insulation.

This annex covers round winding wires having diameters between 0,05 mm and 5,0 mm.

K.2 Sampling tests

The wire shall pass the following type tests, carried out at a temperature between 15 °C and 35 °C and a relative humidity between 45 % and 75 %, unless otherwise specified.

K.2.1 Dielectric strength

The test sample is prepared according to IEC 60851-5, sub-clause 4.4.1 (for a twisted pair). The sample is then subjected to the relevant test of 3.6.14 of this Standard with a test voltage not less than twice the appropriate voltage of table 3.15 of this Standard, with a minimum of

- 6 kV r.m.s. or 8,4 kV (peak) for REINFORCED INSULATION, or
- 3 kV r.m.s. or 4,2 kV (peak) for BASIC INSULATION or SUPPLEMENTARY INSULATION.

K.2.2 Flexibility and adherence

Test 8 of IEC 60851-3, 5.1.1 shall be used, using the mandrel diameters of table K.1.

The test sample is then examined in accordance with IEC 60851-3, sub-clause 5.1.1.4, followed by the relevant test of 3.6.14 of this Standard. The test voltage shall be not less than the appropriate voltage in table 3.15 of this Standard, with a minimum of

- 3 kV r.m.s. or 4,2 kV (peak) for REINFORCED INSULATION, or
- 1,5 kV r.m.s. or 2,1 kV (peak) for BASIC INSULATION or SUPPLEMENTARY INSULATION.

Table K.1 – Mandrel diameter

Nominal conductor diameter	Mandrel diameter
0,05 mm to 0,34 mm	4,0 mm ± 0,2 mm
0,35 mm to 0,49 mm	6,0 mm ± 0,2 mm
0,50 mm to 0,74 mm	8,0 mm ± 0,2 mm
0,75 mm to 2,49 mm	10,0 mm ± 0,2 mm
2,50 mm to 5,00 mm	4 times the conductor diameter 1)
1) In accordance with IEC 60317-43	

The tension to be applied to the wire during winding on the mandrel is calculated from the wire diameter to be equivalent to 118 MPa ± 10 % (118 N/mm^2 ± 10 %).

K.2.3 Heat shock

Test 9 of IEC 60851-6, followed by the dielectric strength test 3.6.14 except that the test voltage is applied between the wire and the mandrel. The test voltage shall be not less than the appropriate voltage in table 3.14 of this Standard, with a minimum of

- 3 kV r.m.s. or 4,2 kV (peak) for REINFORCED INSULATION, or
- 1,5 kV r.m.s or 2,1 kV (peak) for BASIC INSULATION or SUPPLEMENTARY INSULATION.

The oven temperature is the relevant temperature of the thermal class of insulation in table K.2.

The mandrel diameter and tension applied to the wire during winding on the mandrel are as in K.1.

The dielectric strength test is conducted at room temperature after removal from the oven.

Table K.2 – Oven temperature

Thermal class	A (105)	E (120)	B (130)	F (155)	H (180)
Oven temperature	200 °C ± 5 °C	215 °C ± 5 °C	225 °C ± 5 °C	240 °C ± 5 °C	260 °C ± 5 °C

K.2.4 Retention of dielectric strength after bending

Five samples are prepared as in K.2.2 above and tested as follows. Each sample is removed from the mandrel, placed in a container and positioned so that can be surrounded by at least 5 mm of metal shot. The ends of the conductor in the sample shall be sufficiently long to avoid flash over. The shot shall be not more than 2 mm in diameter and shall consist of balls of stainless steel, nickel or nickel plated iron. The shot is gently poured into the container until the sample under test is covered by at least 5 mm of shot. The shot shall be cleaned periodically with a suitable solvent (e.g. 1,1,1, - trichloroethane).

NOTE
The above test procedure is reproduced from 4.6.1 c) of IEC 60851-5 now withdrawn. It is not included in the third edition of that Standard.

The test voltage shall be not less than the appropriate voltage in table 3.14 of this Standard, with a minimum of

- 3 kV r.m.s. or 4,2 kV (peak) for REINFORCED INSULATION, or
- 1,5 kV r.m.s or 2,1 kV (peak) for BASIC INSULATION or SUPPLEMENTARY INSULATION.

The mandrel diameter and tension applied to the wire during winding on the mandrel are as in K.2.

K.3 Testing during manufacture

The wire shall be subjected by the wire manufacturer to dielectric strength tests during manufacture as specified in K.3.1 and K.3.2.

K.3.1 Routine test

The test voltage for routine test shall be the appropriate voltage in table 3.14 of this Standard, with a minimum of

- 3 kV r.m.s. or 4,2 kV (peak) for REINFORCED INSULATION, or
- 1,5 kV r.m.s. or 2,1 kV (peak) for BASIC INSULATION or SUPPLEMENTARY INSULATION.

K.3.2 Sampling test

Twisted pair samples shall be tested in accordance with IEC 60851-5, sub-clause 4.4.1. The minimum breakdown voltage shall be twice the appropriate voltage in table 3.14 of this Standard, but not less than

- 6 kV r.m.s or 8,4 kV (peak) for REINFORCED INSULATION, or
- 3 kV r.m.s. or 4,2 kV (peak) for BASIC INSULATION or SUPPLEMENTARY INSULATION.

Annex L
(normative)

Safety interlocks

L.1 General requirements

SAFETY INTERLOCKS shall be so designed that the hazard will be removed before the cover, door, etc. is in any position that will permit contact of the rigid test finger, test probe 11 of IEC 61032, with hazardous parts.

For protection against electric shock and energy hazards, removal, opening or withdrawal of the cover, door, etc., shall:

- necessitate previous de-energisation of such parts, or
- automatically initiate disconnection of the supply to such parts, and reduce within 2 s the voltage to 42,4 V peak, or 70 V d.c., or less, and the energy level to less than 20 J.

For a moving part which will continue to move through momentum and will continue to present a hazard (e.g. a spinning print drum), removal, opening or withdrawal of the cover, door, etc., shall:

- necessitate previous reduction of movement to an acceptably safe level, or
- automatically initiate reduction of the movement within 2 s to an acceptably safe level.

The following exceptions are permitted for a longer period than 2 s if there is a marking which tells the operator to wait for a longer period:

- temperatures of easily touched parts may exceed the values of table 5.2;
- for moving parts , the above requirements need not be met during the period specified.

Such markings shall be placed on covers and other parts which have to be removed to obtain access, and also on or beside the hazardous part.

L.1.1 Test method

The voltage and/or energy level of parts at hazardous levels are monitored.

Compliance is checked by inspection, measurement and use of the rigid test finger, test probe 11 of IEC 61032.

L.2 Inadvertent reactivation

A SAFETY INTERLOCK shall be designed so that inadvertent reactivation of the hazard cannot occur when covers, guards, doors, etc. are not in the closed position.

Any accessible interlock which can be operated by means of the rigid test finger, test probe 11 of IEC 61032, is considered to be likely to cause inadvertent reactivation of the hazard.

A SAFETY INTERLOCKS switch shall be selected taking into account the mechanical shock and vibration experienced in normal operation, so that this does not cause inadvertent switching to an unsafe condition.

L.2.1 Test method

Compliance is checked by inspection and where necessary by a test with the rigid test finger, test probe 11 of IEC 61032.

With the doors and covers opened and the SAFETY INTERLOCK activated, the test finger is used to attempt to override the interlock.

L.3 Fail-safe operation

A SAFETY INTERLOCK system shall comply with either item a) or item b), as follows:

a) the probable failure mode(s) of the interlock system will not create a hazard for which protection is required;

b) an assessment of the interlock means, equipment, circuit diagrams and available data will result in the conclusion that failure is not likely to occur during the normal life of the equipment.

L.3.1 Test method

Compliance is checked by assessment of the system and completion of the test cycles described below.

