

INTERNATIONAL STANDARD



**Audio/video, information and communication technology equipment –
Part 1: Safety requirements**

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Part 1: Safety requirements**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**AUDIO/VIDEO, INFORMATION AND COMMUNICATION
TECHNOLOGY EQUIPMENT –****Part 1: Safety requirements**

FOREWORD

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International Standard IEC 62368-1 has been prepared by TC 108: Safety of electronic equipment within the field of audio/video, information technology and communication technology.

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

FDIS	Report on voting
108/325/FDIS	108/355/RVD

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

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

Except for text preceded by "Note", all text within a normative figure, or in a box under a normative table, is also normative. Text with a superscript reference is linked to a particular item in the table. Other text in a box under a table applies to the whole table.

Informative annexes and text beginning with the word "NOTE" are not normative. They are provided only to give additional information.

The "in some countries" notes regarding differing national practices are contained in the following subclauses:

0.2.1, 4.1.15, 5.4.2.4.3, 5.4.2.9, 5.4.5.1, 5.5.2.2, 5.5.2.7, 5.7.7, 10.3.2, 10.3.3.3, 10.3.3.4, 10.4.1, F.3.3.5, Table 15 and Table 16.

In this standard, the following print types or formats are used:

- requirements proper and normative annexes: in roman type;
- compliance statements and test specifications: *in italic type*;
- notes/explanatory matter: in smaller roman type;
- normative conditions within tables: in smaller roman type;
- terms that are defined in 3.3: **bold**.

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

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

NOTE 1 The attention of National Committees and National bodies who prepare national standards is drawn to the fact that equipment manufacturers and testing organizations may need a transitional period following publication of a new, amended or revised IEC publication in which to make products in accordance with the new requirements and to equip themselves for conducting new or revised tests. It is the recommendation of TC108 that the content of this publication be adopted for mandatory implementation nationally not earlier than five years from the date of publication of this standard.

NOTE 2 IEC 62368-1 is based on the principles of hazard based safety engineering, which is a different way of developing and specifying safety considerations than that of the current practice. While this standard is different from traditional IEC safety standards in its approach and while it is believed that IEC 62368-1 provides a number of advantages, its introduction and evolution is not intended to result in significant changes to the existing safety philosophy that led to the development of the safety requirements contained in IEC 60065 and IEC 60950-1. The predominant reason behind the creation of IEC 62368-1 is to simplify the problems created by the merging of the technologies of ITE and CE. The techniques used are novel so that a learning process is required and experience is needed in its application. Consequently, IEC/TC108 recommends that the first edition of this standard be considered as an alternative to IEC 60065 or IEC 60950-1 at least over the recommended transition period.

NOTE 3 Explanatory information related to IEC 62368-1 will be published as IEC/TR 62368-2. It will contain rationale together with explanatory information related to this standard.

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

INTRODUCTION

0 Principles of this product safety standard

0.1 Objective

This International Standard is a product safety standard that classifies energy sources, prescribes **safeguards** against those energy sources, and provides guidance on the application of, and requirements for those **safeguards**.

The prescribed **safeguards** are intended to reduce the likelihood of pain, injury and, in the case of fire, property damage.

The objective of the INTRODUCTION is to help designers to understand the underlying principles of safety in order to design safe equipment. These principles are informative and not an alternative to the detailed requirements of this standard.

0.2 Persons

0.2.1 General

This standard describes **safeguards** for the protection of three kinds of persons: the **ordinary person**, the **instructed person**, and the **skilled person**. This standard assumes that a person will not intentionally create conditions or situations that could cause pain or injury.

NOTE In Australia, the work conducted by an **instructed person** or **skilled person** may require formal licensing from regulatory authorities.

0.2.2 Ordinary person

Ordinary person is the term applied to all persons other than **instructed persons** and **skilled persons**. **Ordinary persons** include not only users of the equipment, but also all persons who may have access to the equipment or who may be in the vicinity of the equipment. Under **normal operating conditions** or **abnormal operating conditions**, **ordinary persons** should not be exposed to parts comprising energy sources capable of causing pain or injury. Under a **single fault condition**, **ordinary persons** should not be exposed to parts comprising energy sources capable of causing injury.

0.2.3 Instructed person

Instructed person is a term applied to persons who have been instructed and trained by a **skilled person**, or who are supervised by a **skilled person**, to identify energy sources that may cause pain (see Table 1) and to take precautions to avoid unintentional contact with or exposure to those energy sources. Under **normal operating conditions**, **abnormal operating conditions** or **single fault conditions**, **instructed persons** should not be exposed to parts comprising energy sources capable of causing injury.

0.2.4 Skilled person

Skilled person is a term applied to persons who have training or experience in the equipment technology, particularly in knowing the various energies and energy magnitudes employed in the equipment. A **skilled person** is expected to use their training and experience to recognize energy sources capable of causing pain or injury and to take action for protection from injury from those energies. **Skilled persons** should also be protected against unintentional contact or exposure to energy sources capable of causing injury.

0.3 Model for pain and injury

This subclause presents an engineering-based model for pain and injury and their relationship to an energy source.

An energy source that causes pain or injury does so through the transfer of some form of energy to or from a body part.

This concept is represented by a three-block model (see Figure 1).

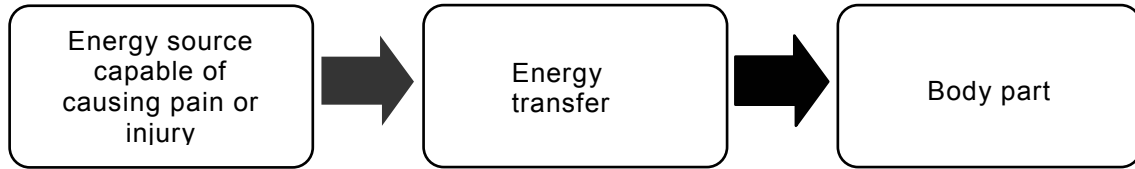


Figure 1 – Three block model for pain and injury

This safety standard specifies three classes of energy sources defined by magnitudes and durations of source parameters relative to either the body or to **combustible material** responses to those energy sources. Each energy class (see 4.2) is a function of the body part or the **combustible material** susceptibility to that energy magnitude (see Table 1).

Table 1 – Response to energy class

Energy source	Effect on the body	Effect on combustible materials
Class 1	Not painful, but may be detectable	Ignition not likely
Class 2	Painful, but not an injury	Ignition possible, but limited growth and spread of fire
Class 3	Injury	Ignition likely, rapid growth and spread of fire

The energy threshold for pain or injury is not constant throughout the population. For example, for some energy sources, the threshold is a function of body mass; the lower the mass, the lower the threshold, and vice-versa. Other body variables include age, state of health, state of emotions, effect of drugs, skin characteristics, etc. Furthermore, even where outward appearances otherwise appear equal, individuals differ in their thresholds of susceptibility to the same energy source.

The effect of duration of energy transfer is a function of the specific energy form. For example, pain or injury from thermal energy can be very short (1 s) for high skin temperature, or very long (several hours) for low skin temperature.

Furthermore, the pain or injury may occur some considerable time after the transfer of energy to a body part. For example, pain or injury from some chemical reaction may not be manifested for days, weeks, months, or years.

0.4 Energy sources

This subclause identifies the energy sources addressed by this standard, and the pain or injury that results from a transfer of that energy to the body, and the likelihood of property damage that results from fire escaping the equipment.

An electrical product is connected to an electrical energy source (for example, the **mains**), an external power supply, or a battery. An electrical product uses the electrical energy to perform its intended functions.

In the process of using electrical energy, the product transforms the electrical energy into other forms of energy, for example thermal energy, kinetic energy, optical energy, audio energy, electromagnetic energy, etc. Some energy transformations may be a deliberate part of the product function (for example, moving parts of a printer, images on a visual display unit, sound from a speaker, etc). Some energy transformations may be a by-product of the product

function (for example, heat dissipated by functional circuits, x-radiation from a cathode-ray tube, etc).

Some products may employ energy sources that are non-electrical energy sources such as batteries, moving parts, or chemicals, etc. The energy in these other sources may be transferred to or from a body part, or may be transformed into other energy forms (for example, a battery transforms chemical energy into electrical energy, or a moving body part transfers its kinetic energy to a sharp edge).

Examples of the types of energy forms and the associated injuries and property damage addressed in this standard are in Table 2.

Table 2 – Examples of body response or property damage related to energy sources

Forms of energy	Examples of body response or property damage	Clause
Electrical energy (for example, energized conductive parts)	Pain, fibrillation, cardiac arrest, respiratory arrest, skin burn, or internal organ burn	5
Thermal energy (for example, electrical ignition and spread of fire)	Electrically-caused fire leading to burn-related pain or injury, or property damage	6
Chemical reaction (for example, electrolyte, poison)	Skin damage, lung and other organ damage, or poisoning	7
Kinetic energy (for example, moving parts of equipment, or a moving body part against an equipment part)	Laceration, puncture, abrasion, contusion, crush, amputation, or loss of a limb, eye, ear, etc.	8
Thermal energy (for example, hot accessible parts)	Skin burn	9
Radiated energy (for example, electromagnetic energy, optical energy, acoustic energy)	Loss of sight, skin burn, or loss of hearing	10

0.5 Safeguards

0.5.1 General

This subclause introduces the three-block model for safety to explain the function of a **safeguard** and describes various manifestations of **safeguards**.

Many products necessarily employ energy capable of causing pain or injury. Equipment design cannot eliminate such energy use. Consequently, such products should employ a scheme that reduces the likelihood of such energy being transferred to a body part. The scheme that reduces the likelihood of energy transfer to a body part is a **safeguard** (see Figure 2).



Figure 2 – Three block model for safety

A **safeguard** is a device or scheme or system that

- is interposed between an energy source capable of causing pain or injury and a body part, and
- reduces the likelihood of transfer of energy capable of causing pain or injury to a body part.

NOTE **Safeguard** mechanisms against transfer of energy capable of causing pain or injury include

- attenuating the energy (reduces the value of the energy), or
- impeding the energy (slows the rate of energy transfer), or
- diverting the energy (changes the energy direction), or
- disconnecting, interrupting, or disabling the energy source, or
- enveloping the energy source (reduces the likelihood of the energy from escaping), or
- interposing a barrier between a body part and the energy source.

A **safeguard** can be applied to the equipment, to the local installation, to a person or can be a learned or directed behaviour (for example, resulting from an **instructional safeguard**) intended to reduce the likelihood of transfer of energy capable of causing pain or injury. A **safeguard** may be a single element or may be a set of elements.

Ideally, the order of preference for providing **safeguards** is:

- **equipment safeguards**;
- **installation safeguards**;
- **instructional safeguards** invoking **personal protective equipment**, or avoidance behaviour.

In practice, **safeguard** selection will take account of the nature of the energy source, the intended user, the functional requirements of the equipment, and similar considerations.

0.5.2 Equipment safeguard

An **equipment safeguard** may be a **basic safeguard**, a **supplementary safeguard**, a **double safeguard**, or a **reinforced safeguard**.

0.5.3 Installation safeguard

Installation safeguards are not controlled by the equipment manufacturer, although in some cases, **installation safeguards** may be specified in the equipment installation instructions.

Generally, with respect to equipment, an **installation safeguard** is a **supplementary safeguard**.

NOTE For example, the protective earthing **supplementary safeguard** is located partly in the equipment and partly in the installation. The protective earthing **supplementary safeguard** is not effective until the equipment is connected to the installation.

Requirements for **installation safeguards** are not addressed in this standard. However, this standard does assume some **installation safeguards**, such as protective earthing, are in place and are effective.

0.5.4 Instructional safeguard

An **instructional safeguard** is a visual indicator (symbols or words or both) or an audible message describing the existence and location of an energy source capable of causing pain or injury and is intended to invoke a specific behaviour on the part of a person to reduce the likelihood of transfer of energy to a body part (see Annex F).

An **instructional safeguard** may be a **basic safeguard**, or a **supplementary safeguard**.

When accessing locations where the unit needs to be energized to perform a service activity, an **instructional safeguard** may be considered acceptable protection to bypass an **equipment safeguard** such that the person is made aware of how to avoid contact with a class 2 energy source.

If **equipment safeguards** would interfere with or prohibit the equipment function, an **instructional safeguard** may be a **reinforced safeguard**.

Provision of an **instructional safeguard** does not result in an **ordinary person** becoming an **instructed person** (see 0.5.8).

0.5.5 Personal safeguard

A **personal safeguard** may be a **basic safeguard**, a **supplementary safeguard**, or a **reinforced safeguard**.

Requirements for **personal safeguards (personal protective equipment)** are not addressed in this standard. However, this standard does assume that **personal safeguards** are available for use as specified by the manufacturer.

0.5.6 Safeguards during ordinary or instructed person service conditions

During **ordinary person** or **instructed person** service conditions, **safeguards** for such persons may be necessary. Such **safeguards** can be **equipment safeguards**, **personal safeguards**, or **instructional safeguards**. Application of these **safeguards** is specified in the respective clauses.

0.5.7 Equipment safeguards during skilled person service conditions

During **skilled person** service conditions, **equipment safeguards** should be provided to protect against the effects of a body's involuntary reaction (for example, startle) that might cause unintentional contact with a class 3 energy source located outside the view of the **skilled person**.

NOTE This **safeguard** typically applies in large equipment, where the **skilled person** may need to partially or wholly enter between two or more class 3 energy source locations while servicing.

0.5.8 Precautionary safeguard

A **precautionary safeguard** is the training and experience or supervision of an **instructed person** by a **skilled person** to use precautions to protect the **instructed person** against class 2 energy sources. **Precautionary safeguards** are not specifically prescribed in this standard but are assumed to be effective when the term **instructed person** is used.

During equipment servicing, an **instructed person** may need to remove or defeat an **equipment safeguard**. In this case, an **instructed person** must then apply precaution as a **safeguard** to avoid injury.

0.5.9 Skill safeguard

A **skill safeguard** is the education, training, knowledge and experience of the **skilled person** that is employed to protect the **skilled person** against class 2 and class 3 energy sources. **Skill safeguards** are not specifically prescribed in this standard but are assumed to be effective when the term **skilled person** is used.

During equipment servicing, a **skilled person** may need to remove or defeat an **equipment safeguard**. In this case, a **skilled person** must then apply skill as a **safeguard** to avoid injury.

0.5.10 Examples of safeguard characteristics

Table 3 lists some examples of **safeguard** characteristics.

Table 3 – Examples of safeguard characteristics

Safeguard	Basic safeguard	Supplementary safeguard	Reinforced safeguard
Equipment safeguard: a physical part of an equipment	Effective under normal operating conditions	Effective in the event of failure of the basic safeguard	Effective under normal operating conditions and in the event of a single fault condition elsewhere in the equipment
	Example: basic insulation	Example: supplementary insulation	Example: reinforced insulation
	Example: normal temperatures below ignition temperatures	Example: fire enclosure	Not applicable
Installation safeguard: a physical part of a man-made installation	Effective under normal operating conditions	Effective in the event of failure of an equipment basic safeguard	Effective under normal operating conditions and in the event of a single fault condition elsewhere in the equipment
	Example: wire size	Example: overcurrent protective device	Example: socket outlet
Personal safeguard: a physical device worn on the body	In the absence of any equipment safeguard , effective under normal operating conditions	Effective in the event of failure of an equipment basic safeguard	In the absence of any equipment safeguard , effective under normal operating conditions and in the event of a single fault condition elsewhere in the equipment
	Example: glove	Example: insulating floor mat	Example: electrically-insulated glove for handling live conductors
Instructional safeguard: a voluntary or instructed behaviour intended to reduce the likelihood of transfer of energy to a body part	In the absence of any equipment safeguard , effective under normal operating conditions	Effective in the event of failure of an equipment basic safeguard	Only effective on an exceptional basis, when providing all appropriate safeguards would prevent the intended functioning of the equipment
	Example: instructional safeguard to disconnect telecommunication cable before opening the cover	Example: after opening a door, an instructional safeguard against hot parts	Example: instructional safeguard of hot parts in an office photocopier, or a continuous roll paper cutter on a commercial printer

0.6 Electrically-caused pain or injury (electric shock)

0.6.1 General

This subclause describes models for electrically-caused pain or injury and models for reducing the likelihood of transfer of electrical energy capable of causing pain or injury to a body part.

0.6.2 Models for electrically-caused pain or injury

Electrically-caused pain or injury may occur when electrical energy capable of causing pain or injury is transferred to a body part (see Figure 3).

Electrical energy transfer occurs when there are two or more electrical contacts to the body:

- the first electrical contact is between a body part and a conductive part of the equipment;
- the second electrical contact is between another body part, and
 - earth, or
 - another conductive part of the equipment.

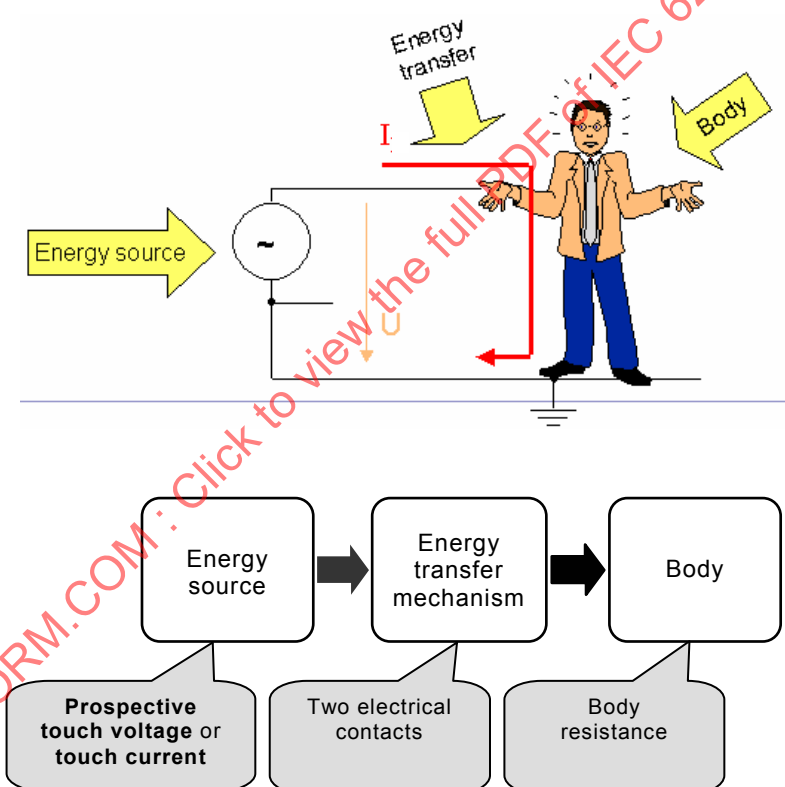


Figure 3 – Schematic and model for electrically-caused pain or injury

Depending on the magnitude, duration, wave shape, and frequency of the current, the effect to the human body varies from undetectable to detectable to painful to injurious.

0.6.3 Models for protection against electrically-caused pain or injury

Protection against electrically-caused pain or injury requires that one or more **safeguards** be interposed between an electrical energy source capable of causing pain or injury and a body part (see Figure 4).

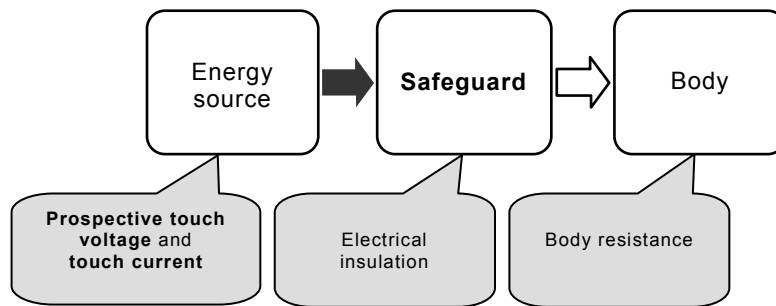


Figure 4 – Model for protection against electrically-caused pain or injury

Protection against electrically-caused pain is provided under **normal operating conditions** and **abnormal operating conditions**. Such protection requires that, under **normal operating conditions** and **abnormal operating conditions**, a **basic safeguard** be interposed between an electrical energy source capable of causing pain and an **ordinary person**.

The most common **basic safeguard** against an electrical energy source capable of causing pain is electrical insulation (also known as **basic insulation**) interposed between the energy source and a body part.

Protection against electrically-caused injury is provided under **normal operating conditions**, **abnormal operating conditions**, and **single fault conditions**. Such protection requires that, under **normal operating conditions** and **abnormal operating conditions**, both a **basic safeguard** and a **supplementary safeguard** be interposed between an electrical energy source capable of causing injury and an **ordinary person** (see 4.3.2.4), or an **instructed person** (see 4.3.3.3). In the event of a failure of either **safeguard**, the other **safeguard** becomes effective.

The **supplementary safeguard** against an electrical energy source capable of causing injury is interposed between the **basic safeguard** and a body part. A **supplementary safeguard** may be additional electrical insulation (**supplementary insulation**) or a protectively earthed conductive barrier or other construction that performs the same function.

The most common **safeguard** against an electrical energy source capable of causing injury is electrical insulation (also known as **double insulation** or **reinforced insulation**) interposed between the energy source and a body part.

Likewise, a **reinforced safeguard** may be interposed between an electrical energy source capable of causing injury and a body part.

0.7 Electrically-caused fire

0.7.1 General

This subclause describes models to reduce the likelihood of ignition (within the equipment) or to reduce the likelihood of fire (originating within the equipment) from spreading beyond the equipment.

0.7.2 Models for electrically-caused fire

Electrically-caused fire is due to conversion of electrical energy to thermal energy (see Figure 5), where the thermal energy heats a fuel material followed by ignition and combustion.

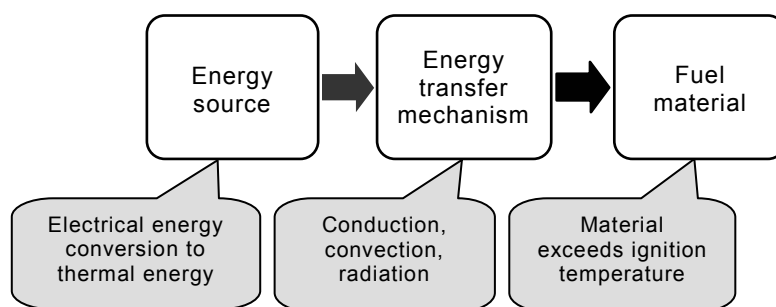


Figure 5 – Model for electrically-caused fire

Electrical energy is converted to thermal energy either in a resistance or in an arc and is transferred to a fuel material by conduction, convection, or radiation. As the fuel material heats, it chemically decomposes into gases, liquids and solids. When the gas is at its ignition temperature, the gas can be ignited by an ignition source. When the gas is at its auto-ignition temperature, the gas will ignite by itself. Both result in fire.

0.7.3 Models for protection against electrically-caused fire

The **basic safeguard** against electrically-caused fire (see Figure 6) is that the temperature of a material, under **normal operating conditions** and **abnormal operating conditions**, does not cause the material to ignite.

The **supplementary safeguard** against electrically-caused fire reduces the likelihood of ignition or, in the case of ignition, reduces the likelihood of spread of fire.