Interlocks with moving parts 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 but not less than 10 000 operations.

Reed switches in circuits at energy level above ES 1 shall be subjected to 100 000 cycling operations.

Assessment of compliance with a) includes not only electro-mechanical components but also, for example, failure of a single semi-conductor device, together with any consequential failure or malfunction.

It is permitted to use simulated interlock systems for tests.

L.4 Override

Where it may be necessary for a SKILLED PERSON to override a safety interlock, the override system shall:

- require an intentional effort to operate, and
- reset automatically to normal operation when servicing is complete, or shall prevent normal operation unless the SKILLED PERSON have carried out restoration, and
- require a TOOL for operation when located in an area accessible to an ORDINARY PERSON, and not be operable with the test finger.

L.4.1 Test method

Compliance is checked by inspection, operation and test with the test finger where necessary.

The operation of service override functions of SAFETY INTERLOCKS are tested by simulating service activities as follows:

- *operation of the interlock override to ensure that it requires an intentional effort to operate;*
- *reassembly of the unit to ensure automatic reset when service is complete.*
- *attempt to override a SAFETY INTERLOCK located in an area accessible to an ORDINARY PERSON with the test finger to verify that it requires a TOOL to operate.*

L.5 Mechanically operated interlock switches

A mechanical interlock switch shall either comply with L.5.1 or pass the tests of L.5.2 and L.5.3.

L.5.1 Contact gaps

The contact gap shall not be less than that for the DISCONNECT DEVICE (see annex M) if located in an ES 3 circuit. For other circuits, the contact gap shall not be less than the CLEARANCE values in 3.6.2.

L.5.1.1 Test method

Compliance is checked by inspection and measurement.

CLEARANCE of contact gaps of interlock switches are measured as follows:

- *Interlock switches located in circuits associated with the MAINS are measured for a contact separation of 3 mm.*
- *Interlock switches located in other circuits are measured for a contact separation in accordance with the CLEARANCE values of table 3.9.*

L.5.2 Reliability

The switch shall successfully perform twice the maximum number of cycles likely to occur during the expected life of the equipment.

Reed switches in circuits at energy level above ES 1 shall withstand 100 000 cycling operations.

L.5.2.1 Test method

Compliance is checked by inspection and test.

The switch shall successfully perform twice the maximum number of cycles likely to occur during the expected life of the equipment at the rate of 6-10 cycles per minute, making and breaking 150 percent of the current imposed in the application except that for a switch that switches a motor load, the test is conducted with the rotor of the motor in a locked condition.

Reed switches in circuits at energy level above ES 1 shall be subjected to 100 000 cycling operations during the test of L.3.

Except for reed switches in circuits at energy level above ES 1, a dielectric strength test, as specified in 3.6.14 for REINFORCED INSULATION, is applied between the contacts after the tests.

Annex M
(normative)

Disconnect devices

M.1 General requirements

A DISCONNECT DEVICE shall be provided to disconnect the equipment from the supply.

The DISCONNECT DEVICE shall have a contact separation of at least 3 mm and, when incorporated in the equipment, shall be connected as closely as practicable to the incoming supply.

A functional switch is permitted to serve as a DISCONNECT DEVICE if it complies with all the requirements for a DISCONNECT DEVICE. However, these requirements do not apply to functional switches where other means of isolation are provided.

The following types of DISCONNECT DEVICES are permitted:

- the plug on the power supply cord,
- an appliance coupler,
- isolating switches,
- circuit breakers,
- any equivalent device offering a degree of safety equal to the above.

M.1.1 Permanently connected equipment

For PERMANENTLY CONNECTED EQUIPMENT the DISCONNECT DEVICE shall be incorporated in the equipment, unless the equipment is accompanied by installation instructions stating that an appropriate DISCONNECT DEVICE shall be provided as part of the building installation.

NOTE
External DISCONNECT DEVICES will not necessarily be supplied with the equipment.

M.1.2 Parts which remain energised

Parts on the supply side of a DISCONNECT DEVICE in the equipment, which remain energised when the DISCONNECT DEVICE is switched off, shall be guarded to reduce the risk of accidental contact by SKILLED PERSONS.

As an alternative, instructions shall be provided in the service manual.

M.1.3 Switches in flexible cords

When an isolating switch is used, it shall not be fitted in a MAINS supply cord.

M.1.4 Single phase equipment

For single-phase equipment, the DISCONNECT DEVICE shall disconnect both poles simultaneously, except that a single-pole DISCONNECT DEVICE can be used to disconnect the phase conductor when it is possible to rely on the identification of the neutral in the MAINS. Instructions shall be given for the provision of an additional two-pole DISCONNECT DEVICE in the building installation when the equipment is used where identification of the neutral in the MAINS is not possible.

NOTE
Three examples of cases where a two-pole DISCONNECT DEVICE is required are:

- *on equipment supplied from an IT power system;*
- *on pluggable equipment supplied through a reversible appliance coupler or a reversible plug (unless the appliance coupler or plug itself is used as the DISCONNECT DEVICE;*
- *on equipment supplied from a socket-outlet with indeterminate polarity.*

M.1.5 Three-phase equipment

For three-phase equipment, the DISCONNECT DEVICE shall disconnect simultaneously all phase conductors of the supply. For equipment requiring a neutral connection to an IT power system, the DISCONNECT

DEVICE shall be a four-pole device and shall disconnect all phase conductors and the neutral conductor. If this four-pole device is not provided in the equipment, the installation instructions shall specify the need for its provision as part of the building installation.

If a DISCONNECT DEVICE interrupts the neutral conductor, it shall simultaneously interrupt all phase conductors.

M.1.6 Switches as disconnect devices

Where the DISCONNECT DEVICE is a switch incorporated in the equipment, its on and off positions shall be marked in accordance with annex F.

M.1.7 Plugs as disconnect devices

Where a plug on the power supply cord is used as the DISCONNECT DEVICE, the installation instructions shall state that for pluggable equipment, the socket-outlet shall be installed near the equipment and shall be easily accessible. For pluggable equipment intended for installation by an ORDINARY PERSON, the installation instructions shall be made available to the ORDINARY PERSON.

M.1.8 Devices for pluggable equipment

For Class I equipment, the supply plug or appliance coupler, if used as the DISCONNECT DEVICE, shall make the protective earthing connection earlier than the supply connections and shall break it later than the supply connections.

M.1.9 Multiple power sources

Where a unit receives power from more than one source (e.g. different voltages/frequencies or as redundant power), there shall be a prominent marking at each DISCONNECT DEVICE giving adequate instructions for the removal of all power from the unit.

If more than one such DISCONNECT DEVICE is provided on a unit, all these devices shall be grouped together. It is not necessary that the devices be mechanically linked.

Equipment incorporating an internal uninterruptible power supply (UPS) shall have provisions for reliably disabling the UPS and disconnecting its output prior to servicing the equipment. Instructions for disconnection of the UPS shall be provided. The internal energy source of the UPS shall be marked appropriately and guarded against accidental contact by a SKILLED PERSON.

M.2 Test method

Compliance is checked by inspection.

Annex N
(normative)

Batteries

N.1 Requirements:

Equipment containing batteries shall be designed to reduce the risk of fire, explosion and chemical leaks under normal conditions and after a single fault in the equipment, including a fault in circuitry within the equipment battery pack. For batteries replaceable by an ORDINARY PERSON, the design shall reduce the likelihood of reverse polarity installation if this would create a hazard.

Battery circuits shall be designed so that:

- the output characteristics of a battery charging circuit are compatible with its rechargeable battery; and
- for non-rechargeable batteries, discharging at a rate exceeding the battery manufacturer's recommendations and unintentional charging are prevented; and
- for rechargeable batteries, charging and discharging at a rate exceeding the battery manufacturer's recommendations and reversed charging are prevented.