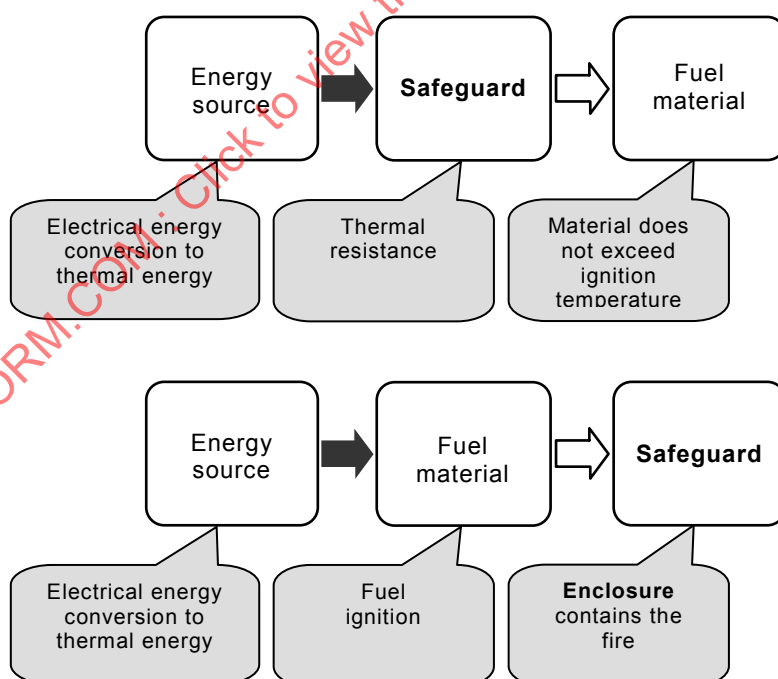


Figure 6 – Models for protection against fire

0.8 Chemically-caused injury

This subclause describes models for reducing the likelihood of injury from exposure to chemicals.

Chemically-caused injury is due to a chemical reaction with a body part. The extent of injury by a given agent depends on both the magnitude and duration of exposure and on the body part susceptibility to that agent.

The **basic safeguard** against chemically-caused injury is containment of the material.

Supplementary safeguards against chemically-caused injury may include:

- a second container or a spill-resistant container;
- containment trays;
- tamper-proof screws to prevent unauthorized access;
- **instructional safeguards**.

National and regional regulations govern the use of and exposure to chemicals used in equipment. These regulations do not enable a practical classification of chemicals in the manner in which other energy sources are classified in this standard. Therefore, energy source classifications are not applied in Clause 7.

0.9 Mechanically-caused injury

This subclause describes models for reducing the likelihood of injuries such as cuts, bruises, broken bones, etc. due to transfer of kinetic energy to a body part.

Mechanically-caused injury is due to kinetic energy transfer to a body part when a collision occurs between a body part and an equipment part. The kinetic energy is a function of the relative motion between a body part and **accessible** parts of the equipment, including parts ejected from the equipment that collide with a body part.

Examples of kinetic energy sources are:

- body motion relative to sharp edges and corners;
- part motion due to rotating or other moving parts, including pinch points;
- part motion due to loosening, exploding, or imploding parts;
- equipment motion due to instability;
- equipment motion due to wall, ceiling, or rack mounting means failure;
- equipment motion due to handle failure;
- part motion due to an exploding battery;
- equipment motion due to cart or stand instability or failure.

The **basic safeguard** against mechanically-caused injury is a function of the specific energy source. **Basic safeguards** may include:

- rounded edges and corners;
- an **enclosure** to prevent a moving part from being **accessible**;
- an **enclosure** to prevent expelling a moving part;
- a **safety interlock** to control access to an otherwise moving part;
- means to stop the motion of a moving part;
- means to stabilize the equipment;
- handles;
- mounting means;
- means to contain parts expelled during **explosion** or implosion.

The **supplementary safeguard** against mechanically-caused injury is a function of the specific energy source. **Supplementary safeguards** may include:

- **instructional safeguards**;
- instructions and training;
- additional **enclosures** or barriers;
- **safety interlocks**.

The **reinforced safeguard** against mechanically-caused injury is a function of the specific energy source. **Reinforced safeguards** may include:

- extra thick glass on the front of a CRT;
- rack slide-rails and means of support;
- **safety interlock**.

0.10 Thermally-caused injury (skin burn)

0.10.1 General

This subclause describes models for thermally-caused injury and models for reducing the likelihood of thermal energy capable of causing pain or injury being transferred to a body part.

0.10.2 Models for thermally-caused injury

Thermally-caused injury may occur when thermal energy capable of causing injury is transferred to a body part (see Figure 7).

Thermal energy transfer occurs when a body touches a hot equipment part. The extent of injury depends on the temperature difference, the thermal mass of the object, rate of thermal energy transfer to the skin, and duration of contact.

The requirements in this standard only address **safeguards** against thermal energy transfer by conduction. This standard does not address **safeguards** against thermal energy transfer by convection or radiation.

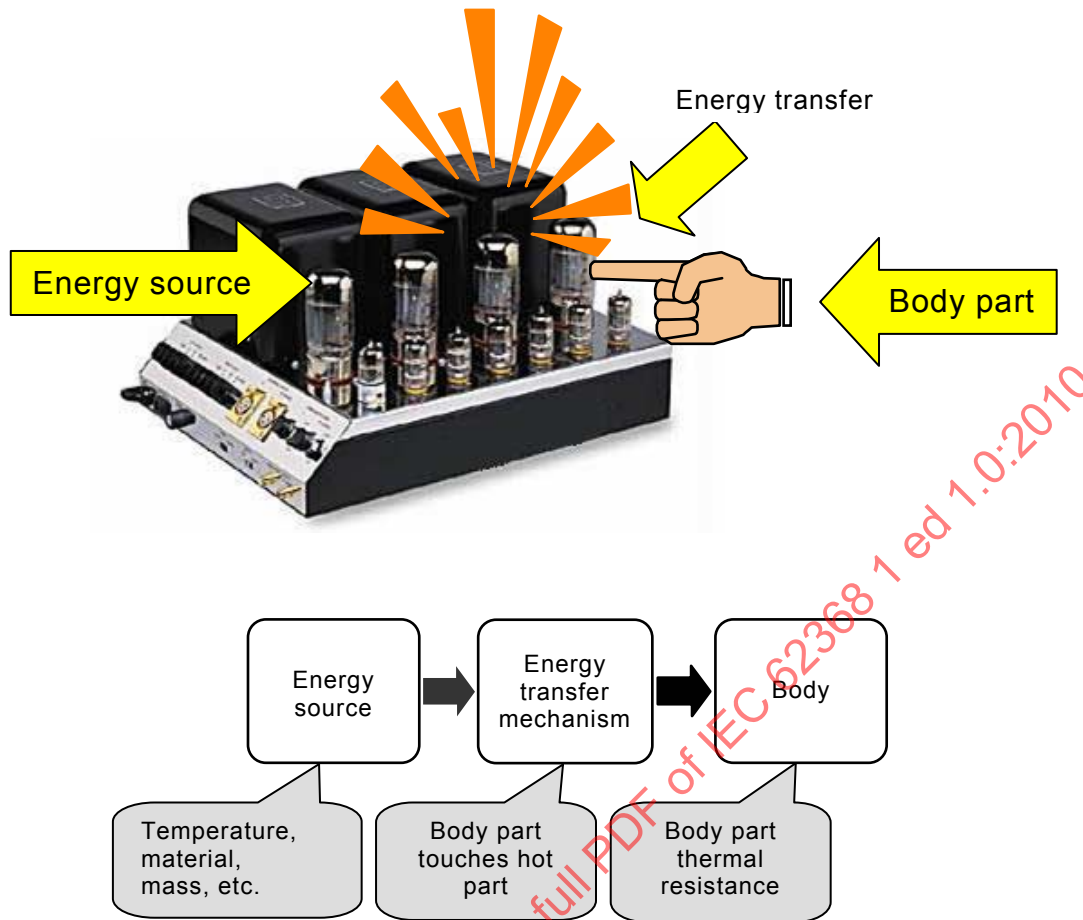


Figure 7 – Schematic and model for thermally-caused injury

Depending on the temperature, contact duration, material properties, and mass of the material, the perception of the human body varies from warmth to heat that may result in pain or injury (burn).

0.10.3 Models for protection against thermally-caused pain or injury

Protection against thermally-caused pain or injury requires that one or more **safeguards** be interposed between a thermal energy source capable of causing pain or injury and an **ordinary person** (see Figure 8).

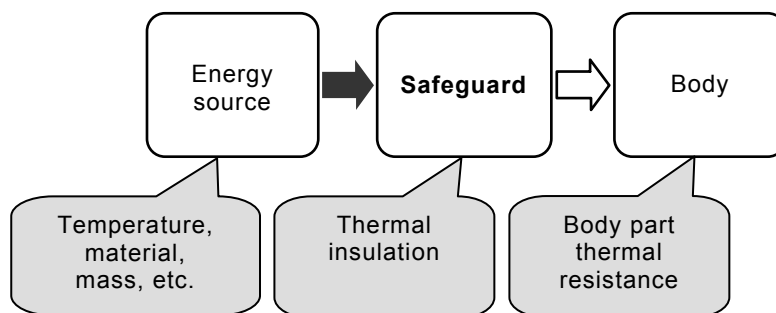


Figure 8 – Model for protection against thermally-caused injury

Protection against thermally-caused pain is required under **normal operating conditions** and **abnormal operating conditions**. Such protection requires that a **basic safeguard** be

interposed between a thermal energy source capable of causing pain and an **ordinary person**.

Protection against thermally-caused injury is required under **normal operating conditions**, **abnormal operating conditions** and **single fault conditions**. Such protection requires that a **basic safeguard** and a **supplementary safeguard** be interposed between a thermal energy source capable of causing injury and an **ordinary person**.

The **basic safeguard** against a thermal energy source capable of causing pain or injury is thermal insulation interposed between the energy source and a body part. In some cases, a **basic safeguard** against a thermal energy source capable of causing pain or injury may be an **instructional safeguard** identifying the hot parts and how to reduce the likelihood of injury. In some cases, a **basic safeguard** reduces the likelihood of a non-injurious thermal energy source from becoming a thermal energy source capable of causing pain or injury.

Examples of such **basic safeguards** are:

- control of electrical energy being converted to thermal energy (for example, a **thermostat**);
- heat sinking, etc.

The **supplementary safeguard** against a thermal energy source capable of causing injury is thermal insulation interposed between the energy source and a body part. In some cases, a **supplementary safeguard** against a thermal energy source capable of causing pain or injury may be an **instructional safeguard** identifying the hot parts and how to reduce the likelihood of injury.

0.11 Radiation-caused injury

This subclause describes models for reducing the likelihood of injury from exposure to radiated energy.

Radiation-caused injury within the scope of this standard is generally attributed to one of the following energy transfer mechanisms:

- heating of a body organ caused by exposure to non-ionising radiation, such as the highly localised energy of a laser impinging on the retina, or heating a larger volume such as the energy from a high frequency wireless, electromagnetic fields, or high frequency transmitter, or
- auditory injury caused by over stimulation of the ear by excessive peaks or sustained loud sound, leading to physical or nerve damage.

Radiated energy is transferred by impingement of wave emission upon a body part.

The **basic safeguard** against radiation-caused injury is containment of the energy within an **enclosure** that is opaque to the radiated energy.

The **basic safeguard** against auditory injury is the provision of warnings and information advising the user how to use the equipment correctly.

Examples of **basic safeguards** against auditory pain and injury are the provision of warnings and information advising the user how to use the equipment correctly. Examples of **supplementary safeguards** against auditory injury are the provision of a **safety interlock** or a soundproof **enclosure**.

There are several **supplementary safeguards** against radiation-caused injury. The **supplementary safeguards** may include **safety interlocks** to disconnect power to the generator, tamper-proof screws to prevent unauthorized access, etc.

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AUDIO/VIDEO, INFORMATION AND COMMUNICATION TECHNOLOGY EQUIPMENT –

Part 1: Safety requirements

1 Scope

This part of IEC 62368 is applicable to the safety of electrical and electronic equipment within the field of audio, video, information and communication technology, and business and office machines with a **rated voltage** not exceeding 600 V. This standard does not include requirements for performance or functional characteristics of equipment.

NOTE 1 Examples of equipment within the scope of this standard are given in Annex A.

This part of IEC 62368 is also applicable to components and subassemblies intended for incorporation in this equipment. Such components and subassemblies need not comply with every requirement of the standard, provided that the complete equipment, incorporating such components and subassemblies, does comply.

This standard specifies **safeguards** for **ordinary persons**, **instructed persons**, and **skilled persons**.

NOTE 2 In Australia, the work conducted by an **instructed person** or a **skilled person** may require formal licensing from regulatory authorities.

This standard assumes an altitude of 2 000 m unless specified otherwise by the manufacturer.

This standard does not apply to equipment to be used in wet areas. Additional requirements may apply.

This standard does not apply to equipment for outdoor installation.

NOTE 3 Information and communication technology equipment that is intended for use outdoors is covered by IEC 60950-22.

This standard does not include requirements for functional safety.

NOTE 4 For specific functional and software safety requirements of electronic safety-related systems (for example, protective electronic circuits), see IEC 61508-1.

This standard does not address:

- manufacturing processes except safety testing;
- injurious effects of gases released by thermal decomposition or combustion;
- disposal processes;
- effects of transport (other than as specified in this standard);
- effects of storage of materials, components, or the equipment itself;
- the likelihood of injury from particulate radiation such as alpha particles and beta particles;
- the likelihood of thermal injury due to radiated or convected thermal energy;
- the likelihood of injury due to flammable liquids;
- the use of the equipment in oxygen-enriched or **explosive** atmospheres;
- exposure to chemicals other than those specified in Clause 7;
- electrostatic discharge events.

2 Normative references

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

IEC 60027-1, *Letter symbols to be used in electrical technology – Part 1: General*

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

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

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

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

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60086-4, *Primary batteries – Part 4: Safety of lithium batteries*

IEC 60107-1:1997, *Methods of measurement on receivers for television broadcast transmissions – Part 1: General considerations – Measurements at radio and video frequencies*

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

IEC 60127 (all parts), *Miniature fuses*

IEC 60127-1:2006, *Miniature fuses – Part 1: Definitions for miniature fuses and general requirements for miniature fuse-links*

IEC 60227-1:2007, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 1: General requirements*

IEC 60227-7:2003, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 7: Flexible cables screened and unscreened with two or more conductors*

IEC 60245-1:2003, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 1: General requirements*

IEC 60309-1, *Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements*

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

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

IEC 60320-1, *Appliance couplers for household and similar general purposes – Part 1: General requirements*

IEC 60320-2-2, *Appliance couplers for household and similar general purposes – Part 2-2: Interconnection couplers for household and similar equipment*

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

IEC 60332-1-3, *Tests on electric and optical fibre cables under fire conditions – Part 1-3: Test for vertical flame propagation for a single insulated wire or cable – Procedure for determination of flaming droplets/particles*

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

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

IEC 60384-14:2005, *Fixed capacitors for use in electronic equipment – Part 14: Sectional specification: Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

IEC 60417, *Graphical symbols for use on equipment*

IEC 60505, *Evaluation and qualification of electrical insulation systems*

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

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

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

IEC 60664-4:2005, *Insulation coordination for equipment within low-voltage systems – Part 4: Consideration of high-frequency voltage stress*

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

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

IEC 60695-10-3, *Fire hazard testing – Part 10-3: Abnormal heat – Mould stress relief distortion test*

IEC 60695-11-5:2004, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

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

IEC 60695-11-20:1999, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test methods*

IEC/TS 60695-11-21, *Fire hazard testing – Part 11-21: Test flames – 500 W vertical flame test method for tubular polymeric materials*

IEC 60728-11:2005, *Cable networks for television signals, sound signals and interactive services – Part 11: Safety*

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

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

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

IEC 60747-5-5:2007, *Semiconductor devices – Discrete devices – Part 5-5: Optoelectronic devices – Photocouplers*

IEC 60825 (all parts), *Safety of laser products*

IEC 60825-1:2007, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60825-2:2004, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*

IEC 60825-12:2004, *Safety of laser products – Part 12: Safety of free space optical communication systems used for transmission of information*

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

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

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

IEC 60896-11, *Stationary lead-acid batteries – Part 11: Vented types – General requirements and methods of tests*

IEC 60896-21:2004, *Stationary lead-acid batteries – Part 21: Valve regulated types – Methods of test*

IEC 60896-22, *Stationary lead-acid batteries – Part 22: Valve regulated types – Requirements*

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

IEC 60906-2, *IEC system of plugs and socket-outlets for household and similar purposes – Part 2: Plugs and socket-outlets 15 A 125 V a.c.*

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

IEC 60950-1:2005, *Information technology equipment – Safety – Part 1: General requirements*

IEC 60950-23, *Information technology equipment – Safety – Part 23: Large data storage equipment*

IEC 60990:1999, *Methods of measurement of touch current and protective conductor current*

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

IEC 60999-1, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units – Part 1: General requirements and particular requirements for clamping units for conductors from 0,2 mm² up to 35 mm² (included)*

IEC 60999-2, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units – Part 2: Particular requirements for clamping units for conductors above 35 mm² up to 300 mm² (included)*

IEC 61051-2:1991, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

IEC 61056-1, *General purpose lead-acid batteries (valve-regulated types) – Part 1: General requirements, functional characteristics – Methods of test*

IEC 61056-2, *General purpose lead-acid batteries (valve-regulated types) – Part 2: Dimensions, terminals and marking*

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

IEC 61140:2001, *Protection against electric shock – Common aspects for installation and equipment*

IEC/TS 61201:2007, *Use of conventional touch voltage limits – Application guide*

IEC/TS 61202-1:2000, *Fibre optic isolators – Part 1: Generic specification*

IEC 61204-7, *Low-voltage power supplies, d.c. output – Part 7: Safety requirements*

IEC 61293, *Marking of electrical equipment with ratings related to electrical supply – Safety requirements*

IEC 61427, *Secondary cells and batteries for photovoltaic energy systems (PVES) – General requirements and methods of test*

IEC/TS 61430, *Secondary cells and batteries – Test methods for checking the performance of devices designed for reducing explosion hazards – Lead-acid starter batteries*

IEC 61434, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Guide to designation of current in alkaline secondary cell and battery standards*

IEC 61558-1:2005, *Safety of power transformers, power supplies, reactors and similar products – Part 1: General requirements and tests*

IEC 61558-2 (all parts), *Safety of power transformers, power supplies, reactors and similar products*

IEC 61810-1:2008, *Electromechanical elementary relays – Part 1: General requirements*

IEC 61959, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Mechanical tests for sealed portable secondary cells and batteries*

IEC 61960, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for portable applications*

IEC 61965:2003, *Mechanical safety of cathode ray tubes*

IEC 61984, *Connectors - Safety requirements and tests*

IEC 62133, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications*

IEC 62282-2, *Fuel cell technologies – Part 2: Fuel cell modules*

IEC/TS 62393, *Portable and hand-held multimedia equipment – Mobile computers – Battery run-time measurement*

IEC 62471:2006, *Photobiological safety of lamps and lamp systems*

IEC 62485-2, *Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries*¹

ISO 178, *Plastics – Determination of flexural properties*

ISO 179-1, *Plastics – Determination of Charpy impact properties – Part 1: Non-instrumented impact test*

ISO 180, *Plastics – Determination of Izod impact strength*

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

ISO 527 (all parts), *Plastics – Determination of tensile properties*

ISO 871, *Plastics – Determination of ignition temperature using a hot-air furnace*

ISO 3864 (all parts), *Graphical symbols – Safety colours and safety signs*

ISO 3864-2, *Graphical symbols – Safety colours and safety signs – Part 2: Design principles for product safety labels*

ISO 4046-4:2002, *Paper, board, pulps and related terms – Vocabulary – Part 4: Paper and board grades and converted products*

ISO 4892-1, *Plastics – Methods of exposure to laboratory light sources – Part 1: General guidance*

ISO 4892-2:2006, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ISO 4892-4, *Plastics – Methods of exposure to laboratory light sources – Part 4: Open-flame carbon-arc lamps*

ISO 7000:2004, *Graphical symbols for use on equipment – Index and synopsis*

¹ To be published.

ISO 7010, *Graphical symbols – Safety colours and safety signs – Safety signs used in workplaces and public areas*

ISO 8256, *Plastics – Determination of tensile-impact strength*

ISO 9772, *Cellular plastics – Determination of horizontal burning characteristics of small specimens subjected to a small flame*

ISO 9773, *Plastics – Determination of burning behaviour of thin flexible vertical specimens in contact with a small-flame ignition source*

3 Terms, definitions and abbreviations

3.1 General

This clause has been subdivided into “terms and abbreviations” and “definitions”. Where the words “voltage” and “current” are used, they are r.m.s. values unless otherwise specified.

3.2 Terms and abbreviations

3.2.1 Terms in alphabetical order

Term	Description	
ES	Electrical energy source	see 5.2
ES1	Electrical energy source class 1	
ES2	Electrical energy source class 2	
ES3	Electrical energy source class 3	
MS	Mechanical energy source	see 8.2
MS1	Mechanical energy source class 1	
MS2	Mechanical energy source class 2	
MS3	Mechanical energy source class 3	
PS	Power source	see 6.2
PS1	Power source class 1	
PS2	Power source class 2	
PS3	Power source class 3	
RS	Radiation energy source	see 10.2
RS1	Radiation energy source class 1	
RS2	Radiation energy source class 2	
RS3	Radiation energy source class 3	
TS	Thermal energy source	see 9.2
TS1	Thermal energy source class 1	
TS2	Thermal energy source class 2	
TS3	Thermal energy source class 3	

3.2.2 Abbreviations in alphabetical order

CD	Compact Disk
CD ROM	Compact Disc Read-Only Memory
CRT	Cathode RayTube
CTI	Comparative Tracking Index
DVD	Digital Versatile Disc
EIS	Electrical Insulation System
EUT	Equipment Under Test
IC	Integrated Circuits
LEL	Lower Explosion Limit
LFC	Liquid Filled Component
LPS	Limited Power Source
MOV	Metal Oxide Varistor
NiCd	Nickel Cadmium
PPE	Personal Protective Equipment
PTC	Positive Temperature Coefficient
Sb	Antimony
SPD	Surge Protection Devices
UPS	Uninterruptible Power Supply
VDR	Voltage Dependent Resistor
VRLA	Valve Regulated Lead Acid

3.3 Terms and definitions

For the purposes of this document the following terms and definitions apply. For the convenience of the user, the defined terms are listed below in alphabetical order by noun indicating the number of the defined term.

accessible	3.3.6.1
area, restricted access	3.3.6.6
cheesecloth	3.3.6.2
chemical, hazardous	3.3.16.4
circuit, external	3.3.1.1
class, material flammability	3.3.4.2
clearance	3.3.12.1
condition, abnormal operating	3.3.7.1
condition, normal operating	3.3.7.4
condition, overload	3.3.7.5
condition, single fault	3.3.7.10
conductor, protective	3.3.11.9
conductor, protective bonding	3.3.11.8
conductor, protective earthing	3.3.11.10
construction, class II	3.3.15.2
cord, non-detachable power supply	3.3.6.4
current, protective conductor	3.3.14.6
current, maximum charging	3.3.14.3
current, rated	3.3.10.1
current, touch	3.3.6.10
cut-off, thermal	3.3.13.4
degree, pollution	3.3.6.5
device, disconnect	3.3.6.3
distance, creepage	3.3.12.2
enclosure	3.3.2.2

enclosure, electrical	3.3.2.1
enclosure, fire	3.3.2.3
enclosure, mechanical	3.3.2.4
equipment, class I	3.3.15.1
equipment, class II	3.3.15.3
equipment, class III	3.3.15.4
equipment, direct plug-in	3.3.3.1
equipment, hand-held	3.3.3.2
equipment, movable	3.3.3.3
equipment, permanently connected	3.3.3.4
equipment, personal protective (PPE)	3.3.16.5
equipment, pluggable, type A	3.3.3.5
equipment, pluggable, type B	3.3.3.6
equipment, stationary	3.3.3.7
equipment, transportable	3.3.3.8
explosion	3.3.16.2
explosive	3.3.16.3
frequency, peak response	3.3.7.6
frequency, rated	3.3.10.2
impedance, rated load	3.3.7.7
insulation, basic	3.3.5.1
insulation, double	3.3.5.2
insulation, functional	3.3.5.3
insulation, reinforced	3.3.5.4
insulation, solid	3.3.5.5
insulation, supplementary	3.3.5.6
interlock, safety	3.3.11.13
limiter, temperature	3.3.13.3
mains	3.3.1.2
material, 5VA class	3.3.4.2.1
material, 5VB class	3.3.4.2.2
material, combustible	3.3.4.1
material, consumable	3.3.16.1
material, HB40 class	3.3.4.2.3
material, HB75 class	3.3.4.2.4
material, HBF class foamed	3.3.4.2.5
material, HF-1 class foamed	3.3.4.2.6
material, HF-2 class foamed	3.3.4.2.7
material, V-0 class	3.3.4.2.8
material, V-1 class	3.3.4.2.9
material, V-2 class	3.3.4.2.10
material, VTM-0 class	3.3.4.2.11
material, VTM-1 class	3.3.4.2.12
material, VTM-2 class	3.3.4.2.13
misuse, reasonably foreseeable	3.3.7.8
operation, intermittent	3.3.7.2
operation, short-time	3.3.7.9
person, instructed	3.3.8.1
person, ordinary	3.3.8.2
person, skilled	3.3.8.3
PIS, arcing	3.3.9.2
PIS, resistive	3.3.9.3
power, non-clipped output	3.3.7.3
power, rated	3.3.10.3
range, rated voltage	3.3.10.5
rating, protective current	3.3.10.6
safeguard	3.3.11.12
safeguard, basic	3.3.11.1
safeguard, double	3.3.11.2
safeguard, equipment	3.3.11.3
safeguard, installation	3.3.11.4
safeguard, instructional	3.3.11.5

safeguard, personal	3.3.11.6
safeguard, precautionary	3.3.11.7
safeguard, reinforced	3.3.11.11
safeguard, skill	3.3.11.14
safeguard, supplementary	3.3.11.15
source, potential ignition (PIS)	3.3.9.1
temperature, highest charging	3.3.13.1
temperature, lowest charging	3.3.13.2
test, routine	3.3.6.7
test, sampling	3.3.6.8
test, type	3.3.6.11
thermostat	3.3.13.5
tissue, wrapping	3.3.6.12
tool	3.3.6.9
voltage, d.c.	3.3.14.1
voltage, mains transient	3.3.14.2
voltage, peak working	3.3.14.4
voltage, prospective touch	3.3.14.5
voltage, r.m.s. working	3.3.14.8
voltage, rated	3.3.10.4
voltage, required withstand	3.3.14.7
voltage, upper limit charging	3.3.14.9
voltage, working	3.3.14.10

3.3.1 Circuit terms

3.3.1.1

external circuit

electrical circuit that is external to the equipment and is not **mains**

NOTE An **external circuit** is classified as ES1, ES2 or ES3, and PS1, PS2, or PS3.