NOTE
Reversed charging of a rechargeable battery occurs when the polarity of the charging circuit is reversed, aiding the discharge of the battery.

Under NORMAL CONDITION and ABNORMAL CONDITION and under fault condition:

- for rechargeable batteries the charging current; and
- for lithium batteries the discharging current and the reverse current

shall not exceed the permissible values given by the battery manufacturer.

Batteries shall be so mounted that the risk of the accumulation of flammable gases is minimised and that it is unlikely that the leakage of electrolyte impairs any insulation.

If equipment is provided with a replaceable battery, where the replacement of the battery with an incorrect type can result in an explosion (for example, some lithium batteries) a warning according to annex F.3.1 shall be provided.

N.2 Test method

For batteries compliance is checked by inspection and by evaluation of the data provided by the equipment manufacturer and battery manufacturer for charging and discharging rates.

When appropriate data is not available, compliance is checked by test. However, batteries that are inherently safe for the conditions given are not tested under those conditions.

NOTE
Consumer grade, non-rechargeable carbon-zinc or alkaline batteries are considered safe under short-circuiting conditions and therefore are not tested for discharge; nor are such batteries tested for leakage under storage conditions.

A new non-rechargeable battery or fully charged rechargeable battery provided with, or recommended by the manufacturer for use with, the equipment shall be used for each of the following tests:

- for evaluating the overcharging of a rechargeable battery, a battery is charged for a period of 7 hours under each of the following conditions in turn:
- with the battery charging circuit adjusted for its maximum charging rate (if such adjustment exists); followed by
- any single component failure that is likely to occur in the charging circuit and which would result in overcharging of the battery; and
- recharging a fully discharged rechargeable battery with one cell short-circuited, and

- for evaluating the unintentional charging of a non-rechargeable battery, a battery is charged for 7 hours with any single component failure that is likely to occur and which would result in unintentional charging of the battery; and
- for evaluating the reversed charging of a rechargeable battery, a battery is charged for 7 hours with any single component failure that is likely to occur and which would result in reversed charging of the battery; and
- for evaluating an excessive discharging rate for any battery, a battery is subjected to rapid discharge by open-circuiting or short-circuiting any current-limiting or voltage-limiting components in the load circuit of the battery under test.

Lithium batteries shall be removed from the circuit and replaced by a short-circuit when measuring currents.

NOTE
Some of the tests specified can be hazardous to the persons carrying them out; all appropriate measures to protect personnel against possible chemical or explosive hazards should be taken.

Annex P
(normative)

Table of electrochemical potentials

	Magnesium, magnesium alloys	Zinc, zinc alloys	80 tin/20 Zn on steel, Zn on iron or steel	Aluminium	Cd on steel	Al/Mg alloy	Mild steel	Duralumin	Lead	Cr on steel, soft solder	Cr on Ni on steel, tin on steel 12% Cr stainless steel	High Cr stainless steel	Copper, copper alloys	Silver solder, Austenitic stainless steel	Ni on steel	Silver	Rh on Ag on Cu, silver/gold alloy	Carbon	Gold, platinum
Magnesium, magnesium alloys	0	0,5	0,55	0,7	0,8	0,85	0,9	1,0	1,05	1,1	1,15	1,25	1,35	1,4	1,45	1,6	1,65	1,7	1,75
Zinc, zinc alloys		0	0,05	0,2	0,3	0,35	0,4	0,5	0,55	0,6	0,65	0,75	0,85	0,9	0,95	1,1	1,15	1,2	1,25
80 tin/20 Zn on steel, Zn on iron or steel			0	0,15	0,2	0,3	0,35	0,45	0,5	0,5	0,6	0,7	0,8	0,85	0,9	1,05	1,1	1,15	1,2
Aluminium				0	0,1	0,15	0,2	0,3	0,35	0,4	0,45	0,55	0,65	0,7	0,75	0,9	0,95	1,0	1,05
Cd on steel					0	0,05	0,1	0,2	0,25	0,3	0,35	0,45	0,55	0,6	0,65	0,8	0,85	0,9	0,95
Al/Mg alloy						0	0,05	0,15	0,2	0,2	0,3	0,4	0,5	0,55	0,6	0,75	0,8	0,85	0,9
Mild steel							0	0,1	0,15	0,2	0,25	0,35	0,45	0,5	0,55	0,7	0,75	0,8	0,85
Duralumin								0	0,05	0,1	0,15	0,25	0,35	0,4	0,45	0,6	0,65	0,7	0,75
Lead									0	0,0	0,1	0,2	0,3	0,35	0,4	0,55	0,6	0,66	0,7
Cr on steel, soft solder										0	0,05	0,15	0,25	0,3	0,35	0,5	0,55	0,6	0,65
Cr on Ni on steel, tin on steel 12% Cr stainless steel											0	0,1	0,2	0,25	0,3	0,45	0,5	0,55	0,6
High Cr stainless steel												0	0,1	0,15	0,2	0,35	0,4	0,45	0,5
Copper, copper alloys													0	0,05	0,1	0,25	0,3	0,35	0,4
Silver solder, Austenitic stainless steel														0	0,15	0,2	0,25	0,3	0,35
Ni on steel															0	0,15	0,2	0,25	0,3
Silver																0	0,5	0,1	0,15
Rh on Ag on Cu, silver/gold alloy																	0	0,05	0,1
Carbon																		0	0,5
Gold, platinum																			0

Ag = Silver
Al = Aluminium
Cr = Chromium
Cd = Cadmium
Cu = Copper
Mg = Magnesium
Ni = Nickel
Rh = Rhodium
Zn = Zinc

93-0103-B

Annex Q
(normative)

Measurement of creepage distances and clearances

In the following figures, the value of X is given in table Q.1. Where the distance shown is less than X, the depth of the gap or groove is disregarded when measuring a CREEPAGE DISTANCE.

Table Q.1 is valid only if the required minimum CLEARANCE is 3 mm or more. If the required minimum CLEARANCE is less than 3 mm, the value of X is the lesser of:

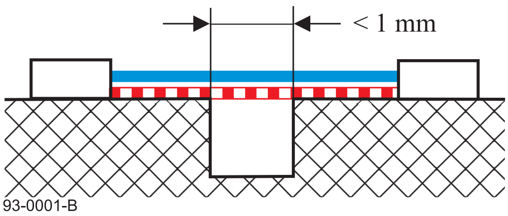
– the relevant value in table Q.1; or

one third of the required minimum clearance.

Table Q.1 – Value of X

Pollution degree (See 3.6.1.5)	X mm
1	0,25
2	1,0
3	1,5

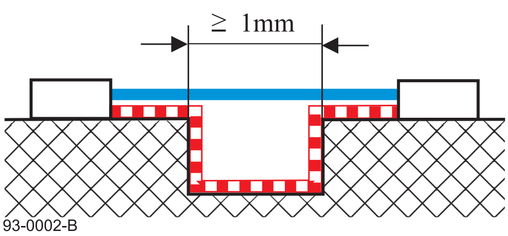
NOTE
Throughout this annex, the following convention is used:



Condition: Path under consideration includes a parallel or converging-sided groove of any depth with width less than 1 mm.

Rule: CREEPAGE DISTANCE and CLEARANCE are measured directly across the groove.

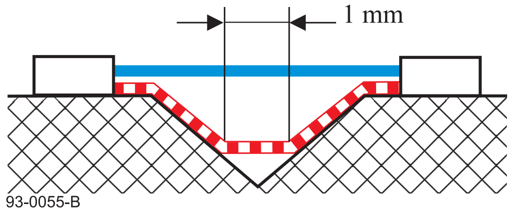
Figure Q.1 – Narrow groove



Condition: Path under consideration includes a parallel-sided groove of any depth, and equal to or more than 1 mm wide.