3.3.1.2

mains

a.c. or d.c. power distribution system (external to the equipment) that supplies operating power to the equipment and is PS3

NOTE **Mains** include public or private utilities and, unless otherwise specified in this standard, equivalent sources such as motor-driven generators and uninterruptible power supplies.

3.3.2 Enclosure terms

3.3.2.1

electrical enclosure

enclosure intended as a **safeguard** against electrically-caused injury

[IEV 195-06-13, modified]

3.3.2.2

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 for an **electrical enclosure**, a **fire enclosure** or a **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.

3.3.2.3**fire enclosure**

enclosure intended as a **safeguard** against the spread of fire from within the **enclosure** to outside the **enclosure**

3.3.2.4**mechanical enclosure**

enclosure intended as a **safeguard** against mechanically-caused injury

3.3.3 Equipment terms**3.3.3.1****direct plug-in equipment**

equipment in which the **mains** plug forms an integral part of the equipment **enclosure**

3.3.3.2**hand-held equipment**

movable equipment, or a part of any kind of equipment, that is intended to be held in the hand during normal use

3.3.3.3**movable equipment**

equipment that is either:

- 18 kg or less in mass and not fixed in place, or
- provided with wheels, casters, or other means to facilitate movement by an **ordinary person** as required to perform its intended use

3.3.3.4**permanently connected equipment**

equipment that can only be electrically connected to the **mains** by the use of a **tool**

3.3.3.5**pluggable equipment type A**

equipment that is intended for connection to the **mains** via a non-industrial plug and socket-outlet (IEC/TR 60083 or national equivalent) or via a non-industrial appliance coupler (IEC 60320-1), or both

3.3.3.6**pluggable equipment type B**

equipment that is intended for connection to the **mains** via an industrial plug and socket-outlet (IEC 60309-1, or national equivalent) or via an industrial appliance coupler (IEC 60320-1), or both

3.3.3.7**stationary equipment**

- fixed equipment, or
- **permanently connected equipment**, or
- equipment that, due to its physical characteristics, is normally not moved

NOTE **Stationary equipment** is neither **movable equipment** nor **transportable equipment**.

3.3.3.8**transportable equipment**

equipment that is intended to be routinely carried

NOTE Examples include notebook computers, CD players and portable accessories, including their external power supplies.

3.3.4 Flammability terms

3.3.4.1

combustible material

organic material, capable of combustion

NOTE 1 For the purpose of this standard, metal other than magnesium, or ceramic are examples of materials that are not capable of being combusted.

NOTE 2 All thermoplastic materials are considered capable of being combusted regardless of the **material flammability class**.

3.3.4.2

material flammability class

recognition of the burning behaviour of materials and their ability to extinguish if ignited

Materials are classified as below when tested in accordance with IEC 60695-11-10, IEC 60695-11-20, ISO 9772 or ISO 9773.

3.3.4.2.1

5VA class material

material tested in the thinnest significant thickness used and classified 5VA according to IEC 60695-11-20

3.3.4.2.2

5VB class material

material tested in the thinnest significant thickness used and classified 5VB according to IEC 60695-11-20

3.3.4.2.3

HB40 class material

material tested in the thinnest significant thickness used and classified HB40 according to IEC 60695-11-10

3.3.4.2.4

HB75 class material

material tested in the thinnest significant thickness used and classified HB75 according to IEC 60695-11-10

3.3.4.2.5

HBF class foamed material

foamed material tested in the thinnest significant thickness used and classified HBF according to ISO 9772

3.3.4.2.6

HF-1 class foamed material

foamed material tested in the thinnest significant thickness used and classified HF-1 according to ISO 9772

3.3.4.2.7

HF-2 class foamed material

foamed material tested in the thinnest significant thickness used and classified HF-2 according to ISO 9772

3.3.4.2.8

V-0 class material

material tested in the thinnest significant thickness used and classified V-0 according to IEC 60695-11-10

3.3.4.2.9**V-1 class material**

material tested in the thinnest significant thickness used and classified V-1 according to IEC 60695-11-10

3.3.4.2.10**V-2 class material**

material tested in the thinnest significant thickness used and classified V-2 according to IEC 60695-11-10

3.3.4.2.11**VTM-0 class material**

material tested in the thinnest significant thickness used and classified VTM-0 according to ISO 9773

3.3.4.2.12**VTM-1 class material**

material tested in the thinnest significant thickness used and classified VTM-1 according to ISO 9773

3.3.4.2.13**VTM-2 class material**

material tested in the thinnest significant thickness used and classified VTM-2 according to ISO 9773

3.3.5 Insulation**3.3.5.1****basic insulation**

insulation to provide a **basic safeguard** against electric shock

[IEV 195-06-06, modified]

NOTE This concept does not apply to insulation used exclusively for functional purposes.

3.3.5.2**double insulation**

insulation comprising both **basic insulation** and **supplementary insulation**

[IEV 195-06-08]

3.3.5.3**functional insulation**

insulation between conductive parts which is necessary only for the proper functioning of the equipment

3.3.5.4**reinforced insulation**

single insulation system that provides a degree of protection against electric shock equivalent to **double insulation**

3.3.5.5**solid insulation**

solid insulating material interposed between two conductive parts or between a conductive part and a body part

[IEC 60664-1:2007, 3.4, modified]

3.3.5.6

supplementary insulation

independent insulation applied in addition to **basic insulation** to provide a **supplementary safeguard** for fault protection against electric shock

[IEV 195-06-07 modified]

3.3.6 Miscellaneous

3.3.6.1

accessible

touchable by a body part

NOTE A body part is represented by one or more of the probes specified in Annex V.

3.3.6.2

cheesecloth

bleached cotton cloth of approximately 40 g/m²

NOTE **Cheesecloth** is a coarse, loosely woven cotton gauze, originally used for wrapping cheese.

3.3.6.3

disconnect device

means to electrically disconnect equipment from the **mains** that, in the open position complies with the requirements specified for the isolating function

3.3.6.4

non-detachable power supply cord

flexible supply cord affixed to or assembled with the equipment and that cannot be removed without the use of **tools**

3.3.6.5

pollution degree

numeral characterising the expected pollution of the micro-environment

3.3.6.6

restricted access area

area **accessible** only to **skilled persons** and **instructed persons** with the proper authorization

[IEV 195-04-04 modified]

3.3.6.7

routine test

test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

[IEC 60664-1:2007, 3.19.2]

3.3.6.8

sampling test

test on a number of devices taken at random from a batch

[IEC 60664-1:2007, 3.19.3]

3.3.6.9

tool

an object that can be used to operate a screw, latch or similar fixing means

NOTE Examples of **tools** include coins, tableware, screwdrivers, pliers, etc.

3.3.6.10**touch current**

electric current through a human body when a body part touches two or more **accessible** parts or one **accessible** part and earth

3.3.6.11**type test**

test on a representative sample with the objective of determining if, as designed and manufactured, it can meet the requirements of this standard

3.3.6.12**wrapping tissue**

tissue between 12 g/m² and 30 g/m²

NOTE The **wrapping tissue** is soft, thin, usually translucent paper used for wrapping delicate articles.

[ISO 4046-4:2002, definition 4.215 modified]

3.3.7 Operating and fault conditions**3.3.7.1****abnormal operating condition**

temporary operating condition that is not a **normal operating condition** and is not a **single fault condition** of the equipment itself

NOTE 1 **Abnormal operating conditions** are specified in Clause B.3.

NOTE 2 An **abnormal operating condition** may be introduced by the equipment or by a person.

NOTE 3 An **abnormal operating condition** may result in a failure of a component, a device or a **safeguard**.

3.3.7.2**intermittent operation**

operation in a series of cycles, each composed of a period of operation followed by a period with the equipment switched off or running idle

3.3.7.3**non-clipped output power**

sine wave power dissipated in the **rated load impedance**, measured at 1 000 Hz at the onset of clipping on either one or both peaks

3.3.7.4**normal operating condition**

mode of operation that represents as closely as possible the most severe conditions of normal use that can reasonably be expected

NOTE Unless otherwise stated, the most severe conditions of normal use are the most unfavourable default values as specified in Clause B.2.

3.3.7.5**overload condition**

an **abnormal operating condition** or **single fault condition** where the load stresses the equipment or circuit beyond **normal operating conditions**, but does not, immediately, result in a non-operating state

3.3.7.6**peak response frequency**

test frequency that produces the maximum output power measured at the **rated load impedance**

NOTE The frequency applied should be within the amplifier/transducer's intended operating range.

3.3.7.7

rated load impedance

impedance or resistance, specified by the manufacturer, in the user instructions or marked on the equipment, by which an output circuit should be terminated

3.3.7.8

reasonably foreseeable misuse

use of a product, process or service in a way not intended by the supplier, but which may result from readily predictable human behaviour

[ISO/IEC Guide 51, definition 3.14]

3.3.7.9

short-time operation

operation under **normal operating conditions** for a specified period, starting when the equipment is cold, the intervals after each period of operation being sufficient to allow the equipment to cool down to room temperature

3.3.7.10

single fault condition

fault under **normal operating condition** of a single **safeguard** (but not a **reinforced safeguard**) or of a single component or a device

3.3.8 Persons

3.3.8.1

instructed person

person instructed or supervised by a **skilled person** as to energy sources and who can responsibly employ equipment and **precautionary safeguards** with respect to those energy sources

[IEV 826-18-02, modified]

NOTE Supervised, as used in the definition, means having the direction and oversight of the performance of others.

3.3.8.2

ordinary person

person who is neither a **skilled person** nor an **instructed person**

[IEV 826-18-03]

3.3.8.3

skilled person

person with relevant education or experience to enable him or her to avoid dangers and to reduce the likelihood of risks that may be created by the equipment

[IEV 826-18-01, modified]

3.3.9 Potential ignition sources

3.3.9.1

potential ignition source

PIS

location where electrical energy can cause ignition

3.3.9.2

arcing PIS

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

NOTE 1 An electronic protection circuit or additional constructional measures may be used to prevent a location from becoming an **arcing PIS**.

NOTE 2 A faulty contact or interruption in an electric connection that may occur in conductive patterns on printed boards is considered to be within the scope of this definition.

3.3.9.3

resistive PIS

location where a component may ignite due to excessive power dissipation

3.3.10 Ratings

3.3.10.1

rated current

input current of the equipment as declared by the manufacturer at **normal operating conditions**

3.3.10.2

rated frequency

supply frequency or frequency range as declared by the manufacturer

3.3.10.3

rated power

input power of the equipment as declared by the manufacturer at **normal operating conditions**

3.3.10.4

rated voltage

value of voltage assigned by the manufacturer to a component, device or equipment and to which operation and performance characteristics are referred

[IEC 60664-1, definition 3.9]

NOTE 1 Equipment may have more than one **rated voltage** value or may have a **rated voltage range**.

NOTE 2 For three-phase supply, the phase-to-phase voltage applies.

3.3.10.5

rated voltage range

supply voltage range as declared by the manufacturer expressed by its lower and upper **rated voltages**

3.3.10.6

protective current rating

rating of an overcurrent protective device that is in the building installation or in the equipment to protect a circuit

3.3.11 Safeguards

3.3.11.1

basic safeguard

safeguard that provides protection under **normal operating conditions** and under **abnormal operating conditions** whenever an energy source capable of causing pain or injury is present in the equipment

3.3.11.2

double safeguard

safeguard comprising both a **basic safeguard** and a **supplementary safeguard**

3.3.11.3

equipment safeguard

safeguard that is a physical part of the equipment

3.3.11.4

installation safeguard

safeguard that is a physical part of a man-made installation

3.3.11.5

instructional safeguard

instruction invoking specified behaviour to avoid contact with or exposure to a class 2 or class 3 energy source (see 4.2)

3.3.11.6

personal safeguard

personal protective equipment that is worn on the body

3.3.11.7

precautionary safeguard

instructed person behaviour to avoid contact with or exposure to a class 2 energy source based on supervision or instructions given by a **skilled person**

3.3.11.8

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

3.3.11.9

protective conductor

conductor provided for the purposes of safety (for example, protection against electric shock)

[IEV 195-02-09]

NOTE A **protective conductor** is either a **protective earthing conductor** or a **protective bonding conductor**.

3.3.11.10

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]

3.3.11.11

reinforced safeguard

single **safeguard** that is operational under:

- **normal operating conditions**,
- **abnormal operating conditions**, and
- **single fault conditions**

3.3.11.12

safeguard

physical part or system or instruction specifically provided to reduce the likelihood of pain or injury, or, for fire, to reduce the likelihood of ignition or spread of fire

NOTE See 0.5 for further explanation of a **safeguard**.

3.3.11.13**safety interlock**

means to automatically change an energy source to a lower class energy source prior to the potential for transfer of the higher energy to a body part

3.3.11.14**skill safeguard**

skilled person behaviour to avoid contact with or exposure to a class 2 or class 3 energy source based on education and experience

3.3.11.15**supplementary safeguard**

safeguard applied in addition to the **basic safeguard** that is or becomes operational in the event of failure of the **basic safeguard**

3.3.12 Spacings**3.3.12.1****clearance**

shortest distance in air between two conductive parts

[IEC 60664-1:2007, definition 3.2]

3.3.12.2**creepage distance**

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

[IEC 60664-1:2007, definition 3.3, modified]

3.3.13 Temperatures and controls**3.3.13.1****highest charging temperature**

highest allowable temperature measured at the surface of a battery during the charging operation

3.3.13.2**lowest charging temperature**

lowest allowable temperature measured at the surface of a battery during the charging operation

3.3.13.3**temperature limiter**

device for limiting the temperature of a system, either below or above a particular value, by controlling, either directly or indirectly, the flow of thermal energy into or out of the system

NOTE A **temperature limiter** may be of the automatic reset or of the manual reset type.

3.3.13.4**thermal cut-off**

device for limiting the temperature of a system, under **single fault conditions**, by controlling, either directly or indirectly, the flow of thermal energy into or out of the system

NOTE A **thermal cut-off** may be one-time operation or manual reset type.

3.3.13.5**thermostat**

device for maintaining the temperature of a system within a range by controlling, either directly or indirectly, the flow of thermal energy into or out of the system

3.3.14 Voltages and currents

3.3.14.1

d.c. voltage

average value of a voltage having a peak-to-peak ripple not exceeding 10 % of the average value

NOTE Where peak-to-peak ripple exceeds 10 % of the average value, the requirements related to peak voltage are applicable.

3.3.14.2

mains transient voltage

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

3.3.14.3

maximum charging current

upper limit of charging current per cell while the battery is charged

NOTE The maximum charging current may be defined for each standard charging temperature range, low charging temperature range and high charging temperature range.

3.3.14.4

peak working voltage

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

3.3.14.5

prospective touch voltage

voltage between simultaneously **accessible** conductive parts when those conductive parts are not being touched

3.3.14.6

protective conductor current

current flowing through the **protective earthing conductor** under **normal operating conditions**

NOTE **Protective conductor current** was previously included in the term "leakage current".

3.3.14.7

required withstand voltage

peak voltage that the insulation under consideration is required to withstand

3.3.14.8

r.m.s. working voltage

the true r.m.s. value of the **working voltage**

NOTE 1 True r.m.s. measurement includes any d.c. component of the waveform.

NOTE 2 The resultant r.m.s. value of a waveform having an a.c. r.m.s. voltage A and a d.c. offset voltage B is given by the following formula:

$$\text{r.m.s. value} = (A^2 + B^2)^{1/2}$$

3.3.14.9

upper limit charging voltage

maximum allowed voltage per cell while the battery is being charged, as specified by the manufacturer of the cell

NOTE A different value of the charging voltage upper limit may be defined for each standard charging temperature range, low charging temperature range and high charging temperature range.

3.3.14.10**working voltage**

highest voltage across any particular insulation that can occur when the equipment is supplied at **rated voltage** or any voltage in the **rated voltage range** under **normal operating conditions**

[IEC 60664-1, definition 3.5, modified]

NOTE External transients are disregarded.

3.3.15 Classes of equipment with respect to protection from electric shock**3.3.15.1****class I equipment**

equipment in which protection against electric shock does not rely on **basic insulation** only, but that includes a **supplementary safeguard** in such a way that means are provided for the connection of **accessible** conductive parts to the **protective earthing conductor** in the fixed wiring of the installation in such a way that **accessible** conductive parts cannot become live in the event of a failure of the **basic insulation**

NOTE For equipment intended for use with a flexible cord or cable, this provision includes a **protective conductor** as part of the flexible cord or cable.

3.3.15.2**class II construction**

part of an equipment for which protection against electric shock relies upon **double insulation** or **reinforced insulation**

[IEC 60335-1, 3.3.11, modified]

3.3.15.3**class II equipment**

equipment in which protection against electric shock does not rely on **basic insulation** only, but in which a **supplementary safeguard** is provided, there being no provision for protective earthing or reliance upon installation conditions

3.3.15.4**class III equipment**

equipment in which protection against electric shock relies upon supply from ES1 and in which ES3 is not generated

[IEC 60950-1, 1.2.4.3, modified]

3.3.16 Chemical terms**3.3.16.1****consumable material**

material that is used by the equipment in performing its intended function, and intended to be periodically or occasionally replaced or replenished, including any material that has a life expectancy less than that of the equipment

3.3.16.2**explosion**

chemical reaction of any chemical compound or mechanical mixture that, when initiated, undergoes a very rapid combustion or decomposition, releasing large volumes of highly heated gases that exert pressure on the surrounding medium

NOTE **Explosion** can also be a mechanical reaction in which failure of the container causes sudden release of pressure, and the contents, from within a pressure vessel. Depending on the rate of energy release, an **explosion** can be categorized as a deflagration, a detonation or pressure rupture.

3.3.16.3

explosive

substance or mixture of substances that can undergo a rapid chemical change with or without an outside source of oxygen, generating large quantities of energy generally accompanied by hot gases

3.3.16.4

hazardous chemical

chemical, having a risk phase or equivalent as provided in the specifications for human health aspects, that can be in the form of a solid, powder, liquid or gas

NOTE Dust and other particulate materials can also be **hazardous chemicals** depending on their composition and potential for interaction with the human body.

3.3.16.5

personal protective equipment

PPE

personal **safeguard**, typically worn on the body, that reduces the known exposure of a person to a class 3 energy source

NOTE Examples of PPE include shields, goggles, gloves, aprons, face masks or breathing apparatus.

4 General requirements

4.1 General

4.1.1 **Application of requirements and acceptance of materials, components and subassemblies**

Requirements are specified in the relevant clauses and, where referenced in those clauses, in the relevant annexes.

Where compliance of materials, components or subassemblies is demonstrated by inspection, such compliance may be by review of published data or previous test results.

Components and subassemblies that comply with IEC 60950-1 or IEC 60065 are acceptable as part of equipment covered by this standard without further evaluation other than to give consideration to the appropriate use of the component or subassembly in the end-product.

NOTE This paragraph will be deleted in a future version of the standard. It is added here to allow a smooth transition from IEC 60950-1 and IEC 60065 to this standard.

4.1.2 **Use of components**

Unless stated otherwise, where the component or a characteristic of a component is a **safeguard**, components shall comply either with the requirements of this standard or with the safety aspects of the relevant IEC component standards.

NOTE 1 An IEC component standard is considered relevant only if the component in question clearly falls within its scope.

Evaluation and testing of components shall be conducted as follows:

- a component shall be checked for correct application and use in accordance with its rating;
- a component that has been demonstrated to comply with a standard harmonized with the relevant IEC component standard shall be subjected to the applicable tests of this standard, as part of the equipment, with the exception of those tests that are part of the relevant IEC component standard;

- a component that has not been demonstrated to comply with a relevant standard as above shall be subjected to the applicable tests of this standard, as part of the equipment, and to the applicable tests of the component standard, under the conditions occurring in the equipment;

NOTE 2 The applicable test for compliance with a component standard is, in general, conducted separately.

- where no relevant IEC component standard exists, or where components are used in circuits not in accordance with their specified ratings, the components shall be tested under the conditions occurring in the equipment. The number of samples required for test is, in general, the same as required by an equivalent standard.

4.1.3 Equipment design and construction

Equipment shall be so designed and constructed that, under **normal operating conditions** (see Clause B.2), **abnormal operating conditions** (see Clause B.3), and **single fault conditions** (see Clause B.4), **safeguards** are provided to reduce the likelihood of injury or, in the case of fire, property damage.

NOTE Under **normal operating conditions**, the **safeguards** specified in this standard may or may not prevent pain, depending on the person and the operating condition of the equipment.

Parts of equipment that could cause injury shall not be **accessible**, and **accessible** parts shall not cause an injury.

For an **ordinary person** or an **instructed person**, the adjustment of a control shall not defeat an **equipment safeguard**.

Compliance is checked by inspection and by the relevant tests.

4.1.4 Equipment installation

The equipment evaluation according to this standard shall take into account manufacturers' instructions with regard to installation, relocation, servicing and operation, as applicable.

4.1.5 Constructions not specifically covered

Where the equipment involves technologies and materials or methods of construction not specifically covered in this standard, the equipment shall provide **safeguards** not less than that generally afforded by this standard and the principles of safety contained herein.

NOTE The need for additional detailed requirements to cope with a new situation should be brought promptly to the attention of the appropriate committee.

4.1.6 Orientation during transport and use

Where it is clear that the orientation of use of equipment is likely to have a significant effect on the application of the requirements or the results of tests, all orientations of use specified in the installation or user instructions shall be taken into account. In addition, for **transportable equipment**, all orientations of transport shall be taken into account.

4.1.7 Choice of criteria

Where the standard indicates a choice between different criteria for compliance, or between different methods or conditions of test, the choice is specified by the manufacturer.

4.1.8 Conductive liquids

For the electrical requirements of this standard, conductive liquids shall be treated as conductive parts.

4.1.9 Electrical measuring instruments

Electrical measuring instruments shall have adequate bandwidth to provide accurate readings, taking into account all components (d.c., **mains** frequency, high frequency and harmonic content) of the parameter being measured.

If an r.m.s. value is measured, care shall be taken that the measuring instrument gives a true r.m.s. reading of non-sinusoidal waveforms as well as sinusoidal waveforms.

Measurements are made with a meter whose input impedance has minimum influence on the measurement.

4.1.10 Temperature measurements

Unless stated otherwise, where the result of a test is likely to depend upon the ambient temperature, the manufacturer's specified ambient temperature range of the equipment (T_{ma}) shall be taken into account. When performing the test at a specific ambient (T_{amb}), extrapolation (above and below) the results of the test may be used to consider the impact of T_{ma} on the result. Components and subassemblies may be considered separately from the equipment if the test results and extrapolation is representative of the whole equipment being so tested. Relevant test data and manufacturer's specifications may be examined in order to determine the effect of temperature variability on a component or subassembly (see B.1.7).

4.1.11 Steady state conditions

Steady state conditions are those conditions when thermal equilibrium is considered to exist (see B.1.7).

4.1.12 Hierarchy of safeguards

Safeguards that are required for **ordinary persons** are acceptable, but may not be required, for **instructed persons** and **skilled persons**. Likewise, **safeguards** that are required for **instructed persons** are acceptable, but may not be required, for **skilled persons**.

A **reinforced safeguard** may be used in place of a **basic safeguard** or a **supplementary safeguard** or a **double safeguard**. A **double safeguard** may be used in place of a **reinforced safeguard**.

Safeguards other than **equipment safeguards** may be specified in specific clauses (for example, see 8.4.1, 8.5.1 and Table 42).

4.1.13 Examples mentioned in the standard

Where examples are given in this standard, other examples, situations, and solutions are not excluded.

4.1.14 Tests on parts or samples separate from the end-product

If a test is conducted on a part or sample separate from the end-product, the test shall be conducted as if the part or sample was in the end-product.

4.1.15 Markings and instructions

Equipment that is required by this standard to

- bear markings, or
- be provided with instructions, or
- be provided with **instructional safeguards**

shall meet the relevant requirements of Annex F.

NOTE In Finland, Norway and Sweden, **class I pluggable equipment type A** intended for connection to other equipment or a network shall, if safety relies on connection to reliable earthing or if surge suppressors are connected between the network terminals and **accessible** parts, have a marking stating that the equipment must be connected to an earthed **mains** socket-outlet.

4.2 Energy source classifications

4.2.1 Class 1 energy source

Unless otherwise specified, a class 1 source is an energy source with levels not exceeding class 1 limits under

- **normal operating conditions** and
- **abnormal operating conditions** that do not lead to a **single fault condition**,

and not exceeding class 2 limits under **single fault conditions**.

Under **normal operating conditions** and **abnormal operating conditions**, the energy in a class 1 source, in contact with a body part, may be detectable, but is not painful nor is it likely to cause an injury. For fire, the energy in a class 1 source is not likely to cause ignition.

Under **single fault conditions**, a class 1 energy source, under contact with a body part, may be painful, but is not likely to cause injury.

4.2.2 Class 2 energy source

Unless otherwise specified, a class 2 source is an energy source with levels exceeding class 1 limits and not exceeding class 2 limits under **normal operating conditions**, **abnormal operating conditions**, or **single fault conditions**. The energy in a class 2 source, under contact with a body part, may be painful, but is not likely to cause an injury. For fire, the energy in a class 2 source can cause ignition under some conditions.

4.2.3 Class 3 energy source

A class 3 source is an energy source with levels exceeding class 2 limits under **normal operating conditions**, **abnormal operating conditions**, or **single fault conditions**, or any energy source declared to be a class 3 source. The energy in a class 3 source, under contact with a body part, is capable of causing injury. For fire, the energy in a class 3 source may cause ignition and the spread of flame where fuel is available.

4.2.4 Energy source classification by declaration

The manufacturer may declare a class 1 energy source to be either a class 2 energy source or a class 3 energy source.

The manufacturer may declare a class 2 energy source to be a class 3 energy source.

Safeguards shall be applied according to the declared class.

A neutral conductor is declared a class 3 electrical energy source.

A **protective conductor** is a class 1 electrical energy source and cannot be declared a higher class energy source.

4.3 Protection against energy sources

4.3.1 General

This subclause specifies protection requirements for **ordinary persons**, **instructed persons**, and **skilled persons**.

The terms "persons", "body", and "body parts" are represented by the accessibility probes of Annex V.

4.3.2 Safeguards for protection of an ordinary person

4.3.2.1 Safeguards between a class 1 energy source and an ordinary person

No **safeguards** need be interposed between a class 1 energy source and an **ordinary person** (see Figure 9). Consequently, a class 1 energy source may be **accessible** to an **ordinary person**.

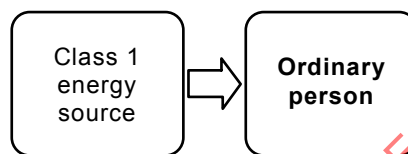


Figure 9 – Model for protection of an ordinary person against a class 1 energy source

4.3.2.2 Safeguards between a class 2 energy source and an ordinary person

During **normal operating conditions** at least one **basic safeguard** shall be interposed between a class 2 energy source and an **ordinary person** (see Figure 10).



Figure 10 – Model for protection of an ordinary person against a class 2 energy source

4.3.2.3 Safeguards between a class 2 energy source and an ordinary person during ordinary person servicing conditions

If **ordinary person** servicing conditions require a **basic safeguard** to be removed or defeated, an **instructional safeguard** as described in Clause F.5 shall be provided and located in such a way that an **ordinary person** will see the instruction prior to removing or defeating the equipment **basic safeguard** (see Figure 11).

The **instructional safeguard** (see Clause F.5) shall include all of the following:

- identify parts and locations of the class 2 energy source;
- specify actions that will protect persons from that energy source; and
- specify actions to reinstate or restore the **basic safeguard**.

If **ordinary person** servicing conditions require a **basic safeguard** to be removed or defeated, and where the equipment is intended for use in the home, an **instructional safeguard** (see Clause F.5), directed towards adults, shall warn against removing or defeating the **basic safeguard** by children.

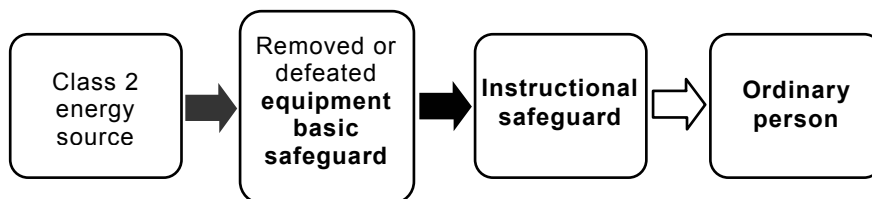


Figure 11 – Model for protection of an ordinary person against a class 2 energy source during ordinary person servicing conditions

4.3.2.4 Safeguards between a class 3 energy source and an ordinary person

An **equipment basic safeguard** and an **equipment supplementary safeguard** (double safeguard) or an **equipment reinforced safeguard** shall be interposed between a class 3 energy source and an **ordinary person** (see Figure 12).

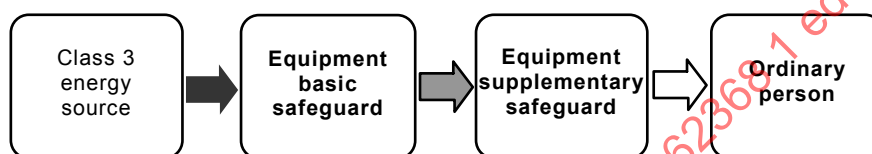


Figure 12 – Model for protection of an ordinary person against a class 3 energy source

4.3.3 Protection of an instructed person

4.3.3.1 Safeguards between a class 1 energy source and an instructed person

No **safeguards** need be interposed between a class 1 energy source and an **instructed person**. Consequently, a class 1 energy source may be **accessible** to an **instructed person** (see Figure 13).

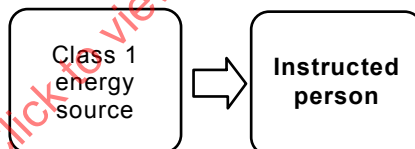


Figure 13 – Model for protection of an instructed person against a class 1 energy source

4.3.3.2 Safeguards between a class 2 energy source and an instructed person

During **instructed person** servicing, the **equipment safeguards** against a class 2 energy source may be removed or defeated. In this case, an **instructed person** is presumed to use precaution as a **safeguard** against a class 2 energy source (see Figure 14).



Figure 14 – Model for protection of an instructed person against a class 2 energy source

4.3.3.3 Safeguards between a class 3 energy source and an instructed person

An **equipment basic safeguard** and an **equipment supplementary safeguard** (double safeguard) or a **reinforced safeguard** shall be interposed between a class 3 energy source and an **instructed person** (see Figure 15).

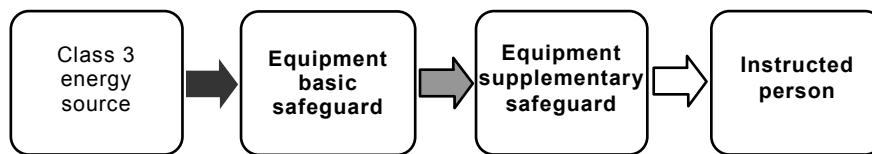


Figure 15 – Model for protection of an instructed person against a class 3 energy source

4.3.4 Protection of a skilled person

4.3.4.1 Safeguards between a class 1 energy source and a skilled person

No **safeguard** need be interposed between a class 1 energy source and a **skilled person** (see Figure 16).

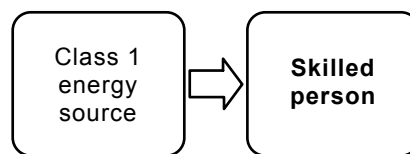


Figure 16 – Model for protection of a skilled person against a class 1 energy source

4.3.4.2 Safeguards between a class 2 energy source and a skilled person

During **skilled person** servicing, the **equipment safeguards** against a class 2 energy source may be removed or defeated. In this case, a **skilled person** is presumed to use skill as a **safeguard** against a class 2 energy source (see Figure 17).



Figure 17 – Model for protection of a skilled person against a class 2 energy source

4.3.4.3 Safeguards between a class 3 energy source and a skilled person

During **skilled person** servicing, the **equipment safeguards** against a class 3 energy source may be removed or defeated. In this case, a **skilled person** is presumed to use skill as a **safeguard** against a class 3 energy source (see Figure 18).



Figure 18 – Model for protection of a skilled person against a class 3 energy source

4.3.4.4 Safeguards between class 3 energy sources and a skilled person during equipment servicing conditions

During equipment servicing conditions on a class 3 energy source, an **equipment safeguard** intended to reduce the likelihood of injury due to an involuntary reaction shall be interposed between:

- another class 3 energy source, not undergoing service and in the same vicinity as the class 3 energy source being serviced; and
- a **skilled person** (see 0.5.7 and Figure 19).

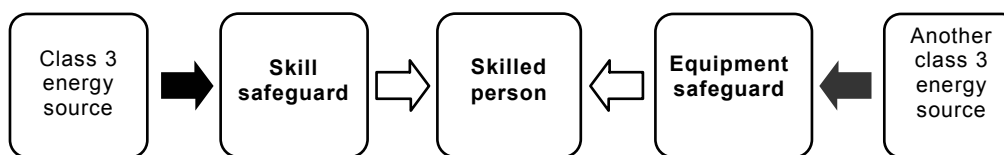


Figure 19 – Model for protection of a skilled person against class 3 energy sources during equipment servicing conditions

4.3.5 Safeguards in a restricted access area

Certain equipment is intended for installation exclusively in **restricted access areas**. Such equipment shall have **safeguards** as required in 4.3.3 for **instructed persons** and 4.3.4 for **skilled persons**.

4.4 Safeguards

4.4.1 General

This subclause specifies composition, accessibility and robustness requirements for **safeguards**.

4.4.2 Equivalent materials or components

Where the standard specifies a particular **safeguard** parameter, such as thermal class of insulation or **material flammability class**, a **safeguard** with a better parameter may be employed.

NOTE For a hierarchy of the **material flammability classes** see Table S.1, Table S.2 and Table S.3.

4.4.3 Composition of a safeguard

A **safeguard** may be comprised of a single element, or may be comprised of two or more elements.

4.4.4 Accessible parts of a safeguard

4.4.4.1 General

Where a solid **safeguard** is **accessible** to an **ordinary person** or to an **instructed person**, only the side of the **safeguard** opposite to the energy source may be **accessible**.

Requirements for **basic safeguards** and **supplementary safeguards**, if they are elements of **double safeguards**, may be interchanged.

4.4.4.2 Accessible parts of a basic safeguard

With respect to a class 2 energy source, the side of the **basic safeguard** opposite to the energy source may be **accessible** to an **ordinary person** (see Figure 20).

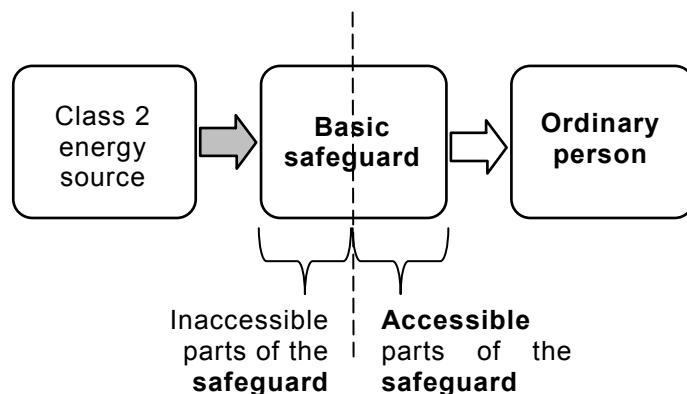


Figure 20 – Illustration of accessible and inaccessible parts of a basic safeguard

4.4.4.3 Accessible parts of supplementary and reinforced safeguards

With respect to a class 3 energy source, the side of the **supplementary safeguard** opposite to the energy source may be **accessible** to an **ordinary person** or an **instructed person**; however, the **basic safeguard** shall not be **accessible** to an **ordinary person** or to an **instructed person** (see Figure 21).

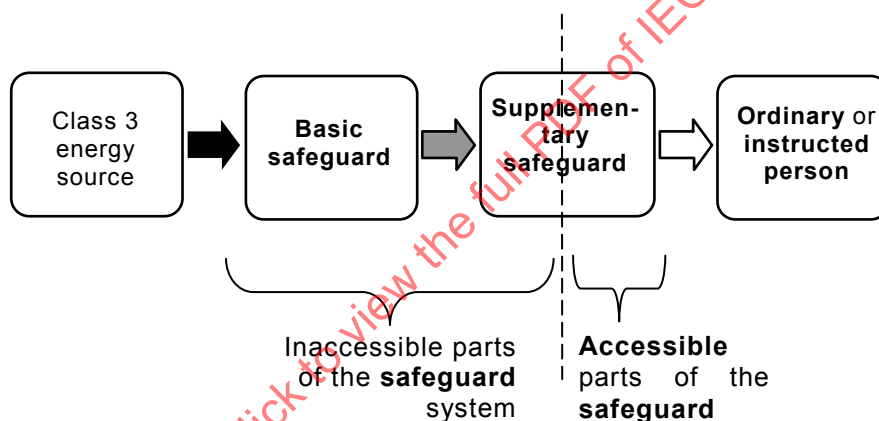


Figure 21 – Illustration of accessible and inaccessible parts of a supplementary safeguard

With respect to a class 3 energy source, the side of the **reinforced safeguard** opposite to the energy source may be **accessible** to an **ordinary person** or an **instructed person** (see Figure 22).

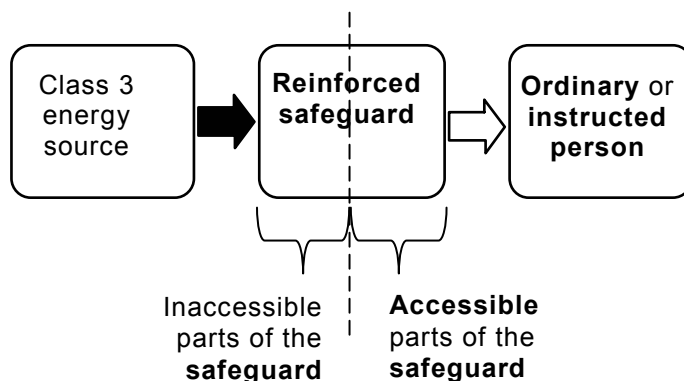


Figure 22 – Illustration of accessible and inaccessible parts of a reinforced safeguard

4.4.5 Safeguard robustness

Where a solid **safeguard** (for example, **solid insulation**, earthed metal, etc.) is **accessible** to an **ordinary person** or to an **instructed person**, the **safeguard** shall comply with the mechanical strength test specified in Annex T for that **safeguard**, as applicable.

A solid **safeguard** that has no **accessible** parts need not comply with the mechanical strength test provided that an **accessible** barrier or **enclosure** that prevents access to the **safeguard** by an **ordinary person** or by an **instructed person** complies with the mechanical strength test specified in Annex T for that **safeguard**.

If a **safeguard** is of thermoplastic material, the **safeguard** shall be so constructed that any shrinkage or distortion of the material due to release of internal stresses shall not defeat its **safeguard** function. See Clause T.8 for stress relief conditioning and Annex V for determination of accessibility.

Other mechanical strength tests are specified in the various clauses.

4.4.6 Air comprising a safeguard

Where a **safeguard** is comprised of air (for example, a **clearance**), a barrier or **enclosure** shall prevent displacement of the air by a body part or a conductive part. The barrier shall comply with the mechanical strength test specified in Annex T, as applicable.

4.5 Explosion

4.5.1 General

Explosion can be caused by

- chemical reaction,
- mechanical deformation of a sealed container,
- rapid combustion or decomposition, producing a large volume of hot gas,
- high pressure,
- high temperature.

NOTE 1 Depending on the energy rate, **explosion** can be categorized as a deflagration, a detonation, or pressure rupture.

NOTE 2 An ultracapacitor (for example, a double layer capacitor) is a high energy source and can explode following overcharging and high temperature.

For requirements regarding **explosion** of batteries, see Annex M.

4.5.2 Requirements

During **normal operating conditions** and **abnormal operating conditions**, an **explosion** shall not occur.

During **single fault conditions**, the equipment shall comply with the relevant parts of Clause 6 and Clause 8.

4.5.3 Compliance

Compliance is checked by inspection and tests as specified in Clauses B.2, B.3 and B.4.

5 Electrically-caused injury

5.1 General

To reduce the likelihood of painful effects and injury due to electric current passing through the human body, equipment shall be provided with the **safeguards** specified in this clause.

5.2 Classification and limits of electrical energy sources

5.2.1 Electrical energy source classifications

5.2.1.1 ES1

ES1 is a class 1 electrical energy source with levels not exceeding ES1 limits under

- **normal operating conditions**, and
- **abnormal operating conditions** that do not lead to a **single fault condition**, and not exceeding ES2 limits under **single fault conditions**.

NOTE ES1 may be **accessible** to an **ordinary person**.

5.2.1.2 ES2

ES2 is a class 2 electrical energy source with levels not exceeding ES2 limits under

- **normal operating conditions**,
- **abnormal operating conditions**, and
- **single fault conditions**,

but is not ES1.

NOTE ES2 may be **accessible** to an **instructed person**.

5.2.1.3 ES3

ES3 is a class 3 electrical energy source with levels exceeding ES2 limits under **normal operating conditions**, **abnormal operating conditions** or **single fault conditions**.

NOTE 1 The energy in ES3 may cause harmful physiological effects under contact with a body part.

NOTE 2 Parts and circuits classed ES3 may be **accessible** to a **skilled person**.

All current-carrying conductors of an a.c. **mains** circuit, including the neutral, are declared ES3.

Conductive parts may be classed ES3 without measurement or evaluation.

5.2.2 ES1, ES2 and ES3 limits

5.2.2.1 General

This subclause specifies the parameters and their magnitudes for electrical energy sources ES1, ES2 and ES3.

The limits specified in this subclause are with respect to earth or with respect to an **accessible** part.

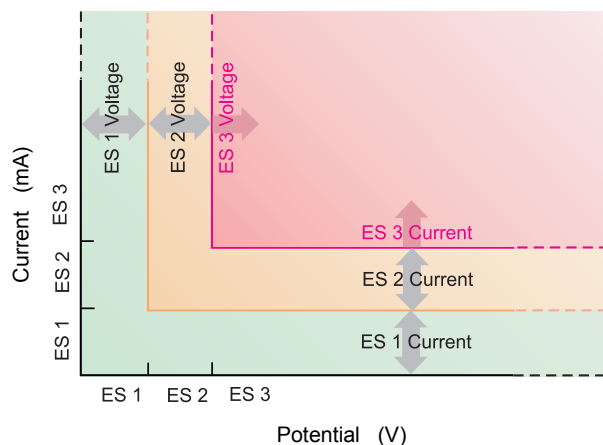


Figure 23 – Illustration that shows that ES limits depend on both voltage and current

As illustrated in Figure 23, for ES1 and ES2, for any voltage up to the limit voltage, there is no limit for the current. Likewise for any current up to the limit current, there is no limit for the voltage. However, for ES1 and ES2, in no case can both the current limit and the voltage limit be exceeded. ES2 is an energy source where both the voltage and current exceed the limits for ES1, but do not exceed the limits for ES2. ES3 is any source where both the voltage limit and current limit exceed ES2. Voltage limits in this figure do not apply to charged capacitors (see 5.2.2.3).

5.2.2.2 Steady-state voltage and current limits

An electrical energy source class is determined from both the available voltage and the available current (see Table 4, Table 5 and Table 6).

The values are the maximum that can be delivered by the source for 2 s or more. Currents are measured according to 5.7.

NOTE The current limits are derived from IEC/TS 60479-1:2005:

- d.c. limits are from Figure 22;
- a.c. limits are from Figure 20.

Table 4 – Electrical energy source limits for d.c. and low frequency a.c. currents

Energy source	ES1 limit	ES2 limit	ES3
DC	2 mA	25 mA	Greater than ES2 limit
AC up to 1 kHz	0,5 mA r.m.s. 0,707 mA peak	5 mA r.m.s. 7,07 mA peak	
Combined a.c. and d.c.	$\frac{I_{dc} \text{ mA}}{2} + \frac{I_{ac} \text{ mA r.m.s.}}{0,5} \leq 1$ $\frac{I_{dc} \text{ mA}}{2} + \frac{I_{ac} \text{ mA peak}}{0,707} \leq 1$	See Figure 24	

Peak values are to be used for non-sinusoidal current.

The current limits are derived from IEC 60479-1 for dry conditions.