Rule: CLEARANCE is the "line of sight" distance. CREEPAGE DISTANCE path follows the contour of the groove.

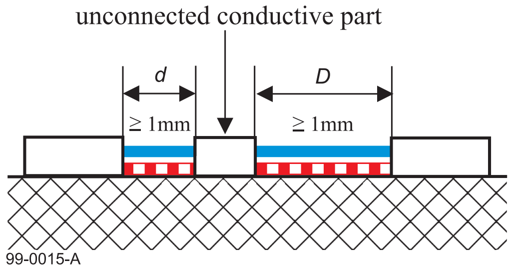
Figure Q.2 – Wide groove



Condition: Path under consideration includes a V-shaped groove with internal angle of less than 80° and a width greater than 1 mm.

Rule: CLEARANCE is the "line of sight" distance. CREEPAGE DISTANCE path follows the contour of the groove but "short-circuits" the bottom of the groove by 1 mm link.

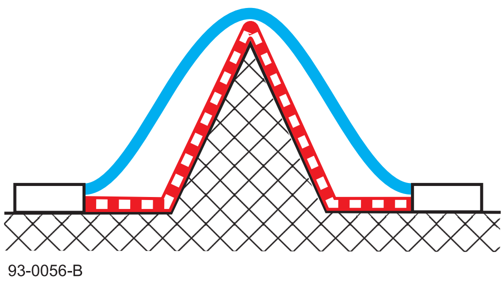
Figure Q.3 – V-shaped groove



Condition: Insulation distance with intervening, unconnected conductive part.

Rule: CLEARANCE is the distance *d+D*, CREEPAGE DISTANCE is also *d+D*. Where the value of *d* or *D* is smaller than 1 mm it shall be considered as zero.

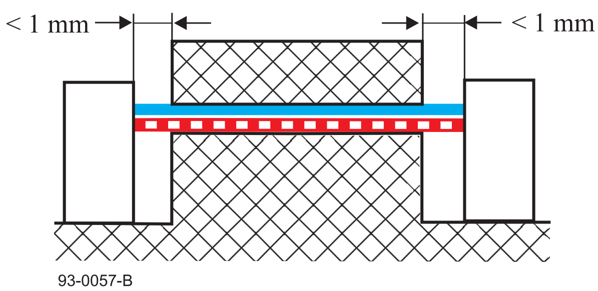
Figure Q.4 – Intervening unconnected conductive part



Condition: Path under consideration includes a rib.

Rule: CLEARANCE is the shortest direct air path over the top of the rib. CREEPAGE DISTANCE path follows the contour of the rib.

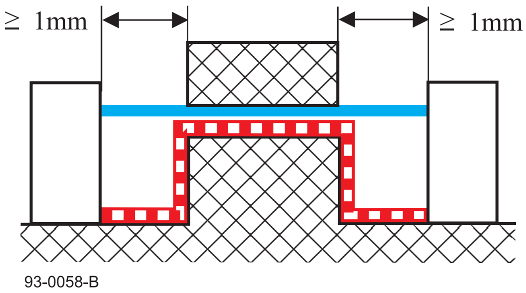
Figure Q.5 – Rib



Condition: Path under consideration includes an uncemented joint with grooves less than 1 mm wide on either side.

Rule: CLEARANCE and CREEPAGE DISTANCE path is the "line of sight" distance shown.

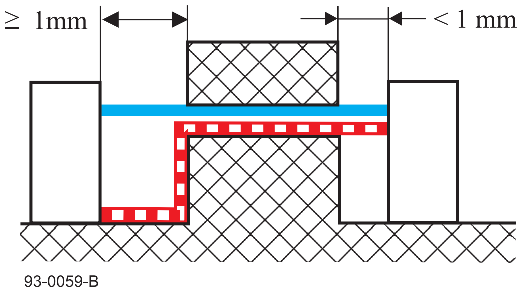
Figure Q.6 – Uncemented joint with narrow groove



Condition: Path under consideration includes an uncemented joint with a groove equal to or more than 1 mm wide each side.

Rule: CLEARANCE is the "line of sight" distance. CREEPAGE DISTANCE path follows the contour of the groove.

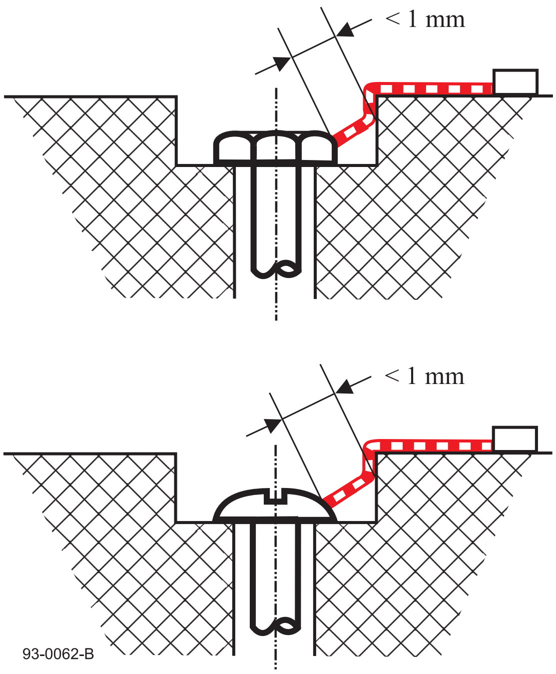
Figure Q.7 – Uncemented joint with wide groove



Condition: Path under consideration includes an uncemented joint with grooves on one side less than 1 mm wide, and a groove on the other equal to or more than 1 mm wide.

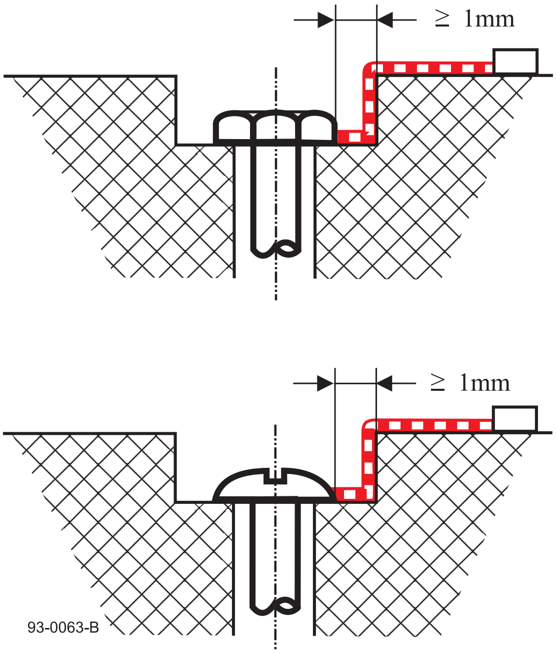
Rule: CLEARANCE and CREEPAGE DISTANCE path are as shown.

Figure Q.8 – Uncemented joint with narrow and wide grooves



Gap between head of screw and wall of recess too narrow to be taken into account.

Figure Q.9 – Narrow recess



Gap between head of screw and wall of recess wide enough to be taken into account.