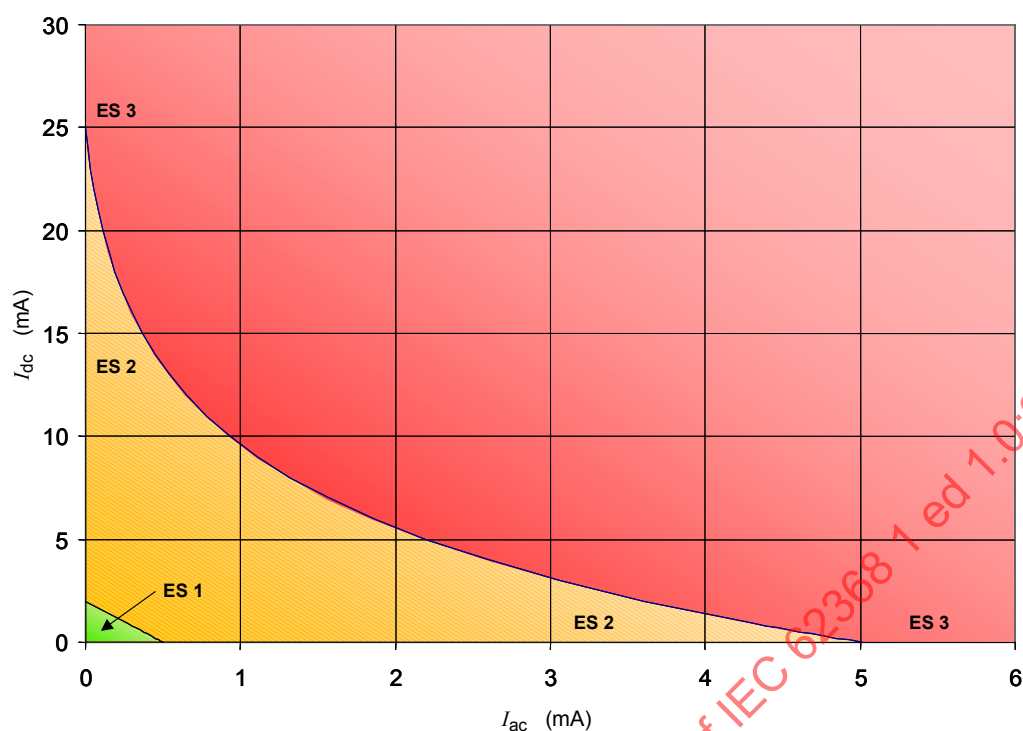


Figure 24 – Maximum values for combined a.c. current and d.c. current

The ES2 limit curve is based on the following formula:

$$5,104 \times e^{(-0,16 \times I_{dc})} - 0,097 \geq I_{ac}$$

where

I_{ac} is the measured a.c. current within the range of 0 mA to 5 mA;

I_{dc} is the measured d.c. current within the range of 0 mA to 25 mA.

Table 5 – Electrical energy source limits for d.c. and low frequency a.c. voltages

Energy source	ES1 limit	ES2 limit	ES3
DC	60 V	120 V	Greater than ES2 limit
AC up to 1 kHz	30 V r.m.s. 42,4 V peak	50 V r.m.s. 70,7 V peak	
Combined a.c. voltage and d.c. voltage	$\frac{U_{dc} \text{ V}}{60} + \frac{U_{ac} \text{ V r.m.s.}}{30} \leq 1$	See Figure 25	
Peak values are to be used for non-sinusoidal voltage.			
The voltage limits are derived from IEC/TS 61202-1:2000 for dry conditions.			

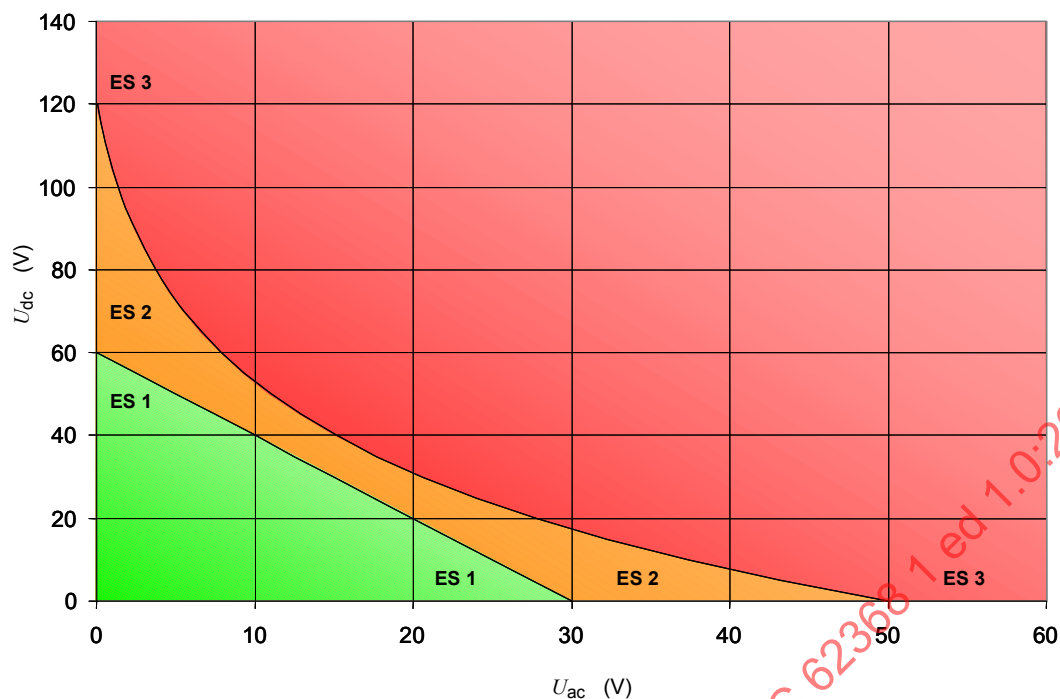


Figure 25 – Maximum values for combined a.c. voltage and d.c. voltage

The ES2 limit curve is based on the following formula:

$$51,746 \times e^{(-0,028 \times U_{dc})} - 1,746 \geq U_{ac}$$

where

U_{ac} is the measured a.c. voltage within the range of 0 V to 50 V r.m.s.

U_{dc} is the measured d.c. voltage within the range of 0 V to 120 V.

Table 6 – Electrical energy source limits for medium and high frequency voltage and current

Energy source		ES1 limit	ES2 limit	ES3
1 kHz up to 100 kHz	Voltage	$30 \text{ V r.m.s.} + 0,4 \times f$	$50 \text{ V r.m.s.} + 0,9 \times f$	Greater than ES2 limit
	Current	$0,5 \text{ mA r.m.s.} \times f$	$5 \text{ mA r.m.s.} + 0,95 \times f$	
Above 100 kHz	Voltage	70 V r.m.s.	140 V r.m.s.	
	Current	50 mA r.m.s.	100 mA r.m.s.	
For non-sinusoidal waveforms and for signals having multiple frequencies, use Figure 4 or 5 of IEC 60990:1999 as applicable to measure the value of the current.				
f is in kHz.				

5.2.2.3 Capacitance limits

Where the electrical energy source is a capacitor, the energy source is classified from both the charge voltage and the capacitance.

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

The ES1 and ES2 limits for various capacitance values are listed in Table 7.

NOTE 1 The capacitance values for ES2 are derived from Table 2 of IEC/TS 61201:2007.

NOTE 2 The values for ES1 are calculated by dividing the values from Table 2 of IEC/TS 61201:2007, by two (2).

Table 7 – Electrical energy source limits for a charged capacitor

C nF	ES1 U_{peak} V	ES2 U_{peak} V
300 or greater	60	120
170	75	150
91	100	200
61	125	250
41	150	300
28	200	400
18	250	500
12	350	700
8,0	500	1 000
4,0	1 000	2 000
1,6	2 500	5 000
0,8	5 000	10 000
0,4	10 000	20 000
0,2	20 000	40 000
0,133 or less	25 000	50 000
Linear interpolation may be used between the nearest two points.		

5.2.2.4 Single pulse limits

Where the electrical energy source is a single pulse, the energy source is classified from both the voltage and the duration or from both the current and the duration. Values are given in Table 8 and Table 9. If the voltage exceeds the limit, then the current shall not exceed the limit. If the current exceeds the limit, the voltage shall not exceed the limit. Currents are measured according to 5.7. For repetitive pulses, see 5.2.2.5.

For pulse durations up to 10 ms, the voltage or current limit for 10 ms applies.

NOTE 1 The pulse limits are calculated from IEC/TS 60479-1:2005, Figure 22 and Table 10.

NOTE 2 These single pulses do not include transients.

NOTE 3 Pulse duration is considered to be the time duration when the voltage or current exceeds ES1 limits.

Table 8 – Voltage limits for single pulses

Pulse duration up to and including ms	Electrical energy source level	
	ES1 U_{peak} V	ES2 U_{peak} V
10	60	196
20		178
50		150
80		135
100		129
200		117
300		110
400		102
500		98
600		97
700		96
800		94
900		93
1 000		89
2 000	80	
If the time duration lies between the values in any two rows, the ES2 value of the U_{peak} in the row below shall be used or a logarithmic interpolation may be used between any two adjacent rows with the calculated value rounded down to the nearest millisecond.		

Table 9 – Current limits for single pulses

Pulse duration up to and including ms	Electrical energy source level	
	ES1 I_{peak} mA	ES2 I_{peak} mA
10	2	200
20	2	153
50	2	107
100	2	81
200	2	62
500	2	43
1 000	2	33
2 000	2	25
If the time duration lies between the values in any two rows, the ES2 value of the I_{peak} in the row below shall be used or a logarithmic interpolation may be used between any two adjacent rows with the calculated value rounded down to the nearest millisecond.		

5.2.2.5 Limits for repetitive pulses

Except for pulses covered in Annex H, a repetitive pulse electrical energy source class is determined from either the available voltage or the available current (see Table 10). If the

voltage exceeds the limit, then the current shall not exceed the limit. If the current exceeds the limit, the voltage shall not exceed the limit. Currents are measured according to 5.7.

The voltage is the maximum that can be delivered by the source into any resistive load not exceeding 1 MΩ.

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

Table 10 – Electrical energy source limits for repetitive pulses

Pulse off time		ES1	ES2	ES3
Less than 3 s	Current	0,707 mA peak	7,07mA peak	Greater than ES2 limit
	Voltage	42,4 V peak	70,7 V peak	
3 s or more	Current	2 mA peak	See Table 9	
	Voltage	60 V peak	See Table 8	

5.2.2.6 Ringing signals

Where the electrical energy source is an analogue telephone network ringing signal as defined in Annex H, the energy source class is considered ES2.

5.2.2.7 Audio signals

For electrical energy sources comprised of audio signals, see Clause E.1 f).

5.3 Protection against electrical energy sources

5.3.1 General

This subclause specifies protection requirements for parts **accessible** to **ordinary persons**, **instructed persons**, and **skilled persons**. See 5.3.6 for accessibility and Table 11 for an overview.

Table 11 – Overview on safeguard requirements (persons)

Person	Required number of equipment safeguards interposed between an electrical energy source and persons		
	ES1	ES2	ES3
Ordinary person	0	1	2
Instructed person	0	0	2
Skilled person	0	0	0 or 1 ^a
^a See 4.3.4.4.			

5.3.2 Protection of an ordinary person

5.3.2.1 Safeguards between ES1 and an ordinary person

No **safeguards** need be interposed between ES1 and an **ordinary person**.

5.3.2.2 Safeguards between ES2 and an ordinary person

At least one **safeguard** shall be interposed between ES2 and an **ordinary person** (see Figure 10 and Figure 11).

5.3.2.3 Safeguards between ES3 and an ordinary person

Unless otherwise specified, at least one **equipment basic safeguard** and one **equipment supplementary safeguard (double safeguard)** or a **reinforced safeguard** shall be interposed between ES3 and an **ordinary person** (see Figure 12).

5.3.3 Protection of an instructed person

5.3.3.1 Safeguards between ES1 or ES2 and an instructed person

No **safeguards** need to be interposed between ES1 or ES2 and an **instructed person** (see Figure 14).

5.3.3.2 Safeguards between ES3 and an instructed person

Unless otherwise specified, at least one **equipment basic safeguard** and one **equipment supplementary safeguard (double safeguard)** or a **reinforced safeguard** shall be interposed between ES3 and an **instructed person** (see Figure 15).

5.3.4 Protection of a skilled person

5.3.4.1 Safeguards between ES1 or ES2 and a skilled person

No **safeguards** need to be interposed between ES1 or ES2 and a **skilled person** (see Figure 16 and Figure 17).

5.3.4.2 Safeguards between ES3 and a skilled person

Bare conductors at ES3 shall be located or guarded so that unintentional contact with such conductors during service operations is unlikely (see Figure 18 and Figure 19).

5.3.5 Safeguards between energy sources

5.3.5.1 General

This subclause specifies **safeguards** between ES1, ES2 and ES3.

Table 12 gives an overview of the required number of **equipment safeguards** between electrical energy sources.

Table 12 – Overview of required number of equipment safeguards

Electrical energy source	Required number of interposed equipment safeguards		
	ES1	ES2	ES3
ES1	0	1	2 ^a
ES2	1	0	2 ^b
ES3	2 ^a	2 ^b	0
^a See 5.3.5.2.			
^b See 5.3.5.3.			

5.3.5.2 Safeguards between ES1, ES2 and ES3

At least one **basic safeguard** shall be interposed between ES2 and ES1 (see Figure 26, Figure 27 and Figure 28).



Figure 26 – Model for protection of ES1 against ES2

At least one **basic safeguard** and one **supplementary safeguard** shall be interposed between ES3 and ES1 (see Figure 27 and Figure 28).

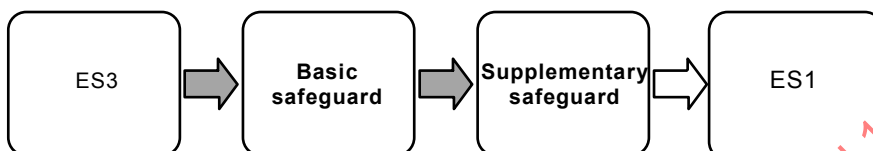


Figure 27 – Model for protection of ES1 against ES3

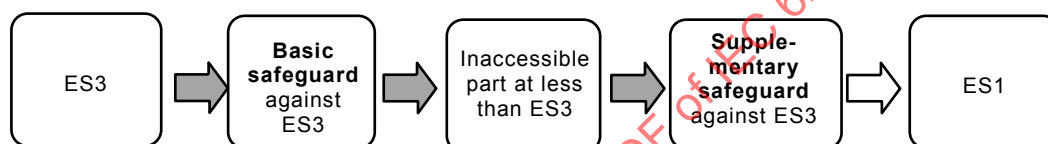


Figure 28 – Model for protection of ES1 against ES3

5.3.5.3 Protection of ES2 against ES3

At least one **basic safeguard** and one **supplementary safeguard** shall be interposed between ES3 and ES2 (see Figure 29 and Figure 30).

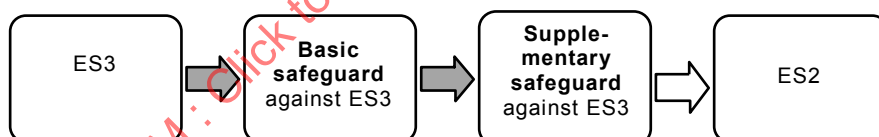


Figure 29 – Model for protection of ES2 against ES3



Figure 30 – Model for protection of ES2 against ES3

5.3.6 Accessibility to electrical energy sources and safeguards

5.3.6.1 Requirements

For **ordinary persons**, the following shall not be **accessible**:

- bare parts at ES2, except for the pins of connectors. However, such pins shall not be **accessible** under **normal operating conditions** by the blunt probe of Figure V.3; and
- bare parts at ES3; and

- an ES3 **basic safeguard**.

For **instructed persons**, the following shall not be **accessible**:

- bare parts at ES3; and
- an ES3 **basic safeguard**.

5.3.6.2 Contact requirements

For ES3 voltages up to 420 V peak, the appropriate test probe from Annex V shall not contact a bare internal conductive part.

For ES3 voltages above 420 V peak, the appropriate test probe from Annex V shall not contact a bare internal conductive part and shall have an air gap from that part (see Figure 31).

The air gap shall either:

- pass an electric strength test in accordance with 5.4.11.1 at a test voltage (d.c. or peak a.c.) equal to the **peak working voltage**; or
- have a minimum distance according Table 13.

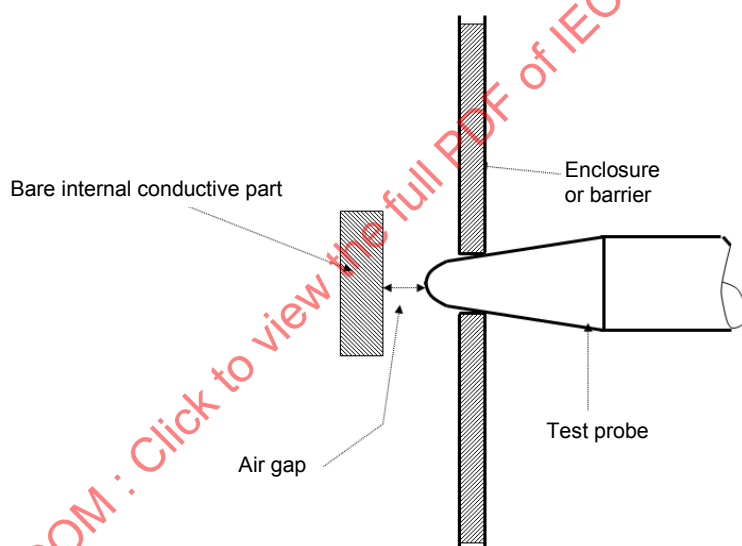


Figure 31 – Contact requirements to bare internal conductive parts

Table 13 – Minimum airgap distance

Peak working voltage	Air gap distance mm	
V peak or d.c. up to and including	Pollution degree	
	2	3
>420 and ≤ 1 000	0,2	0,8
1 200	0,25	
1 500	0,5	
2 000	1,0	
2 500	1,5	
3 000	2,0	
4 000	3,0	
5 000	4,0	
6 000	5,5	
8 000	8,0	
10 000	11	
12 000	14	
15 000	18	
20 000	25	
25 000	33	
30 000	40	
40 000	60	
50 000	75	
60 000	90	
80 000	130	
100 000	170	
Linear interpolation may be used between the nearest two points, the calculated minimum airgap distance being rounded up to the next higher 0,1 mm increment or the value in the next row below whichever is lower.		

5.3.6.3 Compliance

Compliance is checked by the relevant test of Annex T, followed by the tests of Annex V.

In addition, for bare ES3 parts at a voltage above 420 V peak, compliance is checked by distance measurement or by an electric strength test.

Components and subassemblies that comply with their respective IEC standards are not subjected to the finger probe of V.1.2 when such components and subassemblies are used in the final product.

5.3.6.4 Terminals for connecting stripped wire

The use of a stripped wire to make connection with a terminal intended to be used by an **ordinary person** (for example, a loudspeaker terminal of an audio amplifier) shall not result in contact with ES2 or ES3 (for audio signal voltages, see Table E.1 for values of ES2 and ES3).

Compliance is checked by the test of V.1.6.

5.4 Insulation materials and requirements

5.4.1 General

5.4.1.1 Insulation

This subclause specifies insulating materials, **clearances**, **creepage distances** and **solid insulation**, including the use of these materials in components.

Insulation providing a **safeguard** function is designated **basic insulation**, **supplementary insulation**, **double insulation**, or **reinforced insulation**.

5.4.1.2 Properties of insulating material

The choice and application of insulating material shall take into account the needs for electrical strength, mechanical strength, dimension, frequency of the **working voltage** and other properties for the working environment (temperature, pressure, humidity and pollution) as specified in this Clause 5 and Annex T.

Insulating material shall not be hygroscopic as determined by 5.4.1.3.

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

5.4.1.3 Compliance

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 5.4.10. The insulation is then subjected to the relevant electric strength test of 5.4.11.1 while still in the humidity chamber, or in the room in which the samples were brought to the prescribed temperature.

5.4.1.4 Frequency

For fundamental frequencies higher than 30 kHz, the **clearances**, **creepage distances** and **solid insulation** shall comply with 5.4.2, 5.4.3 and 5.4.4.9 respectively.

NOTE 1 For fundamental frequencies higher than 30 kHz, the requirements are based on IEC 60664-1 and IEC 60664-4.

If the circuit has both a **mains** frequency and a fundamental frequency exceeding 30 kHz, then the worst-case requirements for **clearances**, **creepage distances**, and **solid insulation** shall be applied.

As an alternative, for **solid insulation** and frequencies above 30 kHz, the high frequency test of 5.4.4.9 can be substituted by the electric strength test of 5.4.11.1 under the following conditions:

- the field strength is approximately uniform; and
- no voids or air gaps are present in the **solid insulation**.

NOTE 2 In this context, the electric field is considered to be approximately uniform if the deviations are less than $\pm 20\%$ from the average value of the field strength.

5.4.1.5 Maximum operating temperatures for insulating materials

5.4.1.5.1 Requirements

Under **normal operating conditions**, insulating material temperatures shall not exceed the temperature limit of the insulating material, including insulating materials of components, or the maximum temperature limit of the insulation system as given in Table 14.

For maximum temperatures below or equal to 100 °C, no classified insulation system is required.

5.4.1.5.2 Test method

Insulating material temperatures are measured in accordance with B.1.7.

*The equipment or parts of the equipment are operated under **normal operating conditions** (see Clause B.2) as follows:*

- for continuous operation, until steady state conditions are established; and*
- for **intermittent operation**, until steady state 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 specified in the installation instructions.

5.4.1.5.3 Compliance

The temperature of the electrical insulation material or EIS shall not exceed the limits in Table 14.

For a single insulating material, the declared relative temperature index information from the material manufacturer can be used if it is suitable for the applicable class of insulation.

NOTE For example, a material rated for 124 °C is considered suitable for classes whose temperature is lower (class with letter codes E and A) and not for classes whose temperature is higher (class with letter codes B, F, H, N, R and C).

No tests are necessary if the thermal classification is class 105 in accordance with IEC 60085.

For thermal classifications above class 105, the EIS shall comply with IEC 60085.

Table 14 – Temperature limits for materials, components and systems

Part	Maximum temperature $T_{\max}$ °C
Insulation, including winding insulation:	
of Class 105 (A) material or EIS	100 ^a
of Class 120 (E) material or EIS	115 ^a
of Class 130 (B) material or EIS	120 ^a
of Class 155 (F) material or EIS	140 ^a
of Class 180 (H) material or EIS	165 ^a
of Class 200 (N) material or EIS	180 ^a
of Class 220 (R) material or EIS	200 ^a
of Class 250 material or EIS	225 ^a
Insulation of internal and external wiring, including power supply cords:	
– without temperature marking	70
– with temperature marking	Temperature marked on the wire or spool, or rating assigned by the manufacturer
Other thermoplastic insulation	See 5.4.1.11
Components	See also Annex G
^a If the temperature of a winding is determined by thermocouples, these values are reduced by 10 K, except in the case of a – motor, or – winding with embedded thermocouples. The classes are related to the temperature classes of electrical insulating materials and electrical insulating systems in accordance with IEC 60085. The assigned letter designations are given in parentheses. For each material, account shall be taken of the data for that material to determine the appropriate maximum temperature.	

5.4.1.6 Pollution degrees

This subclause describes different degrees of pollution of the operating environment for products covered by this standard.

Pollution degree 1

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

NOTE 1 Within the equipment, components or subassemblies that are sealed to exclude dust and moisture are examples of **pollution degree 1**.

Pollution degree 2

Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

NOTE 2 **Pollution degree 2** is generally appropriate for equipment covered by the scope of this standard.

Pollution degree 3

Conductive pollution occurs or dry non-conductive pollution occurs that becomes conductive due to condensation, which is to be expected.

5.4.1.7 Insulation in transformers with varying dimensions

This subclause specifies the method of determining **clearances**, **creepage distances**, and distances through insulation along the length of the winding of a transformer.

If the insulation of a transformer has 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 or connected to a common point at one end.

5.4.1.8 Insulation in circuits generating starting pulses

This subclause specifies the method of determining **clearances**, **creepage distances** and distance through insulation for circuits generating starting pulses.

For circuits generating starting pulses (for example, to ignite a discharge lamp), the requirements for **basic insulation**, **supplementary insulation** and **reinforced insulation** apply to **creepage distances** and distances through insulation. For **clearances**, see G.12.2.

NOTE For **working voltages** in the above cases, see 5.4.1.9.1, i).

5.4.1.9 Determination of working voltage

5.4.1.9.1 General

This subclause specifies various parameters and assumptions that need to be taken into account when determining **working voltage**.