Figure Q.10 – Wide recess

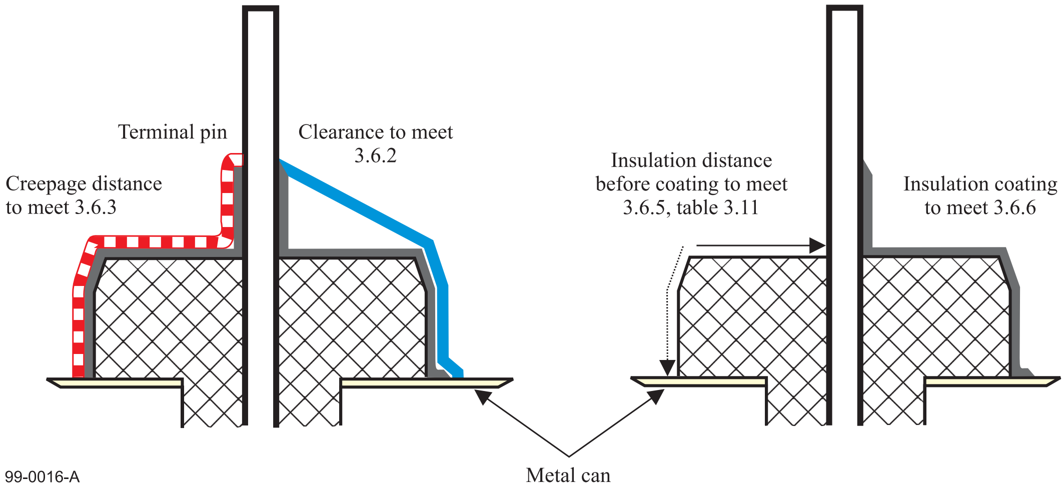


Figure Q.11 – Coating around terminals

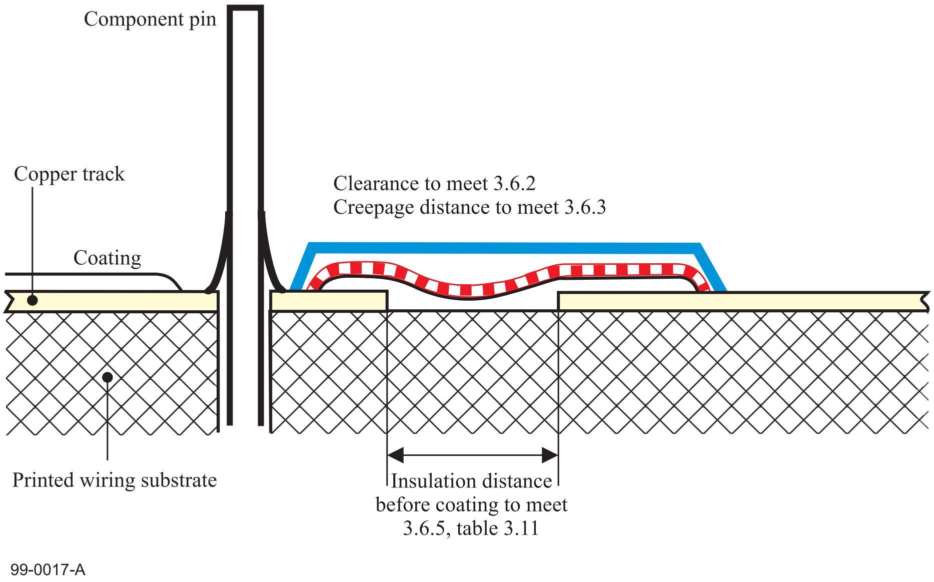
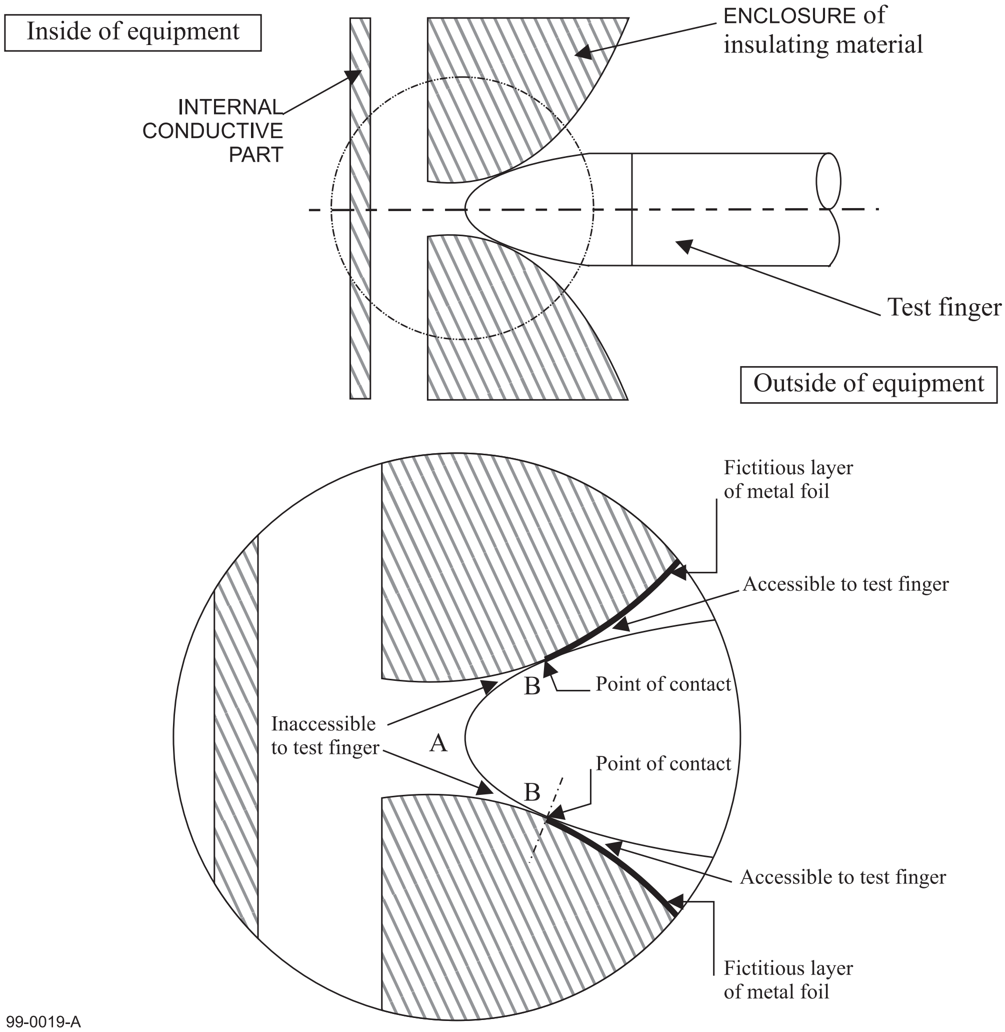


Figure Q.12 – Coating over printed wiring



Point A is used for determining accessibility (see 3.2). Point B is used for measurement of CLEARANCE and CREEPAGE DISTANCES.

Figure Q.13 – Example of measurements in an enclosure of insulating material

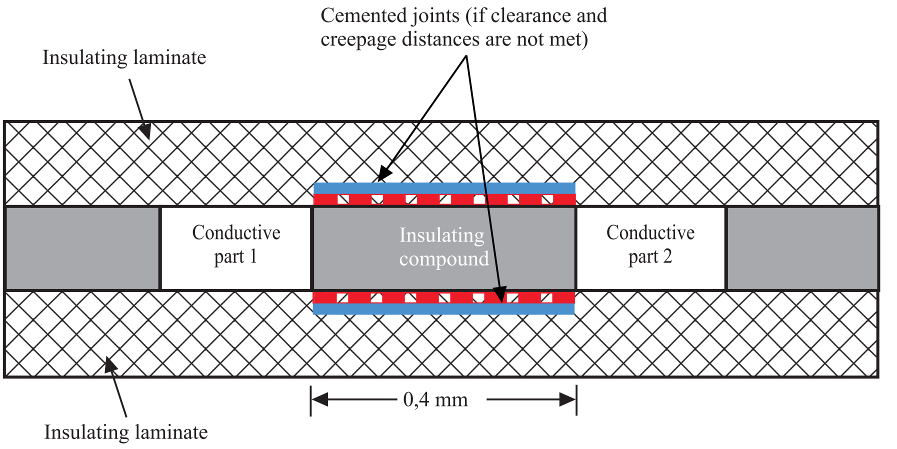


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Figure Q.14 – Cemented joints in multi-layer printed boards