In determining **working voltages**, all of the following requirements apply:

- a) unearthed **accessible** conductive parts are assumed to be earthed;
- b) if a transformer winding or other part is not connected to a circuit that establishes its potential relative to earth, the winding or other part are assumed to be earthed at a point by which the highest **working voltage** is obtained;
- c) except as specified in 5.4.1.7, for insulation between two transformer windings, the highest voltage between any two points in the two windings is the **working voltage**, taking into account the voltages to which the input windings will be connected;
- d) except as specified in 5.4.1.7, for insulation between a transformer winding and another part, the highest voltage between any point on the winding and the other part is the **working voltage**;
- e) where **double insulation** is used, the **working voltage** across the **basic insulation** is determined by imagining a short circuit across the **supplementary insulation**, and vice versa. For **double insulation** between transformer windings, the short circuit is assumed to take place at the point by which the highest **working voltage** is produced in the other insulation;
- f) when the **working voltage** is determined by measurement, the input power supplied to the equipment shall be the **rated voltage** or the voltage within the **rated voltage range** that results in the highest measured value;
- g) the **working voltage** between
 - any point in the circuit supplied by the **mains** and any part connected to earth; and
 - any point in the circuit supplied by the **mains** and any point in a circuit isolated from the **mains**, shall be assumed to be the greater of the following:
 - the **rated voltage** or the upper voltage of the **rated voltage range**; and
 - the measured voltage;

- h) when determining the **working voltage** for an ES1 or ES2 **external circuit**, the normal operating voltages shall be taken into account. If the operating voltages are not known, the **working voltage** shall be taken as the upper limits of ES1 or ES2 as applicable.

Short duration signals (such as telephone ringing) shall not be taken into account for determining **working voltage**;

- i) for circuits generating starting pulses (for example, discharge lamps, see Clause G.12), the **peak working voltage** is the peak value of the pulses with the lamp connected but before the lamp ignites. The **working voltage** to determine minimum **creepage distances** is the voltage measured after the ignition of the lamp;
- j) temporary overvoltages and recurring peak voltages have to be considered.

5.4.1.9.2 RMS working voltage

In determining the **r.m.s. working voltage**, short-term conditions (for example, cadenced telephone ringing signals in **external circuits**) and non-repetitive transients (for example, due to atmospheric disturbances) are not taken into account.

NOTE The **creepage distances** are determined from the **r.m.s. working voltages**.

5.4.1.9.3 Peak working voltage

For the **peak working voltage** used to determine the **required withstand voltage** for minimum **clearances** and test voltages for electric strength:

- when determining the **peak working voltage** between circuits connected to the **mains** and circuits isolated from the **mains**, the voltage of any ES2 circuit, ES1 circuit or **external circuits** (including telephone ringing signals) shall be regarded as zero;
- when determining the **peak working voltage** for an **external circuit** that does not have transients, the **peak working voltage** of repetitive signals, such as telephone ringing signals, shall be taken into account;
- non-repetitive transients (for example, due to atmospheric disturbances) shall not be taken into account.

5.4.1.10 Insulating surfaces

An **accessible** insulating surface is considered to be covered by a thin metallic foil for determining **clearances**, **creepage distances** and distance through insulation (see Figure O.13).

5.4.1.11 Thermoplastic parts on which conductive metallic parts are directly mounted

5.4.1.11.1 Requirements

Thermoplastic parts on which conductive metallic parts are directly mounted shall be sufficiently resistant to heat if softening of the plastic could result in the failure of a **safeguard**.

5.4.1.11.2 Compliance

Compliance is checked by examination of the Vicat test data from the material manufacturer. If the data is not available, compliance is checked by either the Vicat test of this subclause or the ball pressure test of 5.4.1.11.3.

*The measured temperature during **normal operating conditions**, as specified in Clause B.2, shall be at least 15 K less than the Vicat softening temperature as specified in Vicat test B50 of ISO 306.*

*The measured temperature during **abnormal operating conditions** of Clause B.3 shall be less than the Vicat softening temperature.*

The Vicat softening temperature of a non-metallic part supporting parts in a circuit supplied from the **mains** shall be not less than 125 °C.

5.4.1.11.3 Ball pressure test

Compliance is checked by examination of the ball pressure test data from the manufacturer or by subjecting the part to the ball pressure test according to IEC 60695-10-2. The test is made in a heating cabinet at a temperature of $(T - T_{\text{amb}} + T_{\text{ma}} + 15 \text{ °C}) \pm 2 \text{ °C}$. However, a thermoplastic part supporting parts in a circuit supplied from the **mains** is tested at a minimum of 125 °C.

The significances of T , T_{ma} and T_{amb} are as given in B.2.6.1.

After the test, dimension d (diameter of the indentation) shall not exceed 2 mm.

The test is not made if it is clear from examination of the physical characteristics of the material that it will meet the requirements of this test.

5.4.2 Clearances

5.4.2.1 General

This subclause specifies the required **clearances** for a given **working voltage** and the various other parameters that affect **clearances**.

Clearances shall be so dimensioned that overvoltages and transients that may enter the equipment, and peak voltages that may be generated within the equipment, do not break down the **clearance**.

The parameter, **required withstand voltage**, accounts for overvoltages and transients that may enter the equipment or that may be generated within the equipment. The dimension for a **clearance** that is affected by the transients from the **mains** or an **external circuit** is determined from the **required withstand voltage** for that **clearance**.

The **peak working voltage** (including steady state voltages and recurring peak voltages) and temporary overvoltages are taken into account to determine the **clearance**.

High frequency voltages are taken into account to determine the **clearance**.

Clearances functioning as **basic insulation**, **supplementary insulation** and **reinforced insulation** shall be not less than the minimum dimensions as determined in 5.4.2.7, or shall be determined in accordance with 5.4.2.8.

The minimum **clearances** as determined in 5.4.2.7 do not apply to the air gap between the contacts of **thermostats**, **thermal cut-offs**, overload protection devices, switches of microgap construction, and similar components where the air gap varies with the contacts.

NOTE 1 For air gaps between contacts of **safety interlocks**, see Annex K. For air gaps between contacts of **disconnect devices**, see Annex L.

The **clearance** between the outer insulating surface (see 5.4.2.2) of a connector (including an opening in the **enclosure**) and conductive parts that are connected to ES2 within the connector (or in the **enclosure**) shall comply with the requirements for **basic insulation**.

The **clearance** between the outer insulating surface (see 5.4.2.2) of a connector (including an opening in the **enclosure**) and conductive parts that are connected to ES3 within the connector (or in the **enclosure**) shall comply with the requirements for **reinforced insulation**. As an exception, the **clearance** may comply with the requirements for **basic insulation** if the connector is:

- fixed to the equipment; and
- located internally to the outer **electrical enclosure** of the equipment; and
- only **accessible** after removal of a subassembly that
 - is required to be in place during **normal operating conditions**, and
 - is provided with an **instructional safeguard** to replace the removed subassembly.

NOTE 2 The tests of 5.4 apply to such connectors after removal of the subassembly.

For all other **clearances** in connectors, including connectors that are not fixed to the equipment, the minimum values determined in accordance with 5.4.2.7 apply.

The above minimum **clearances** for connectors do not apply to connectors listed in Clause G.20.

5.4.2.2 Compliance

Compliance is checked by measurement taking into account the relevant clauses of Annex O and Annex T.

The following conditions apply:

- **movable parts** are placed in their most unfavourable positions;
- **clearances** from an **enclosure** of insulating material through a slot or opening are measured according to Figure O.13, point X;
- the dimensions for **clearances** functioning as **basic insulation**, **supplementary insulation** and **reinforced insulation** are measured after the tests of Annex T;
- after the tests of Annex T the electric strength test shall be applied;
- during the force tests, metal **enclosures** shall not come into contact with bare conductive parts of
 - ES2 circuits, unless the product is in a **restricted access area**, or
 - ES3 circuits;
- for the glass breakage test, see Clause T.9. Damage to the finish, small dents that do not reduce **clearances** below the specified values, surface cracks and the like are ignored. If a through crack appears, **clearances** shall not be reduced. For cracks not visible to the naked eye, an electric strength test shall be conducted.

5.4.2.3 Procedure for determining minimum clearances

5.4.2.3.1 General

To determine the minimum value for each required **clearance**, the highest value of the following three methods shall be used:

Method 1: Determine **clearances** according to 5.4.2.3.2 using the **required withstand voltages**.

Method 2: Measure the **peak working voltage** and determine the **clearance** from Table 18.

Method 3: If the fundamental frequency is higher than 30 kHz, measure the **peak working voltage** at the fundamental frequency and determine the **clearance** from Table 19.

5.4.2.3.2 Determination of the clearance using required withstand voltage

The **clearance** shall be determined using the following steps.

- a) Determine the transient voltage:
 - 1) for equipment intended for connection to the **mains**, determine the a.c. **mains transient voltage** according to 5.4.2.4.1;
 - 2) for equipment intended for connection to a **d.c. mains**, determine the transient voltage according to 5.4.2.4.2 and the nominal **d.c. voltage**;
 - 3) for equipment intended for connection to an **external circuit**, determine the **external circuit** transient voltage according to 5.4.2.4.3;
- b) Determine the **required withstand voltage** according to 5.4.2.5;
- c) Determine the minimum **clearance** according to 5.4.2.7.

The effect of transients from an **external circuit** consisting of a coaxial cable or an antenna is not taken into account when determining **clearances**.

5.4.2.4 Determination of transient voltages

5.4.2.4.1 Determination of a.c. mains transient voltages

This subclause specifies the method to determine the a.c. **mains transient voltage** that needs to be taken into account when determining the **required withstand voltage**.

For equipment to be supplied from the a.c. **mains**, the value of the **mains transient voltage** depends on the overvoltage category and the a.c. **mains** voltage. In general, **clearances** in equipment intended to be connected to the a.c. **mains**, shall be designed for overvoltage category II.

NOTE See Annex I for further guidance on the determination of overvoltage categories.

Equipment that is likely, when installed, to be subjected to transient voltages 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 a.c. **mains** voltage using Table 15.

Table 15 – Mains transient voltages

AC mains voltage ^a up to and including		Mains transient voltage ^b V peak			
V r.m.s.	V peak ^c	Overvoltage category			
		I	II	III	IV
50	71	330	500	800	1 500
100 ^d	141	500	800	1 500	2 500
150 ^e	210	800	1 500	2 500	4 000
300 ^f	420	1 500	2 500	4 000	6 000
600 ^g	840	2 500	4 000	6 000	8 000

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

^b The **mains transient voltage** is always one of the values in the table. Interpolation is not permitted.

^c See 5.4.2.5.1.

^d In Japan, the value of the **mains transient voltages** for the nominal a.c. **mains** supply voltage of 100 V is determined from columns applicable to the nominal a.c. **mains** supply voltage of 150 V.

^e Including 120/208 V and 120/240 V.

^f Including 230/400 V and 277/480 V.

^g Including 400/690 V.

5.4.2.4.2 Determination of d.c. mains transient voltages

This subclause specifies the method to determine the transient voltages from d.c. power distribution systems that need to be taken into account when determining the **required withstand voltage**.

If an earthed d.c. power distribution system is entirely within a single building, the transient voltage is selected as follows:

- if the d.c. power distribution system is earthed at a single point, the transient voltage is assumed to be 500 V peak; or
- if the d.c. power distribution system is earthed at the source and the equipment, the transient voltage is assumed to be 350 V peak; or

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 the cabling associated with the d.c. power distribution system is shorter than 4 m or is installed entirely in continuous metallic conduit, the transient voltage is assumed to be 150 V peak.

If a d.c. power distribution system is not earthed or is not within the same building, 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, however, the d.c. power distribution system is not within the same building, and is constructed using installation and protection techniques similar to those of **external circuits**, the transient voltage shall be determined using the relevant classification from 5.4.2.4.3.

If equipment is supplied from a dedicated battery that has no provision for charging from an external **mains** supply, the transient voltage shall be disregarded.

5.4.2.4.3 Determination of external circuit transient voltages

This subclause specifies **external circuit** transient voltages for various physical configurations of the **external circuit**.

The applicable value of the transient voltage on an **external circuit** shall be determined using Table 16. Where more than one location or condition is applicable, the highest transient applies. A ringing or other interrupted signal shall not be taken into account if the voltage of this signal is less than that of the transient.

Transient voltages from **external circuits** do not require a **safeguard**, but the transient voltages shall be taken into account when dimensioning a **safeguard** that is required between different categories of circuits (for example, ES1, ES2 and ES3).

If the **external circuit** transient voltages are known, the known value should be used.

NOTE 1 Australia has published its overvoltage limits in AS/ACIF G624:2005.

NOTE 2 It is assumed that adequate measures have been taken to reduce the likelihood that the transients presented to the equipment exceed the values specified in Table 16. In installations where transients presented to the equipment may exceed the values specified in Table 16, additional measures such as surge suppression may be necessary.

Table 16 – External circuit transient voltages

Installed wholly within the building structure ^c			
ID	Cable type	Additional conditions	Transient voltages ^a
1	Paired conductor ^d – unshielded		1 000 V 1,2/50 µs Only differential if one conductor is earthed in the equipment
2	Paired conductor ^d – unshielded	Cable is installed wholly within an Equipment Bonding Network (Mesh-BN, Mesh-IBN or star-IBN) (no connection to outside)	500 V 1,2/50 µs Only differential if one conductor is earthed in the equipment
3	Paired conductor ^d – unshielded	Cable length is less than or equal to 4 m. The cable connects equipment that is normally expected to be part of the same bonding network or powered from the same branch circuit (no connection to outside)	Not applicable
4	Paired conductor ^d – shielded ^b		Not applicable
5	Any other conductors	Interfaces with equipment that does not have an earth connection or reference	Not applicable
6	Coaxial cable ^b	Cable shield is earthed at both ends	Not applicable
7	Coaxial cable	Cable shield is not earthed at the equipment	Centre conductor to shield is disregarded 1 000 V 1,2/50 µs shield to earth
8	Integral antenna		Not applicable
9	Any conductor		Not applicable
10	Coaxial cable	Cable is connected to a socket outlet of a cable distribution system	Not applicable

Table 16 (concluded)

Some portion of the cable or the connected network is outside the building or structure ^c			
ID	Cable type	Additional conditions	Transient voltages ^a
11	Paired conductor ^d – unshielded	The building or structure may or may not have equipotential bonding	1 500 V 10/700 µs Only differential if one conductor is earthed in the equipment
12	Paired conductor ^d – shielded		1 500 V 10/700 µs Only differential if one conductor is earthed in the equipment
13	Paired conductor ^d – shielded	The building or structure has equipotential bonding	1 500 V 10/700 µs Only differential if one conductor is earthed in the equipment
14	Any other conductors	The external circuit is not earthed at either end, but there is an earth reference (for example, from connection to mains)	Mains transient voltage or external circuit transient voltage of the circuit from which the circuit in question is derived whichever is higher
15	Coaxial cable	Equipment other than power-fed coaxial repeaters. Cable shield is earthed at the equipment	4 000 V 10/700 µs Centre conductor to shield
16	Coaxial cable	Power fed coaxial repeaters (up to 4,4 mm coaxial cable). Cable shield is earthed at the equipment	5 000 V 10/700 µs Centre conductor to shield
17	Coaxial cable	Equipment other than power-fed coaxial repeaters. Cable shield is not earthed at the equipment. Cable shield is earthed at building entrance	4 000 V 10/700 µs Centre conductor to shield 1 500 V 1,2/50 µs shield to earth
18	Coaxial cable	Cable connects to an outdoor antenna	10 kV from a 1 nF
19	Paired conductor ^d	Cable connects to an outdoor antenna	10 kV from a 1 nF
20	Coaxial cable	The connection of the cable coming from outside the building is made via a transfer point. The shield of the coaxial cable from outside the building and the shield of the coaxial cable of the cable within the building are connected together and are connected to earth.	Not applicable
NOTE 1 In Norway and Sweden, the cable shield on coaxial cables is normally not earthed at the building entrance. For installation conditions, see EN 60728-11. NOTE 2 The effects of unwanted steady-state voltages generated outside the equipment (for example, earth potential differences and voltages induced on telecommunication networks by electric train systems) are controlled by installation practices. Such practices are application dependent and are not dealt with by this standard. ^a See ITU-T, Recommendation K.68. If power induction occurs, transient voltages of 650 V r.m.s. for 0,35 s < t < 0,5 s may be present. ^b For a shielded cable to affect a reduction in transients, the shield shall be continuous, earthed at both ends, and have a maximum transfer impedance of 20 Ω/km (for f less than 1 MHz). ^c Conductor is considered to leave the building if it terminates on equipment earthed to a different earthing network. ^d A paired conductor includes a twisted pair.			

5.4.2.5 Determination of required withstand voltage

5.4.2.5.1 Mains transient voltages

Unless 5.4.2.5.2 applies, the **required withstand voltage** is determined according to a), b) or c) of this subclause.

For equipment supplied from the a.c. **mains**, a) and b) apply. For equipment supplied from the d.c. **mains**, c) applies.

The following abbreviations are used.

$U_{\text{required withstand}}$	the peak value of the a.c. mains supply voltage in the second column of Table 15 corresponding to the rated voltage or the upper limit of the rated voltage range
$U_{\text{mains transient}}$	the mains transient voltage determined in 5.4.2.4
$U_{\text{measured transient}}$	the maximum transient voltage from the a.c. mains , determined according to 5.4.2.6

a) For circuits supplied from the a.c. **mains**, either a)1) or a)2) may be used.

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

2) $U_{\text{required withstand}} = U_{\text{measured transient}}$

b) For circuits isolated from the a.c. **mains**, either b)1), b)2), or b)3) may be used.

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

2) $U_{\text{required withstand}} = U_{\text{measured transient}}$

3) Determine the a.c. **mains transient voltage** from 5.4.2.4.1. $U_{\text{required withstand}}$ is one overvoltage category lower in Table 15 for a given a.c. **mains voltage**.

b)3) is normally applied for the following cases:

- an isolated circuit derived from the **mains**, and that is connected to the main protective earthing terminal in accordance with 5.6.4;
- an isolated circuit, derived from the **mains** and separated from the circuit connected to the **mains** by a metal screen that is connected to the main protective earthing terminal in accordance with 5.6.4.

c) For circuits supplied from a d.c. **mains**, b)1) or b)3) shall be applied.

5.4.2.5.2 DC source transient voltages

In a circuit isolated from the **mains** supplied by a d.c. source with capacitive filtering, and connected to protective earth, the **required withstand voltage** shall be assumed to be equal to the peak value of the **d.c. voltage** of the source, or the **peak working voltage** of the circuit isolated from the **mains**, whichever is higher.

If equipment is supplied from a dedicated battery that has no provision for charging from an external **mains**, the transient voltage is disregarded.

5.4.2.5.3 External circuit transient voltages

Except as specified in 5.5.4, for transient voltages from an **external circuit**, the **required withstand voltage** is

- the **external circuit** transient voltage determined in 5.4.2.4.3, or
- the value measured in accordance with 5.4.2.6 c).

If the transient voltage is smaller than the peak voltage of the short duration signal (such as telephone ringing), this short duration signal shall be taken into account for determination of the **required withstand voltage**.

For circuits connected to coaxial cable distribution and outdoor antennas, compliance is checked by the tests of 5.5.4.

5.4.2.5.4 Combination of transient voltages

If the transient voltages described in 5.4.2.5.1, 5.4.2.5.2 and 5.4.2.5.3 affect the same **clearance**, the largest of those voltages is used when determining **required withstand voltage**. The values shall not be added together.

5.4.2.6 Measurement of transient voltage levels

This subclause specifies the method to measure the actual transient levels from any circuit (when the manufacturer has provided a transient suppression network).

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 not connected to the **mains**, external d.c. power distribution system or to any **external circuit**. Any surge suppressors internal to the equipment in circuits connected to the **mains** or the external d.c. power distribution system are disconnected. If the equipment is intended to be used with a separate power supply, it is connected to the equipment during the tests.

A voltage measuring device is connected across the **clearance** in question.

a) Transient voltages from an a.c. **mains**

To measure the transient voltage across a **clearance** due to transient voltages on a **mains** the impulse test generator circuit 2 of Table D.1 is used to generate 1,2/50 μ s impulses. U_c is equal to the **mains transient voltage** determined in 5.4.2.4.1.

At least three impulses of each 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) Transient voltages from a d.c. **mains**

To measure the transient voltage across a **clearance** due to transient voltages on a d.c. power distribution system, the impulse test generator circuit 2 of Table D.1 is used to generate 1,2/50 μ s impulses. U_c is equal to the transient voltage determined in 5.4.2.4.2.

At least three impulses of each 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) Transient voltages from an **external circuit**

To measure the transient voltage across a **clearance** due to transient voltages on an **external circuit**, the appropriate test generator of Annex D is used to generate impulses as applicable and described in Table 16. U_c is equal to the **external circuit** transient voltage determined in 5.4.2.4.3.

At least three impulses of each 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.

5.4.2.7 Determination of the minimum clearance

Minimum **clearances** may be determined by measurement as specified in this subclause or by electric strength test in accordance with 5.4.2.8.

NOTE The homogeneous field distribution on which Table 20 is based, is in practice not achievable. Only a distribution between inhomogeneous and homogenous can be achieved.

Lower values than in Table 17, Table 18 or Table 19 can be used if an electric strength test according to 5.4.2.8 is conducted as a **type test** using the value of **required withstand voltage** determined according to 5.4.2.5.

Table 17 – Minimum clearances up to 2 000 m above sea level, inhomogeneous field distribution (when transients from mains or external circuits are present)

Required withstand voltage	Basic insulation or supplementary insulation mm			Reinforced insulation mm		
V peak or d.c. up to and including	Pollution degree			Pollution degree		
	1 ^a	2	3	1 ^a	2	3
330	0,01	0,2	0,8	0,04	0,6	1,5
400	0,02			0,07		
500	0,04			0,10		
600	0,06			0,14		
800	0,10			0,5		
1 000	0,15			0,6		
1 200	0,25			0,9		
1 500	0,5		1,5			
2 000	1,0			2,2		
2 500	1,5			3,0		
3 000	2,0			3,8		
4 000	3,0			5,5		
5 000	4,0			8,0		
6 000	5,5			8,0		
8 000	8,0			14		
10 000	11			19,4		
12 000	14			24		
15 000	18			31,4		
20 000	25			44		
25 000	33			60		
30 000	40			72		
40 000	60			98		
50 000	75			130		
60 000	90			162		
80 000	130			226		
100 000	170			290		

Linear interpolation may be used between the nearest two points, the calculated minimum **clearances** being rounded up to the next higher 0,1 mm increment or the value in the next row below whichever is lower.

^a The values for **pollution degree** 1 may be used if a sample complies with the tests of 5.4.8.

Table 18 – Minimum clearances up to 2 000 m above sea level, inhomogeneous field distribution (for steady-state voltages, temporary overvoltages and recurring peak voltages)

Peak working voltage	Basic insulation or supplementary insulation			Reinforced insulation		
	mm			mm		
V peak or d.c. up to and including	Pollution degree			Pollution degree		
	1 ^a	2	3	1 ^a	2	3
330	0,01	0,2	0,8	0,04	0,6	1,5
400	0,02			0,07		
500	0,04			0,10		
600	0,06			0,18		
800	0,18			0,76	0,76	
1 000	0,26	0,26				
1 200	0,42			0,9		1,8
1 500	0,76			1,8		
2 000	1,27			2,2		
2 500	1,8			3,8		
3 000	2,4			3,9		
4 000	3,8			7,9		
5 000	6,7			11		
6 000	7,9			11		
8 000	11,0			19		
10 000	15,2			25		
12 000	19			31		
15 000	25			40		
20 000	34			55		
25 000	44			71		
30 000	55			88		
40 000	77			124		
50 000	100			160		
60 000	120			192		
80 000	175			280		
100 000	230			368		

The values in the above table are derived from IEC 60664-1:2007, Table F.7a.

Linear interpolation may be used between the nearest two points, the calculated minimum **clearances** being rounded up to the next higher 0,1 mm increment or the value in the next row below whichever is lower.

^a The values for **Pollution degree** 1 may be used if a sample complies with the tests of 5.4.8.

Table 19 – Minimum clearances up to 2 000 m above sea level, inhomogeneous field distribution (for steady-state voltages, temporary overvoltages and recurring peak voltages for frequencies above 30 kHz)

Peak working voltage up to and including V peak	Basic insulation or supplementary insulation mm	Reinforced insulation mm
600	0,06	0,12
800	0,18	0,36
1 000	0,5	1,0
1 200	1,4	2,8
1 400	2,35	4,7
1 600	4,0	8,0
1 800	6,7	13,4
2 000	11	22,0
Linear interpolation may be used between the nearest two points, the calculated minimum clearances being rounded up to the next higher 0,1 mm increment.		

5.4.2.8 Minimum clearances based on electric strength test

Clearances for basic insulation, supplementary insulation, and reinforced insulation shall withstand an electric strength test in addition to compliance with the minimum clearance values of Table 20. The test may be conducted using an impulse voltage or a.c. voltage or a **d.c. voltage**. The impulse withstand voltage test is carried out with a voltage having an appropriate waveform (see Annex D) with the values specified in Table 20. The a.c. voltage test is conducted using a sinusoidal voltage with r.m.s. value as specified in Table 20.

The **d.c. voltage** test is conducted using a **d.c. voltage** with average **d.c. voltage** value as specified in Table 20. The **required withstand voltage** is determined as given in 5.4.2.5. The test is carried out as follows:

- by applying five impulses of each polarity with an interval of at least 1 s between pulses; or
- by applying an a.c. r.m.s. voltage for 5 s; or
- by applying a **d.c. voltage** for 5 s in one polarity and then for 5 s in reverse polarity.

NOTE When verifying clearances within equipment by an electric strength test (for example, an impulse voltage), ensure that the specified electric test voltage appears at the clearance under test.

Table 20 – Minimum clearances based on electric strength test

Required withstand voltage	Basic insulation or supplementary insulation			Reinforced insulation		
	mm			mm		
V peak or d.c. up to and including	Pollution degree			Pollution degree		
	1 ^a	2	3	1 ^a	2	3
330	0,01	0,2	0,8	0,04	0,43	1,45
400	0,02			0,07		
500	0,04			0,10		
600	0,06			0,14		
800	0,10			0,3		
1 000	0,15			0,33		
1 200	0,2			0,43		
1 500	0,3			0,6		
2 000	0,45		0,88			
2 500	0,6		1,2			
3 000	0,8		1,45			
4 000	1,2			2,0		
5 000	1,5			3,0		
6 000	2,0			3,0		
8 000	3,0			4,5		
10 000	3,5			6,0		
12 000	4,5			7,5		
15 000	5,5			9,6		
20 000	8,0			13,4		
25 000	10			17		
30 000	12,5			21		
40 000	17			28,6		
50 000	22			35		
60 000	27			43		
80 000	35			59		
100 000	45			75		

Linear interpolation may be used between the nearest two points, the calculated minimum clearances being rounded up to the next higher 0,1 mm increment or the value in the next row below whichever is lower.

This table is based on the data for homogeneous fields.

^a The values for **pollution degree** 1 may be used if a sample complies with the tests of 5.4.8.

Table 21 – Test voltages for verifying clearances up to 2 000 m above sea level

Required withstand voltage up to and including kV peak	Test voltage for electric strength for clearances for basic insulation or supplementary insulation		
	kV peak 1,2/50 μ s impulse	kV r.m.s.	kV d.c.
0,33	0,35	0,23	0,35
0,5	0,55	0,4	0,55
0,8	0,91	0,52	0,74
1,5	1,75	0,95	1,35
2,5	2,95	1,89	2,67
4,0	4,8	2,61	3,69
6,0	7,3	3,97	5,61
8,0	9,8	5,34	7,55
12,0	14,8	8,08	11,43
U^a	$1,23 \times U$	$0,68 \times U$	$0,95 \times U$
Linear interpolation may be used between the nearest two points, the calculated minimum test voltage being rounded up to the next higher 0,01 kV increment. For reinforced insulation , the test voltage for electric strength is 160 % of the value for the basic insulation . For routine tests , the test voltage is reduced by 20 % and the duration is reduced to 1 s. If the EUT fails the r.m.s. or d.c. test, the impulse test shall be used.			
^a U is any required withstand voltage higher than 12,0 kV.			

5.4.2.9 Multiplication factors for altitudes higher than 2 000 m above sea level

For equipment intended to be used 2 000 m above sea level, the minimum **clearances** in Table 17, Table 18, Table 19 and Table 20 and the electric strength test voltages in Table 21 are multiplied by the applicable multiplication factor for the desired altitude according to Table 22 (tests conducted at sea level).

NOTE 1 It is acceptable to use a vacuum chamber to simulate higher altitudes.

NOTE 2 In China, special requirements in choosing multiplication factors for altitudes above 2 000 m exist.

Table 22 – Multiplication factors for clearances and test voltages

Altitude m	Normal barometric pressure kPa	Multiplication factor for clearances	Multiplication factor for electric strength test voltages			
			$\geq 0,01$ mm to $< 0,0625$ mm	$\geq 0,0625$ mm to < 1 mm	≥ 1 mm to < 10 mm	≥ 10 mm to < 100 mm
2 000	80,0	1,00	1,00	1,00	1,00	1,00
3 000	70,0	1,14	1,05	1,05	1,07	1,10
4 000	62,0	1,29	1,10	1,10	1,15	1,20
5 000	54,0	1,48	1,17	1,16	1,24	1,33
Linear interpolation may be used between the nearest two points, the calculated minimum multiplication factor being rounded up to the next higher 0,01 increment.						

5.4.3 Creepage distances

5.4.3.1 General

Creepage distances for frequencies up to 30 kHz shall be so dimensioned that, for a given **r.m.s. working voltage**, **pollution degree** and material group, no flashover or breakdown of insulation (for example, due to tracking) will occur.

Creepage distances for frequencies higher than 30 kHz are under consideration. The **creepage distance** requirements for frequencies up to 30 kHz can be used for frequencies over 30 kHz until additional data is available.

The **creepage distance** between the outer insulating surface (see 5.4.3.2) of a connector (including an opening in the **enclosure**) and conductive parts that are connected to ES2 within the connector (or in the **enclosure**) shall comply with the requirements for **basic insulation**.

The **creepage distance** between the outer insulating surface (see 5.4.3.2) of a connector (including an opening in the **enclosure**) and conductive parts that are connected to ES3 within the connector (or in the **enclosure**) shall comply with the requirements for **reinforced insulation**.

As an exception, the **creepage distance** may comply with the requirements for **basic insulation** if the connector is:

- fixed to the equipment; and
- located internally to the outer **electrical enclosure** of the equipment; and
- only **accessible** after removal of a subassembly that
 - is required to be in place during normal operating conditions, and
 - is provided with an instructional safeguard to replace the removed subassembly.

NOTE 1 The tests of 5.4 apply to such connectors after removal of the subassembly.

For all other **creepage distances** in connectors, including connectors that are not fixed to the equipment, the minimum values determined in accordance with this subclause apply.

The above minimum **creepage distances** for connectors do not apply to connectors listed in Clause G.20.

NOTE 2 For **creepage distances** below 2 mm, additional information is available in IEC 60664-5.

5.4.3.2 Test method

5.4.3.2.1 Test conditions

*This subclause specifies physical conditions that need to be taken into account when determining **creepage distances**.*

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 Clause 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 in the **enclosure** or through an opening in an **accessible** connector, the **accessible** insulated surface shall be considered to be conductive as if it were covered by a metal foil during the test of V.1.2, applied without appreciable force (see Figure O.13, point X);*
- *the dimensions for **creepage distances** functioning as **basic insulation**, **supplementary insulation** and **reinforced insulation** are measured after the tests of Annex T;*
- *for the glass breakage test, see Clause T.9. Damage to the finish, small dents that do not reduce **creepage distances** below the specified values, surface cracks and the like are ignored. If a through crack appears, **creepage distances** shall not be reduced.*

Compliance is checked by measurement, taking into account Annex O, Annex T, and Annex V.

5.4.3.2.2 Material group and CTI

Material groups are based on the CTI and are classified as follows:

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

The 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.

5.4.3.3 Compliance

Creepage distances for basic insulation and supplementary insulation shall be not less than the minimum values specified in Table 23, 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 distances are twice the values for basic insulation in Table 23.

If the minimum creepage distance derived from Table 23 is less than the minimum clearance, then the 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, the value of minimum clearance may be applied as the minimum creepage distance.

Table 23 – Minimum creepage distances for basic insulation and supplementary insulation in mm

RMS working voltage up to and including V	Pollution degree						
	1 ^a	2			3		
	Material group						
	I, II, IIIa, IIIb	I	II	IIIa, IIIb	I	II	IIIa, IIIb see Note
10	0,08	0,4	0,4	0,4	1,0	1,0	1,0
12,5	0,09	0,42	0,42	0,42	1,05	1,05	1,05
16	0,1	0,45	0,45	0,45	1,1	1,1	1,1
20	0,11	0,48	0,48	0,48	1,2	1,2	1,2
25	0,125	0,5	0,5	0,5	1,25	1,25	1,25
32	0,14	0,53	0,53	0,53	1,3	1,3	1,3
40	0,16	0,56	0,8	1,1	1,4	1,6	1,8
50	0,18	0,6	0,85	1,2	1,5	1,7	1,9
63	0,2	0,63	0,9	1,25	1,6	1,8	2,0
80	0,22	0,67	0,95	1,3	1,7	1,9	2,1
100	0,25	0,71	1,0	1,4	1,8	2,0	2,2
125	0,28	0,75	1,05	1,5	1,9	2,1	2,4
160	0,32	0,8	1,1	1,6	2,0	2,2	2,5
200	0,42	1,0	1,4	2,0	2,5	2,8	3,2
250	0,56	1,25	1,8	2,5	3,2	3,6	4,0
320	0,75	1,6	2,2	3,2	4,0	4,5	5,0
400	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	3,6	5,0	6,3	7,1	8,0
630	1,8	3,2	4,5	6,3	8,0	9,0	10
800	2,4	4,0	5,6	8,0	10	11	12,5
1 000	3,2	5,0	7,1	10	12,5	14	16
1 250	4,2	6,3	9,0	12,5	16	18	20
1 600	5,6	8,0	11	16	20	22	25
2 000	7,5	10	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			

Table 23 (concluded)

RMS working voltage up to and including V	Pollution degree						
	1 ^a	2			3		
	Material group						
	I, II, IIIa, IIIb	I	II	IIIa, IIIb	I	II	IIIa, IIIb see Note
32 000	125	160	220	320			
40 000	160	200	280	400			
50 000	200	250	360	500			
63 000	250	320	450	600			
NOTE Material group IIIb is not recommended for applications in pollution degree 3 with an r.m.s. working voltage above 630 V.							
Linear interpolation may be used between the nearest two points, the calculated minimum creepage distance being rounded to the next higher 0,1 mm increment or the value in the next row below whichever is lower.							
For reinforced insulation , the rounding to the next higher 0,1 mm increment or to double the value in the next row is done after doubling the calculated value for basic insulation .							
^a The values for pollution degree 1 may be used if a sample complies with the tests of 5.4.8.							

Table 24 – Minimum values of creepage distances for frequencies higher than 30 kHz

Peak working voltage kV	Creepage distances						
	mm						
	30 kHz < f ≤ 100 kHz	100 kHz < f ≤ 200 kHz	200 kHz < f ≤ 400 kHz	400 kHz < f ≤ 700 kHz	700 kHz < f ≤ 1 MHz	1 MHz < f ≤ 2 MHz	2 MHz < f ≤ 3 MHz
NOTE Requirements for creepage distances at frequencies above 30 kHz are under consideration.							

5.4.4 Solid insulation

5.4.4.1 General requirements

This subclause specifies general requirements for **solid insulation**.

The requirements of this subclause also apply to compounds and gel materials used as insulation. They do not apply to thin sheet materials.

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 as given in G.11.1.2.

Except for printed boards, **solid insulation** shall either:

- comply with minimum distances through insulation in accordance with 5.4.4.2; or
- meet the requirements and pass the tests in 5.4.4.3 to 5.4.4.7, as applicable.

Glass used as **solid insulation** shall comply with the glass breakage test as specified in Clause T.9. Damage to the finish, small dents that do not reduce **clearances** below the

specified values, surface cracks and the like are ignored. If a through crack appears, **clearances** shall not be reduced below the specified values.

For printed boards, see Clause G.18. For antenna terminals, see 5.4.5. For **solid insulation** on internal wiring, see 5.4.6.

5.4.4.2 Minimum distance through insulation

Except where another subclause of Clause 5 applies, distances through insulation shall be dimensioned according to the application of the insulation and as follows (see Figure O.15 and Figure O.16):

- if the **working voltage** does not exceed ES2 voltage limits, there is no requirement for distance through insulation;
- if the **working voltage** exceeds ES2 voltage limits, the following rules apply:
 - for **basic insulation**, there is no minimum distance through insulation specified;
 - for **supplementary insulation** or **reinforced insulation** comprised of a single layer, the minimum distance through insulation shall be 0,4 mm;
 - for **supplementary insulation** or **reinforced insulation** comprised of multiple layers, the minimum distance through insulation shall comply with 5.4.4.6.

5.4.4.3 Insulating compound forming solid insulation

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 optocoupler) provided that (see Figure O.15):

- the component or subassembly meets the minimum distances through insulation of 5.4.4.2; and
- a single sample passes the tests of 5.4.8.

NOTE 1 Alternative requirements for semiconductor devices are given in 5.4.4.4, and in Clause G.16.

For printed boards, see Clause G.18 and for wound components, see 5.4.4.7.

NOTE 2 Some examples of such treatment are variously known as potting, encapsulation and vacuum impregnation.

NOTE 3 Such constructions may contain cemented joints in which case 5.4.4.5 also applies.

5.4.4.4 Solid insulation in semiconductor devices

There is no minimum internal **clearance** or **creepage distance**, and no minimum distance through insulation for **supplementary insulation** or **reinforced insulation** consisting of an insulating compound completely filling the casing of a semiconductor component (for example, an optocoupler) provided that the component satisfies one of the following a) or b) (see Figure O.15):

- a) passes the **type tests** and inspection criteria of 5.4.9; and passes **routine tests** for electric strength during manufacturing, using the appropriate test in 5.4.11.1; or
- b) complies with Clause G.16.

As an alternative to a) and b) above, a semiconductor may be evaluated according to 5.4.4.3, if applicable.

NOTE Such constructions may contain cemented joints in which case 5.4.4.5 also applies.

5.4.4.5 Insulating compound forming cemented joints

This subclause specifies requirements when an insulating compound forms a cemented joint between two non-conductive parts or between another non-conductive part and itself.

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 Figure O.14, Figure O.15 and Figure O.16), one of the following a), b) or c) applies.

- a) The distance along the path between the two conductive parts shall be not less than the minimum **clearances** and **creepage distances** for **pollution degree** 2. The requirements for distance through insulation of 5.4.4.2 do not apply along the joint.
- b) The distance along the path between the two conductive parts shall not be less than the minimum **clearances** and **creepage distances** for **pollution degree** 1. Additionally, one sample shall pass the test of 5.4.8. The requirements for distance through insulation in 5.4.4.2 do not apply along the joint.
- c) The requirements for distance through insulation of 5.4.4.2 apply between the conductive parts along the joint. Additionally, three samples shall pass the test of 5.4.9.

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 5.4.8 and 5.4.9 are not applied to the inner layers of a printed board made using pre-preg if the temperature of the printed board measured during the heating test of 5.4.1.5 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 O.14) or the split bobbin of a transformer where the centre limb is secured by adhesive (see Figure O.16);
- spirally wrapped insulation on a winding wire, sealed by adhesive insulating compound, is an example of PD1;
- the joint between a non-conductive part (the casing) and the insulating compound itself in an optocoupler (see Figure O.15).

5.4.4.6 Thin sheet material

5.4.4.6.1 General requirements

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

NOTE An instrument to carry out the electric strength test on thin sheets of insulating material is described in Figure 36.

Insulation in thin sheet materials may be used for **supplementary insulation** and **reinforced insulation**, irrespective of the distance through insulation, provided that

- two or more layers are used;
- the insulation is within the equipment **enclosure**;
- the insulation is not subject to handling or abrasion during **ordinary person** or **instructed person** servicing; and
- the requirements and tests of 5.4.4.6.2 (for separable layers) or 5.4.4.6.3 (for non-separable layers) are met.

It is not required for the two or more layers to be fixed to the same conductive part. The two or more layers can be:

- fixed to one of the conductive parts requiring separation; or
- shared between the two conductive parts; or
- not fixed to either conductive part.

For insulation in three or more layers of non-separable thin sheet materials:

- minimum distances through insulation are not required; and
- each layer of insulation does not have to be of the same material.

5.4.4.6.2 Separable thin sheet material

In addition to the requirements of 5.4.4.6.1, for:

- **supplementary insulation** consisting of two layers of material, each layer shall pass the electric strength test for **supplementary insulation**; or
- **supplementary insulation** consisting of three layers of material, any combination of two layers shall pass the electric strength test for **supplementary insulation**; or
- **reinforced insulation** consisting of two layers of material, each layer shall pass the electric strength test for **reinforced insulation**; or
- **reinforced insulation** consisting of three layers of material, any combination of two layers shall pass the electric strength test for **reinforced insulation**.

If more than three layers are used, layers may be divided into two or three groups of layers. Each group of layers shall pass the electric strength test for the appropriate insulation.

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

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

5.4.4.6.3 Non-separable thin sheet material

For insulation consisting of non-separable thin sheet materials, in addition to the requirements of 5.4.4.6.1, the test procedures in Table 25 are applied. There is no requirement for all layers of insulation to be of the same material and thickness.

Compliance is checked by inspection and by the tests specified in Table 25.

Table 25 – Tests for insulation in non-separable layers

Number of layers	Test procedure
Supplementary insulation	
Two or more layers:	The test procedure of 5.4.4.6.4 is applied
Reinforced insulation	
Two layers:	The test procedure of 5.4.4.6.4 is applied
Three or more layers:	The test procedures of 5.4.4.6.4 and 5.4.4.6.5 ^a are applied
NOTE The purpose of the tests in 5.4.4.6.5 is to ensure that the material has adequate strength to resist damage when hidden in inner layers of insulation. Therefore, the tests are not applied to insulation in two layers. The tests in 5.4.4.6.5 are not applied to supplementary insulation .	
^a Where the insulation is integral to winding wire, the test does not apply.	

5.4.4.6.4 Standard test procedure for non-separable thin sheet material

For non-separable layers, electric strength tests are applied in accordance with 5.4.11.1 to all layers together. The test voltage is:

- 200 % of U_{test} if two layers are used; or
- 150 % of U_{test} if three or more layers are used,

where U_{test} is the highest of the test voltages specified in Table 31, Table 32 or Table 33 for **supplementary insulation** or **reinforced insulation** as appropriate.

NOTE Unless all the layers are of the same material and have the same thickness, there is a possibility that the test voltage will be shared unequally between layers, causing breakdown of a layer that would have passed if tested separately.

5.4.4.6.5 Mandrel test

This subclause specifies the test requirements for **reinforced insulation** made of three or more thin insulating sheets of material that are inseparable.

NOTE This test is based on IEC 61558-1 and will give the same results.

Three test samples, each individual sample consisting of three or more layers of non-separable thin sheet material forming **reinforced insulation**, are used. One sample is fixed to the mandrel of the test fixture (Figure 32) as shown in Figure 33.

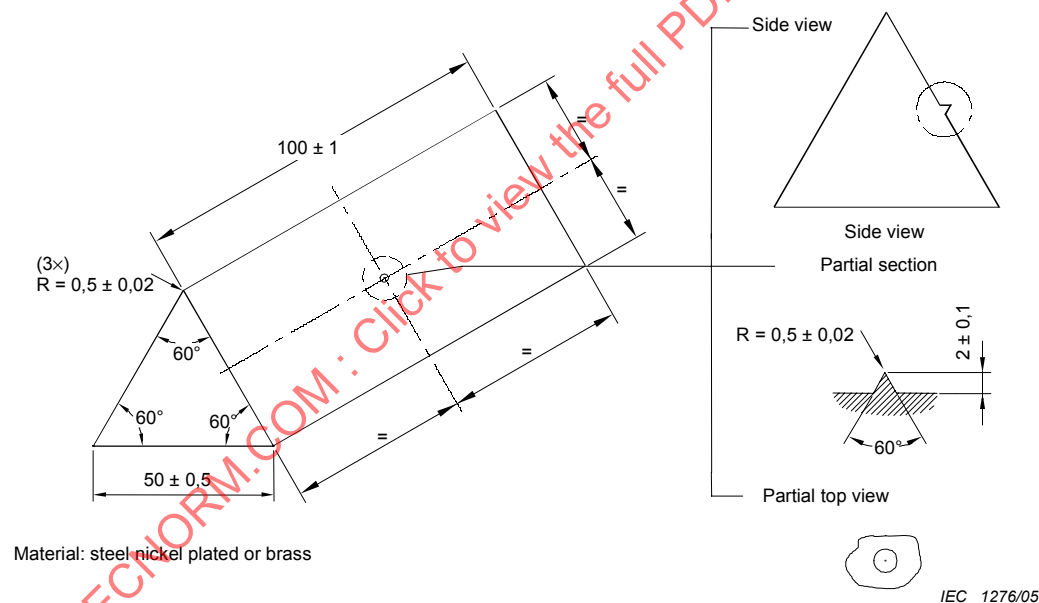
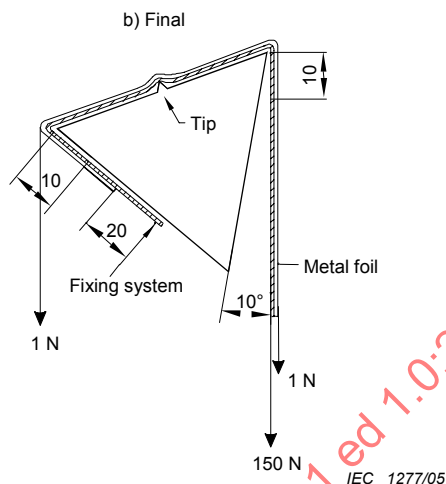
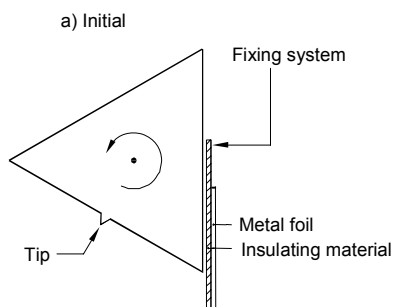


Figure 32 – Mandrel



The final position of the mandrel is rotated $230^\circ \pm 5^\circ$ from the initial position.

Figure 33 – Initial position of mandrel

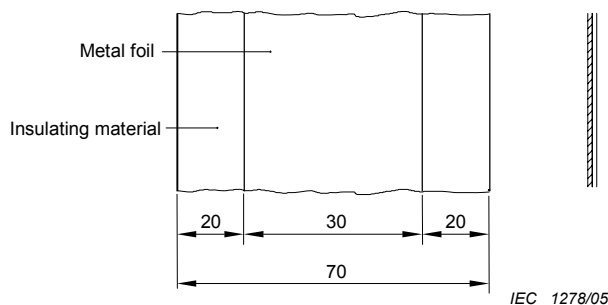
Figure 34 – Final position of mandrel

A pull is applied to the free end of the sample, using an appropriate clamping device. The mandrel is rotated:

- from the initial position (Figure 33) to the final position (Figure 34) and back;
- as above for a second time;
- from the initial position to the final position.

If a sample breaks during rotation where it is fixed to the mandrel or to the clamping device, this does not constitute a failure. If a sample breaks at any other place, the test has failed.

After the above test, a sheet of metal foil, $0,035 \text{ mm} \pm 0,005 \text{ mm}$ thick, at least 200 mm long, is placed along the surface of the sample, hanging down on each side of the mandrel (see Figure 34). The surface of the foil in contact with the sample shall be conductive, not oxidized or otherwise insulated. The foil is positioned so that its edges are not less than 20 mm from the edges of the sample (see Figure 35). The foil is then tightened by two equal weights, one at each end, using appropriate clamping devices.