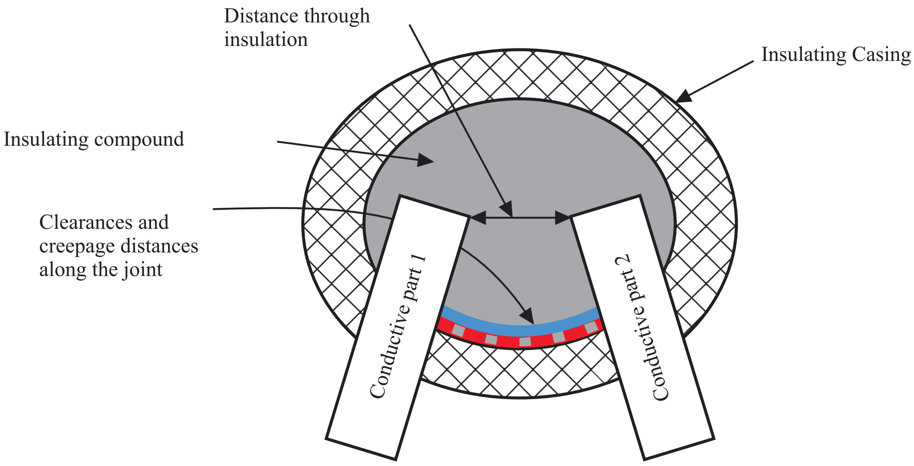

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Figure Q.15 – Device filled with insulating compound

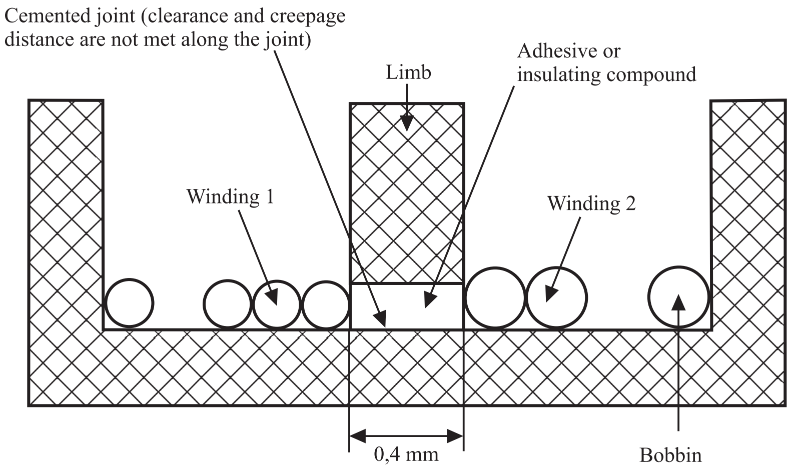

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Figure Q.16 – Partitioned bobbin

Annex R

(reserved for future work)

Annex S
(normative)

Limited power sources

S.1 Definition

A limited power source shall comply with one of the following:

- the output is inherently limited in compliance with table S.1; or
- an impedance limits the output in compliance with table S.1. If a positive temperature coefficient device is used, it shall pass the tests specified in IEC 60730-1, clauses 15, 17, J15 and J17; or
- an overcurrent protective device is used and the output is limited in compliance with table S.2; or
- a regulating network limits the output in compliance with table S.1, both under NORMAL CONDITION and after any single fault (see annex B) in the regulating network (open circuit or short circuit); or
- a regulating network limits the output in compliance with table S.1 under NORMAL CONDITION, and an overcurrent protective device limits the output in compliance with table S.2 after any single fault (see annex B) in the regulating network (open circuit or short circuit).

Where an overcurrent protective device is used, it shall be a fuse or a non-adjustable, non-autoreset, electromechanical device.

A limited power source operated from MAINS, or a battery-operated limited power source that is recharged from MAINS while supplying the load, shall incorporate an isolating transformer.

S.2 Test method

Compliance is checked by inspection and measurement and, where appropriate, by examination of the manufacturer's data for batteries. Batteries shall be fully charged when conducting the measurements for U_{oc} and I_{sc} according to tables S.1 and S.2.

The load referenced in items 2) and 3) of tables S.1 and S.2 is adjusted to develop maximum current and power transfer respectively. Single faults in a regulating network are applied under these maximum current and power conditions.

Table S.1 – Limits for inherently limited power sources

Output voltage 1) (U_{OC})		Output current 2) (I_{SC})	Apparent power 3) (S)
V a.c.	V d.c.	A	VA
≤ 20	≤ 20	≤ 8,0	≤ 5 × U_{OC}
20 < U_{OC} ≤ 30	20 < U_{OC} ≤ 30	≤ 8,0	≤ 100
–	30 < U_{OC} ≤ 60	≤ 150/U_{OC}	≤ 100

1) U_{OC}: Output voltage measured in accordance with 1.4.5 with all load circuits disconnected. Voltages are for substantially sinusoidal a.c. and ripple free d.c. For non-sinusoidal a.c. and d.c. with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

2) I_{SC}: Maximum output current with any non-capacitive load, including a short circuit, measured 60 s after application of the load.

3) S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of the load.

Table S.2 – Limits for power sources not inherently limited (overcurrent protective device required)

Output voltage [1] (U_{OC})		Output current [2] (I_{SC})	Apparent power [3] (S)	Current rating of overcurrent protective device [4]
V a.c.	**V d.c.**	**A**	**VA**	**A**
≤ 20	≤ 20	≤ 1 000/U_{OC}	≤ 250	≤ 5,0
20 < U_{OC} ≤ 30	20 < U_{OC} ≤ 30			≤ 100/U_{OC}
–	30 < U_{OC} ≤ 60			≤ 100/U_{OC}

0) U_{OC}: Output voltage measured in accordance with 1.4.5 with all load circuits disconnected. Voltages are for substantially sinusoidal a.c. and ripple free d.c. For non-sinusoidal a.c. and for d.c. with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

1) I_{SC}: Maximum output current with any non-capacitive load, including a short circuit, measured 60 s after application of the load. Current limiting impedances in the equipment remain in the circuit during measurement, but overcurrent protective devices are bypassed.

2) S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of the load. Current limiting impedances in equipment remain in the circuit during measurement, but overcurrent protective devices are bypassed.

NOTE
The reason for making measurements with overcurrent protective devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the overcurrent protective devices.

3) The current ratings of overcurrent protective devices are based on fuses and circuit breakers that break the circuit within 120 s with a current equal to 210 % of the current rating specified in the table.

Annex T
(normative)

Constructional requirements for potential ignition sources 1 and 2

T.1 General

Appropriate use of materials and suitable construction shall be used to limit the spread of flame from a POTENTIAL IGNITION SOURCE. Acceptable construction fulfils the following two requirements:

Base material of printed boards, on which a potential ignition source is located, shall be of flammability class V-1 or better.

When the distance between a POTENTIAL IGNITION SOURCE and components and parts is less than specified in figures T.1 and T.2, as applicable, the components and parts shall either:

a) comply with flammability category V-1; or

b) contribute negligible fuel to a fire; or

c) be shielded from potential ignition source by a barrier made of metal or meeting the flammability category V-1. The barrier shall be solid and rigid and shall have dimensions covering at least the areas specified in figure T.2, T.3, T.4, T.5 as applicable. The dimensions of a non-metallic barrier shall be sufficient to prevent ignition of its edges and of edges of openings in the barrier. Printed boards carrying POTENTIAL IGNITION SOURCE are not considered to be a barrier against fire.

Minimum distance from POTENTIAL IGNITION SOURCE to a non-metallic barrier is 5 mm. Minimum distance from arcing contacts to a non-metallic barrier is 13 mm.

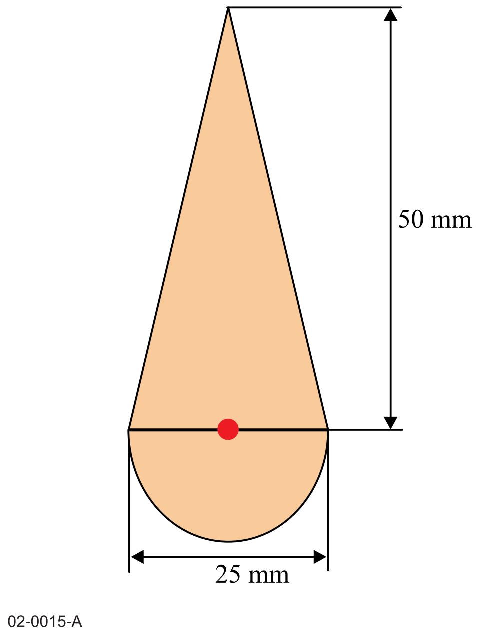

Figure T.1 – Basic keep-out volume for a point source.

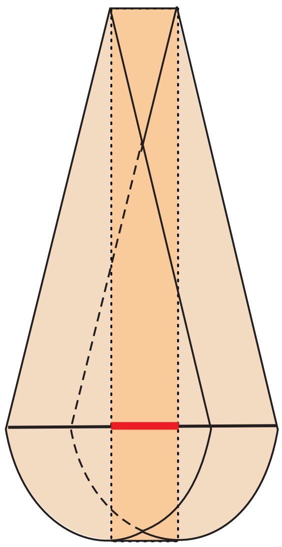

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Figure T.2 – Extended keep-out volume for a linear source

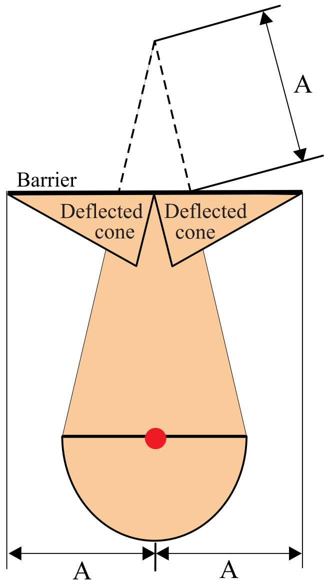

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Figure T.3 – Deflected keep-out volume when a horizontal barrier is used

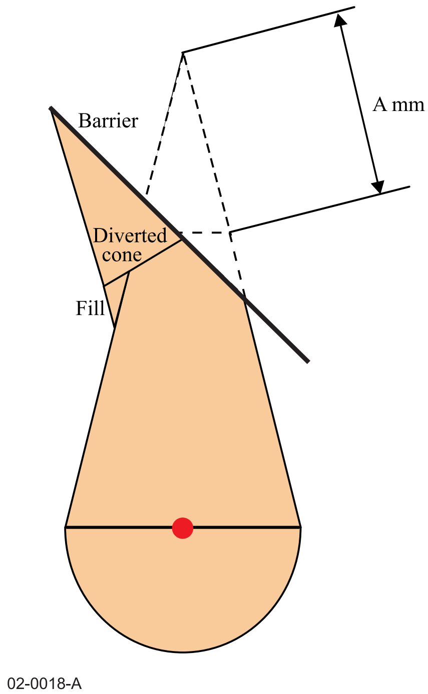

Figure T.4 – Deflected keep-out volume when an angled barrier is used

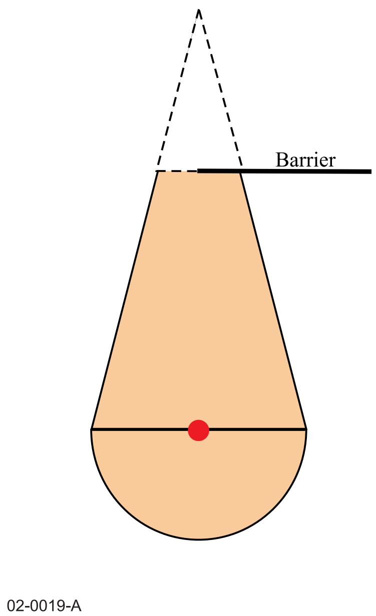

Figure T.5 – Partially-diverted fire cone with horizontal barrier and keep-out volume

Annex U
(normative)

Tests for resistance to heat and fire

NOTE
Toxic fumes may be given off during the tests. Where appropriate the tests should be carried out either under a ventilated hood or in a well-ventilated room, but free from draughts which could invalidate the tests.

U.1 Flammability test for fire enclosures of transportable equipment having a total mass not exceeding 18 kg, and for material and components located within fire enclosures

U.1.1 Samples

Three samples are tested. For FIRE ENCLOSURES, each sample consists of either a complete FIRE ENCLOSURE or a section of the FIRE ENCLOSURE representing the thinnest significant wall thickness and including any ventilation opening. For material to be located within the FIRE ENCLOSURE, each sample of the material consists of one of the following:

- the complete part; or
- a section of the part representing the thinnest significant wall thickness; or
- a test plaque or bar of uniform thickness representing the thinnest significant section of the part.

For components to be located within the FIRE ENCLOSURE, each sample is to be a complete component.

U.1.2 Conditioning of samples

Prior to being tested, the samples are conditioned in a circulating air oven for a period of 7 days (168 h), at a temperature 10 K higher than the maximum temperature of the part measured during the test of 5.1 or 70°C, whichever is the higher, and then cooled to room temperature.

U.1.3 Mounting of samples

Samples are mounted and oriented as they would be in actual use according to the manufacturers instructions.

U.1.4 Test flame

The test flame according to IEC 60695-11-4 shall be used.

U.1.5 Test procedure

The test flame is applied to an inside surface of the sample at a point judged to be likely to become ignited because of its proximity to a source of ignition. For the evaluation of materials located within the FIRE ENCLOSURE, it is permitted to apply the test flame to an external surface of the sample. For the evaluation of components to be located within the FIRE ENCLOSURE, the test flame is applied directly to the component.

If a vertical part is involved, the flame is applied at an angle of approximately 20° from the vertical. If ventilation openings are involved, the flame is applied to an edge of an opening, otherwise to a solid surface. In all cases, the tip of the flame is to be in contact with the sample. The flame is applied for 30 s and removed for 60 s, then reapplied to the same location for 30 s. The test is repeated on the remaining two samples. If any part being tested is near a source of ignition at more than one point, each sample is tested with the flame applied to a different point which is near a source of ignition.

U.1.6 Compliance criteria

During the test, the samples shall not continue to burn for more than 1 min after the second application of the test flame, and shall not be consumed completely.

U.1.7 Alternative test

As an alternative to the equipment and procedure specified in U.1.4 and U.1.5, it is permitted to use the equipment and procedure specified in clauses 4 and 8 of IEC 60695-2-2. The manner, duration and number of flame applications are as specified in U.1.5 and compliance is in accordance with U.1.6.

NOTE
Compliance with the method of either U.1.4 and U.1.5 or of U.1.7 is acceptable; it is not required to comply with both methods.

U.2 Flammability tests for the bottom of fire enclosures

U.2.1 Mounting of samples

A sample of the complete finished bottom of the FIRE ENCLOSURE is securely supported in a horizontal position. Bleached cheesecloth of approximately 40 g/m^2 is placed in one layer over a shallow, flat-bottomed pan approximately 50 mm below the sample, and is of sufficient size to cover completely the pattern of openings in the sample, but not large enough to catch any of the oil that runs over the edge of the sample or otherwise does not pass through the openings.

NOTE
Use of a metal screen or a wired-glass enclosure surrounding the test area is recommended.

U.2.2 Test procedure

A small metal ladle (preferably no more than 65 mm in diameter), with a pouring lip and a long handle whose longitudinal axis remains horizontal during pouring, is partially filled with 10 ml of a distillate fuel oil which is a medium volatile distillate having a mass per unit volume between 0,845 g/ml and 0,865 g/ml, a flash point between 43,5 °C and 93,5 °C and an average calorific value of 38 MJ/l. The ladle containing the oil is heated and the oil ignited and permitted to burn for 1 min, at which time all of the hot flaming oil is poured at the rate of approximately 1 ml/s in a steady stream onto the centre of the pattern of openings, from a position approximately 100 mm above the openings.

The test is repeated twice at 5 min intervals, using clean cheesecloth.

U.2.3 Compliance criteria

During these tests the cheesecloth shall not ignite.

U.3 Flammability test for high voltage cables

Compliance of cables and insulation of wires is checked according to IEC 60695-2-2.

For the purpose of this Standard, the following applies with regard to IEC 60695-2-2.

Clause 5 – Severities

The values of duration of the application of the test flame are as follows:

- first specimen: 10 s
- second specimen: 60 s
- third specimen: 120 s

Clause 7 – Initial measurements

Not applicable

Clause 8 – Test procedure

- Add the following to 8.4:

  The burner is supported so that its axis is in an angle of 45° to the vertical. The cable or wire is held in an angle of 45° to the vertical, its axis being in a vertical plane perpendicular to the vertical plane containing the axis of the burner.

- Subclause 8.5 is replaced by the following:

The test is made on three specimens taken from each type of cable or wire as used in the equipment, for example with additional screening and sleeves.

Clause 9 – Observations and measurements

- Subclause 9.1
  Not applicable.

- Subclause 9.2
  The second paragraph is replaced by the following:

  Duration of the burning denotes the time interval from the moment the test flame is removed until any flame has extinguished.

Clause 10 – Evaluation of the results

- The existing text is replaced by the following:
  During the test, any burning of the insulating materials shall be steady and shall not spread appreciably. Any flame shall self-extinguish in 30 s from the removal of the test flame.

U.4 Flammability classification of materials

Materials are classified according to the burning behaviour and their ability to extinguish, if ignited. Tests are made with the material in the thinnest significant thickness used.

Table U.1 – Foamed materials

Class	ISO standard	Replacing previously used class
FH-1 regarded better than FH-2	9772	HF-1
FH-2 regarded better than FH-3	9772	HF-2
FH-3	9772	HF-3

Table U.2 – Rigid (engineering structural) foamed materials

Class	IEC standard	Replacing previously used class
5VA regarded better than 5VB	6069511-20	5V
5VB regarded better than V-0	6069511-20	5V
V-0 regarded better than V-1	6069511-10	-
V-1 regarded better than V-2	6069511-10	-
V-2 regarded better than HB40	6069511-10	-
HB40 regarded better than HB75	6069511-10	HB
HB75	6069511-10	HB

Table U.3 – VTM materials

Class	ISO standard	Comparable, only with respect to flammability
VTM-0 regarded better than VTM-1	9773	V-0
VTM-1 regarded better than VTM-2	9773	V-1
VTM-2	9773	-

NOTE
When VTM materials are used, also relevant electrical and mechanical requirements should be considered.

Annex V
(normative)

Tests for enclosures

V.1 Steady force test, 30 N

ENCLOSURES or parts thereof, and barriers are subjected to a steady force of 30 N ±3 N for a period of 5 s applied by means of the rigid test finger, test probe 11 of IEC 61032. This test may be applied on the complete equipment or on a separate sub-assembly.

V.2 Impact test

External surfaces of ENCLOSURES, the failure of which would give access to hazardous rotating or otherwise moving parts, are tested as follows:

A sample consisting of the complete ENCLOSURE or a portion thereof, representing the largest un-reinforced area is supported in its normal position. A solid, smooth, steel sphere, approximately 50 mm in diameter and with a mass of 500 g ± 25 g, is used to perform the following tests:

- On horizontal surfaces, the sphere is permitted to fall freely from rest through a vertical distance of 1300 mm onto the sample, see figure V.1.

  This test is not applied to the platen glass of equipment (e.g. copying machines).

- On vertical surfaces, the sphere is suspended by a cord and swung as a pendulum in order to apply a horizontal impact, dropping through a vertical distance of 1300 mm onto the sample, see figure V.1.

Alternatively it is permitted to simulate horizontal impacts on vertical or sloping surfaces by mounting the sample at 90° to its normal position and applying the vertical impact test instead of the pendulum test. This test does not apply to ENCLOSURES of TRANSPORTABLE EQUIPMENT and of equipment intended to be held in the hand when operating.

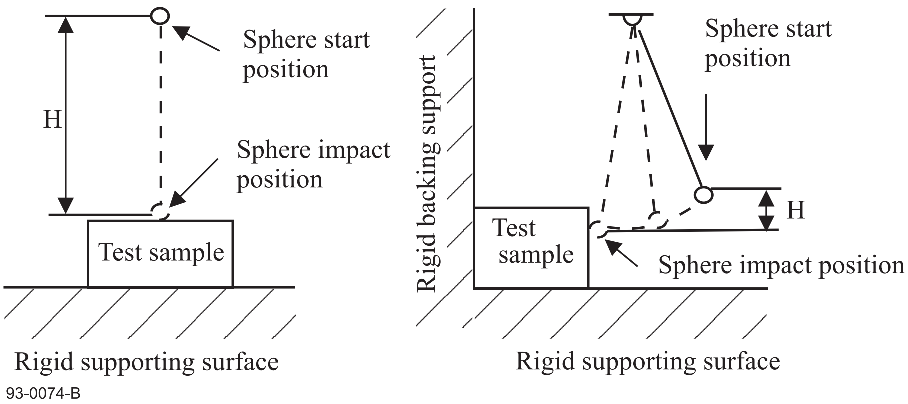

Figure V.1 – Impact test using sphere

Annex W
(normative)

Mechanical strength of picture tubes and protection against the effects of implosion

W.1 General

Picture tubes with a maximum face dimension exceeding 16 cm either shall be intrinsically protected with respect to effects of implosion and to mechanical impact, or the ENCLOSURE of the equipment shall provide adequate protection against the effects of an implosion of the tube.

A non-intrinsically protected picture tube shall be provided with an effective protective screen, which cannot be removed by hand. If a separate screen of glass is used, it shall not be in contact with the surface of the tube.

W.1.1 Test method

Compliance is checked by inspection, by measurement, and by the tests of:

- IEC 61965 for intrinsically protected tubes, including those having integral protective screens;
- W.2 for equipment having non-intrinsically protected tubes.

NOTE 1
A picture tube is considered to be intrinsically protected with respect to the effects of implosion if, when it is correctly mounted, no additional protection is necessary.

NOTE 2
To facilitate the tests, the tube manufacturer may indicate the most vulnerable area on the tubes to be tested.

W.2 Non-intrinsically protected picture tubes

W.2.1 Test method

The equipment, with the picture tube and the protective screen in position, is placed on a horizontal support at a height of (75 ± 5) cm above the floor, or directly on the floor if the equipment is obviously intended to be positioned on the floor.

The tube is made to implode inside the ENCLOSURE of the equipment by the following method.

Cracks are propagated in the envelope of each tube as follows:

An area on the side or on the face of each tube is scratched with a diamond stylus and this place is repeatedly cooled with liquid nitrogen or the like until a fracture occurs. To prevent the cooling liquid from flowing away from the test area, a dam of modelling clay or the like should be used.

W.2.2 Compliance criteria

After this test, no particles having a mass exceeding 2 g shall have passed a 25 cm high barrier, placed on the floor, 50 cm from the projection of the front of the equipment, and no particle shall have passed a similar barrier at 200 cm.

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