Dimensions in millimetres

Figure 35 – Position of metal foil on insulating material

While the mandrel is in its final position, and within the 60 s following the final positioning, an electric strength test is applied between the mandrel and the metal foil in accordance with 5.4.11.1. The test voltage is 150 % of U_{test} , but not less than 5 kV r.m.s. U_{test} is the highest of the test voltages specified in Table 31, Table 32 or Table 33 for **reinforced insulation** as appropriate.

The test is repeated on the other two samples.

5.4.4.7 Solid insulation in wound components

Planar transformers are not considered to be wound components.

NOTE 1 Planar transformers are subject to the requirements of Clause G.18.

Basic insulation, supplementary insulation or reinforced insulation in a wound component may be provided by

- the insulation on winding wire or other wire (see G.11.1); or
- other insulation (see G.11.2); or
- a combination of the two.

NOTE 2 Wound components may contain cemented joints in which case 5.4.4.5 also applies.

For **double insulation** between the conductor of a wire and another conductive part, **basic insulation** may be provided by insulation complying with G.11.1 on the wire or wires and **supplementary insulation** by additional insulation complying with G.11.2, or vice versa.

Basic insulation, supplementary insulation and reinforced insulation in the finished wound component shall pass **routine tests** for electric strength in accordance with 5.4.11.1.

5.4.4.8 Compliance

Compliance with the requirements of 5.4.4.2 to 5.4.4.7 for the adequacy of **solid insulation** is verified by inspection and measurement, taking into account Annex O, by the electric strength tests of 5.4.11.1 and the additional tests required in 5.4.4.2 to 5.4.4.7, as applicable.

5.4.4.9 Solid insulation requirements at frequencies higher than 30 kHz

The suitability of the **solid insulation** shall be determined as follows.

- Determine the value of the breakdown electric field strength of the insulation material or each individual foil at power frequency E_P in kV/mm for the insulating material. Selected materials are listed in Table 26.
- Determine the reduction factor K_R for the breakdown electric field strength of the insulating material or each individual foil at the applicable frequency from Table 27 or Table 28. If the material is not one listed in Table 27 or Table 28, use the average reduction factor in the last row of Table 27 or Table 28 as applicable.
- Determine the value of the breakdown electric field strength at the applicable frequency E_F by multiplying the value E_P with the reduction factor K_R .

$$E_F = E_P \times K_R$$

- Determine the actual electric strength V_W of the insulating material by multiplying the value E_F with the total thickness (d in mm) of the insulating material.

$$V_W = E_F \times d$$

- For **basic insulation** or **supplementary insulation**, V_W shall exceed the measured high frequency **peak working voltage** V_{PW} by 20 %.

$$V_W > 1,2 \times V_{PW}$$

- For **reinforced insulation**, V_W shall exceed twice the measured high frequency **peak working voltage** V_{PW} by 20 %.

$$V_W > 1,2 \times 2 \times V_{PW}$$

Table 26 – Electric field strength E_p for some commonly used materials

Material	Breakdown electric field strength E_p				
	kV/mm				
	Thickness of the material mm				
	0,75	0,08	0,06	0,05	0,03
Porcelain	9,2	-	-	-	-
Silicon-glass	14	-	-	-	-
Phenolic	17	-	-	-	-
Ceramic	19	-	-	-	-
Teflon	27	-	-	-	-
Melamine-glass	27	-	-	-	-
Mica	29	-	-	-	-
Paper phenolic	38	-	-	-	-
Polyethylene	50	-	-	52	-
Polystyrene	55	65	-	-	-
Glass	60	-	-	-	-
Polyethylene	49	-	-	-	-
Kapton	303	-	-	-	-
TIW	70	-	-	-	-
FR530L	33	-	-	-	-
Mica-filled phenolic	28	-	-	-	-
Glass-silicone laminate	18	-	-	-	-
Cellulose-acetobutyrate	-	-	120	-	210
Polycarbonate	-	-	160	-	270
Cellulose-triacetate	-	-	120	-	210
NOTE 1 It is assumed that materials are equal to or thicker than 0,75 mm where no thickness has been mentioned. Such materials that do not have E_p information at very small thickness actually have a better E_p value at the small thickness than the E_p value at 0,75 mm thickness.					
NOTE 2 Missing values are under investigation.					

Table 27 – Reduction factors for the value of breakdown electric field strength E_p at higher frequencies

Material ^a	Frequency kHz										
	30	100	200	300	400	500	1 000	2 000	3 000	5 000	10 000
	Reduction factor K_R										
Porcelain	0,52	0,42	0,40	0,39	0,38	0,37	0,36	0,35	0,35	0,34	0,30
Silicon-glass	0,79	0,65	0,57	0,53	0,49	0,46	0,39	0,33	0,31	0,29	0,26
Phenolic	0,82	0,71	0,53	0,42	0,36	0,34	0,24	0,16	0,14	0,13	0,12
Ceramic	0,78	0,64	0,62	0,56	0,54	0,51	0,46	0,42	0,37	0,35	0,29
Teflon	0,57	0,54	0,52	0,51	0,48	0,46	0,45	0,44	0,41	0,37	0,22
Melamine-glass	0,48	0,41	0,31	0,27	0,24	0,22	0,16	0,12	0,10	0,09	0,06
Mica	0,69	0,55	0,48	0,45	0,41	0,38	0,34	0,28	0,26	0,24	0,20
Paper phenolic	0,58	0,47	0,40	0,32	0,26	0,23	0,16	0,11	0,08	0,06	0,05
Polyethylene	0,36	0,28	0,22	0,21	0,20	0,19	0,16	0,13	0,12	0,12	0,11
Polystyrene	0,35	0,22	0,15	0,13	0,13	0,11	0,08	0,06	0,06	0,06	0,06
Glass	0,37	0,21	0,15	0,13	0,11	0,10	0,08	0,06	0,05	0,05	0,04
Other materials	0,43	0,35	0,30	0,27	0,25	0,24	0,20	0,17	0,16	0,14	0,12

^a This data is for materials that are 0,75 mm thick.

Table 28 – Breakdown electric field strength reduction values at a.c. frequency for thin foils

Thin foil material	Frequency kHz										
	30	100	200	300	400	500	1 000	2 000	3 000	5 000	10 000
	Reduction factor K_R										
Cellulose-acetobutyrate (0,03 mm)	0,67	0,43	0,32	0,27	0,24	0,20	0,15	0,11	0,09	0,07	0,06
Cellulose-acetobutyrate (0,06 mm)	0,69	0,49	0,36	0,30	0,26	0,23	0,17	0,13	0,11	0,08	0,06
Polycarbonate (0,03 mm)	0,61	0,39	0,31	0,25	0,23	0,20	0,14	0,10	0,08	0,06	0,05
Polycarbonate (0,06 mm)	0,70	0,49	0,39	0,33	0,28	0,25	0,19	0,13	0,11	0,08	0,06
Cellulose-triacetate (0,03 mm)	0,67	0,43	0,31	0,26	0,23	0,20	0,14	0,10	0,09	0,07	0,06
Cellulose-triacetate (0,06 mm)	0,72	0,50	0,36	0,31	0,27	0,23	0,17	0,13	0,10	0,10	0,06
Other thin foil materials	0,68	0,46	0,34	0,29	0,25	0,22	0,16	0,12	0,10	0,08	0,06

5.4.5 Antenna terminal insulation

5.4.5.1 General

This subclause specifies the tests for insulation

- between antenna terminals and **mains**, and
- between antenna terminals and ES1 circuits or ES2 circuits
 - isolated from the antenna circuits, and
 - having terminals for connection to **external circuits**.

The insulation shall withstand surges due to overvoltages at the antenna terminals.

This test does not apply to equipment where one antenna terminal on the equipment is connected to earth in accordance with 5.6.8.2.

NOTE In China, connection of the CATV to the main protective earthing terminal of equipment is not permitted.

If a **mains**-connected equipment provides non-**mains** supply voltages to other equipment having antenna terminals, the test shall apply between **mains** terminals and the non-**mains** supply voltage terminals.

5.4.5.2 Test method

*The insulation shall be tested as described in G.14.3.2. The equipment shall be placed on an insulating surface. The impulse test generator output shall be connected to the antenna terminals connected together and to the **mains** terminals connected together. The equipment is not energized during this test.*

*If the equipment has ES1 circuits or ES2 circuits that are isolated from the antenna circuits and that have terminals for connection to **external circuits**, the test is repeated with the generator connected to the antenna terminals connected together and the **external circuit** terminals connected together.*

NOTE Test personnel are cautioned not to touch the equipment during this test.

5.4.5.3 Compliance

Compliance is checked by measuring the insulation resistance with 500 V d.c.

The apparatus is deemed to comply with the requirement, if the insulation resistance measured after 1 min is not less than the values given in Table 29.

Table 29 – Values for insulation resistance

Insulation requirements between parts	Insulation resistance MΩ
Between parts separated by basic insulation or by supplementary insulation	2
Between parts separated by double insulation or reinforced insulation	4

5.4.6 Insulation of internal wire as a part of a supplementary safeguard

The requirements of this subclause apply where the insulation of an internal wire, alone, meets the requirements for **basic insulation**, but does not meet the requirements for **supplementary insulation**.

An example of such internal wiring is the wiring in a circuit isolated from the **mains** at a voltage level not exceeding ES1 voltage level.

These requirements apply to a wire that is located in a circuit isolated from the **mains** at a voltage level not exceeding ES1 voltage level that is isolated from ES3 by a **basic safeguard** only.

Where wire insulation is employed as part of a **supplementary insulation** system and the wire insulation is **accessible** to an **ordinary person**:

- the wire insulation does not need to be handled by the **ordinary person**;

- the wire is placed such that the **ordinary person** is unlikely to pull on it, or the wire shall be so fixed that the connecting points are relieved from strain;
- the wire is routed and fixed such as not to touch unearthed **accessible** conductive parts;
- the wire insulation passes the electric strength test of 5.4.11.1 for **supplementary insulation**;
- the distance through the wire insulation shall be at least as given in Table 30.

Table 30 – 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

Compliance is checked by inspection and measurement, and by the test of 5.4.11.1.

5.4.7 Thermal cycling test procedure

A sample of a component or subassembly is subjected to the following sequence of tests. The sample is subjected 10 times to the following sequence of thermal cycling:

68 h	at	$T_1 \pm 2\text{ °C}$;
1 h	at	$25\text{ °C} \pm 2\text{ °C}$;
2 h	at	$0\text{ °C} \pm 2\text{ °C}$;
≥1 h	at	$25\text{ °C} \pm 2\text{ °C}$.

$T_1 = T_2 + T_{\text{ma}} - T_{\text{amb}} + 10\text{ K}$, measured in accordance with B.1.7, 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 5.4.1.5.

The significance of T_{ma} and T_{amb} are as given in B.2.6.1.

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

5.4.8 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 5.4.4.3.

A sample is subjected to the thermal cycling sequence of 5.4.7.

It is allowed to cool to room temperature and is then subjected to the humidity conditioning of 5.4.10, followed immediately by the electric strength tests of 5.4.11.1.

Compliance is checked by inspection and measurement. There shall be no visible cracks in the insulating material. For compliance with 5.4.4.3, the sample is also sectioned, and there shall be no visible voids in the insulating material.

5.4.9 Tests for semiconductor components and for cemented joints

Three samples are subjected to the thermal cycling sequence of 5.4.7. 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 electric strength test of 5.4.11.1, immediately after the last period at $T_1 \pm 2^\circ\text{C}$ 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 5.4.11.1 after the humidity conditioning of 5.4.10, except that the test voltage is multiplied by 1,6.

Compliance is checked by inspection of the cross-sectional area and measurement. There shall be no visible voids, gaps or cracks in the insulating material. In the case of multilayer printed boards, there shall be no delamination.

5.4.10 Humidity conditioning

Humidity conditioning is carried out for 48 h in a cabinet or room containing air with a relative humidity of $93\% \pm 3\%$. 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 so 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 $40^\circ\text{C} \pm 2^\circ\text{C}$ and a relative humidity of $93\% \pm 3\%$.

Before the humidity conditioning, the sample is brought to a temperature between the specified temperature t and $(t + 4)^\circ\text{C}$.

5.4.11 Electric strength test

5.4.11.1 Test procedure for a solid insulation type test

Unless otherwise specified, compliance is checked either

- immediately following the temperature test in 5.4.1.5, or
- if a component or subassembly is tested separately outside the equipment, it is brought to the temperature attained by that part during the temperature test in 5.4.1.5 (for example, by placing it in an oven) prior to performing the electric strength test.

Alternatively, thin sheet material for **supplementary insulation** or **reinforced insulation** may be tested at room temperature.

Unless otherwise specified elsewhere in this standard, the test voltage for the electric strength of **basic insulation**, **supplementary insulation** or **reinforced insulation** is the highest value of the following three methods:

Method 1: Determine the test voltage according to Table 31 using the **required withstand voltage** (based on transient voltages from the a.c. **mains** or d.c. **mains** or from **external circuits**).

Method 2: Determine the test voltage according to Table 32 using the **peak working voltage**.

Method 3: Determine the test voltage according to Table 33 using the nominal **mains** voltage (to cover temporary overvoltages).

The insulation is subjected to the highest test voltage as follows:

- by applying an a.c. voltage of substantially sine-wave form having a frequency of 50 Hz or 60 Hz; or
- by applying a **d.c. voltage** in one polarity and then in reverse polarity.

The voltage applied to the insulation under test is gradually raised from zero to the prescribed voltage and maintained at that value for 60 s (for **routine tests** see 5.4.11.2).

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 insulations that are not involved in the test, ICs, or the like, may be disconnected and equipotential bonding may be used. An MOV complying with Clause G.10 may be removed during the test.

For equipment incorporating **basic insulation** and **supplementary insulation** in parallel with **reinforced insulation**, care is taken that the voltage applied to the **reinforced insulation** does not overstress **basic insulation** or **supplementary insulation**.

NOTE 1 Where capacitors are in parallel with the insulation under test (for example, radio-frequency filter capacitors), d.c. test voltages should be used.

NOTE 2 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 5.4.1.7, an electric strength test method is used that stresses the insulation accordingly.

NOTE 3 An example of such a test method is an induced voltage test that is applied at a frequency sufficiently high to avoid saturation of the transformer. The input voltage is raised to a value that would induce an output voltage equal to the required test voltage.

Table 31 – Test voltages for electric strength tests based on transient voltages

Required withstand voltage up to and including kV peak	Test voltage for basic insulation or supplementary insulation	Test voltage for reinforced insulation
	kV peak a.c. or d.c.	
0,33	0,33	0,5
0,5	0,5	0,8
0,8	0,8	1,5
1,5	1,5	2,5
2,5	2,5	4
4,0	4	6
6,0	6	8
8,0	8	12
12	12	18
U_R^a	U_R^a	$1,5 \times U_R^a$
Linear interpolation may be used between the nearest two points.		
^a U_R is any required withstand voltage higher than 12,0 kV.		

Table 32 – Test voltages for electric strength tests based on peak working voltages

Peak working voltage up to and including	Test voltage for basic insulation or supplementary insulation	Test voltage for reinforced insulation
kV peak	kV peak or d.c.	
0,33	0,43	0,53
0,5	0,65	0,80
0,8	1,04	1,28
1,5	1,95	2,4
2,5	3,25	4,0
4,0	5,20	6,40
6,0	7,80	9,60
8,0	10,40	12,8
12,0	15,60	19,2
U_P^a	$1,3 \times U_P^a$	$1,6 \times U_P^a$
^a U_P is any peak working voltage higher than 12,0 kV.		

Table 33 – Test voltages for electric strength tests based on temporary overvoltages

Nominal mains voltage	Test voltage for basic insulation or supplementary insulation	Test voltage for reinforced insulation
V r.m.s.	V peak or d.c.	
120	1 867	3 734
230	2 022	4 044
600	2 545	5 090

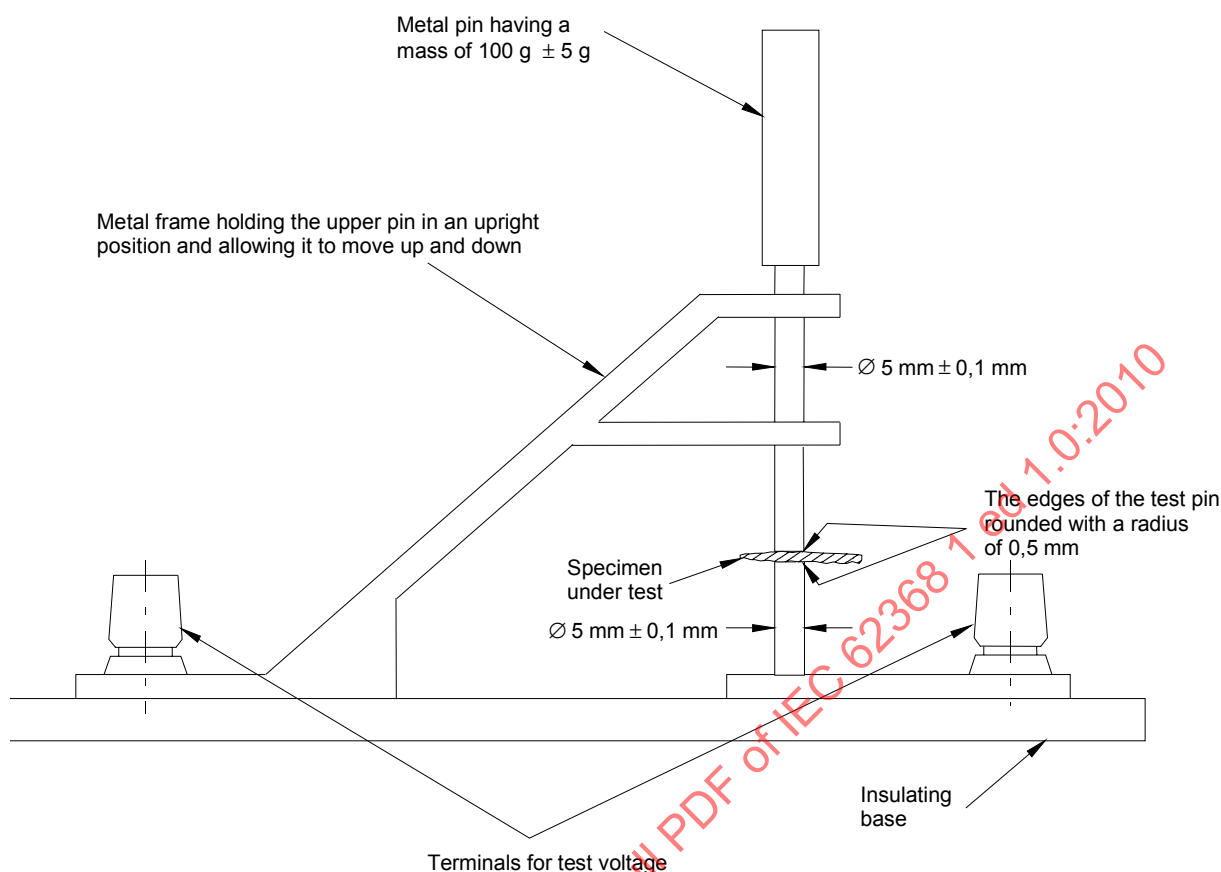


Figure 36 – Example of electric strength test instrument for solid insulation

NOTE 4 The instrument of Figure 36 may be used for testing specimens of thin sheet insulation.

There shall be no insulation breakdown during the test. Insulation breakdown is considered to have occurred when the current that 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.

5.4.11.2 Test procedure for routine tests

Routine tests are performed according to 5.4.11.1, except for the following:

- the test may be performed at room temperature; and
- the duration of the electric strength test shall be between 1 s to 4 s; and
- the test voltages in Table 31, Table 32 and Table 33 may be reduced by 10 %.

NOTE The above test condition is also applicable to **routine tests** in production of the equipment or subassemblies.

There shall be no insulation breakdown during the test. Insulation breakdown is considered to have occurred when the current that 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.

5.4.12 Protection against transient voltages from external circuits

5.4.12.1 Requirements

Equipment with **external circuits** as indicated in Table 16, ID numbers 11, 12, 13, 14, 15, 16, and 17 shall provide adequate electrical separation between an **external circuit** and:

- unearthed conductive parts; or
- non-conductive parts of the equipment expected to be held or otherwise maintained in continuous contact with the body during normal use (for example, a telephone handset or head set or the palm rest surface of a laptop or notebook computer); or
- another ES1 or ES2 part separated from the **external circuit**; or
- **accessible** parts and circuitry, except for the pins of connectors. However, such pins shall not be **accessible** under **normal operating conditions** by the blunt probe of Figure V.3.

5.4.12.2 Compliance and test method

*Compliance is checked by electric strength test for **basic insulation** in accordance with 5.4.11.1 applied across the electrical separation. For the tests, all conductors, including shield of coaxial cable, intended to be connected to the **external circuit** are connected together, including any conductors that may be connected to earth in the **external circuit**. Similarly, all conductors intended to be connected to other **external circuits** are connected together.*

Non-conductive parts are tested with metal foil in contact with the surface.

*The test voltage shall be selected from the highest of Table 31, Table 32 and Table 33. For parts expected to be held or touched during **normal operating conditions**, the test voltage shall be for **reinforced insulation**.*

5.4.13 Separation between external circuits and earth

5.4.13.1 General

These requirements apply only to **external circuits** indicated in Table 16, ID numbers 11, 12, 13 and 14.

These requirements do not apply to **external circuits** of:

- **permanently connected equipment**, or
- **pluggable equipment type B**; or
- **stationary pluggable equipment type A**, that is intended to be used in a location having equipotential bonding (such as a telecommunication centre, a dedicated computer room or a **restricted access area**) and has installation instructions that require verification of the **protective earthing connection** of the socket-outlet by a **skilled person**; or
- **stationary pluggable equipment type A**, that has provision for a permanently connected **protective earthing conductor**, including instructions for the installation of that conductor to building earth by a **skilled person**.

NOTE In Norway and Sweden, the exclusions are applicable for **permanently connected equipment**, **pluggable equipment type B** and equipment intended to be used in a **restricted access area** where equipotential bonding has been applied, for example, in a telecommunication centre, and which has provision for a permanently connected **protective earthing conductor** and is provided with instructions for the installation of that conductor by a **skilled person**.

5.4.13.2 Requirements

There shall be insulation between circuitry intended to be connected to **external circuits** mentioned above and any parts or circuitry that will be earthed in some applications, either within the EUT or via other equipment.

SPDs that bridge the insulation between ES1 or ES2 **external circuits** and earth shall have a minimum rated operating voltage U_{op} (for example, the sparkover voltage of a gas discharge tube) of:

$$U_{op} = U_{peak} + \Delta U_{sp} + \Delta U_{sa}$$

where

U_{peak} is one of the following values:

- for equipment intended to be installed in an area where the nominal voltage of the a.c. **mains** exceeds 130 V: 360 V
- for all other equipment: 180 V.

ΔU_{sp} is the maximum increase of the rated operating voltage due to variations in SPD production. If this is not specified by the SPD manufacturer, ΔU_{sp} shall be taken as 10 % of the rated operating voltage of the SPD.

ΔU_{sa} is the maximum increase of the rated operating voltage due to the SPD ageing over the expected life of the equipment. If this is not specified by the SPD manufacturer, ΔU_{sa} shall be taken as 10 % of the rated operating voltage of the SPD.

NOTE ($\Delta U_{sp} + \Delta U_{sa}$) may be a single value provided by the component manufacturer.

5.4.13.3 Compliance and test method

Compliance is checked by inspection and by the electric strength test of 5.4.11.1.

Components that bridge the insulation, other than capacitors, may be removed during electric strength testing. Components that are left in place during the test shall not be damaged.

If components are removed, the following additional test with a test circuit according to Figure 37 is performed with all components in place.

*For equipment powered from a.c. **mains**, the test is performed with a voltage equal to the **rated voltage** of the equipment or to the upper voltage of the **rated voltage range**. For equipment powered from d.c. **mains**, the test is performed with a voltage equal to the highest nominal voltage of the a.c. **mains** in the region where the equipment is to be used (for example, 230 V for Europe or 120 V for North America).*

The current flowing in the test circuit of Figure 37 shall not exceed 10 mA.

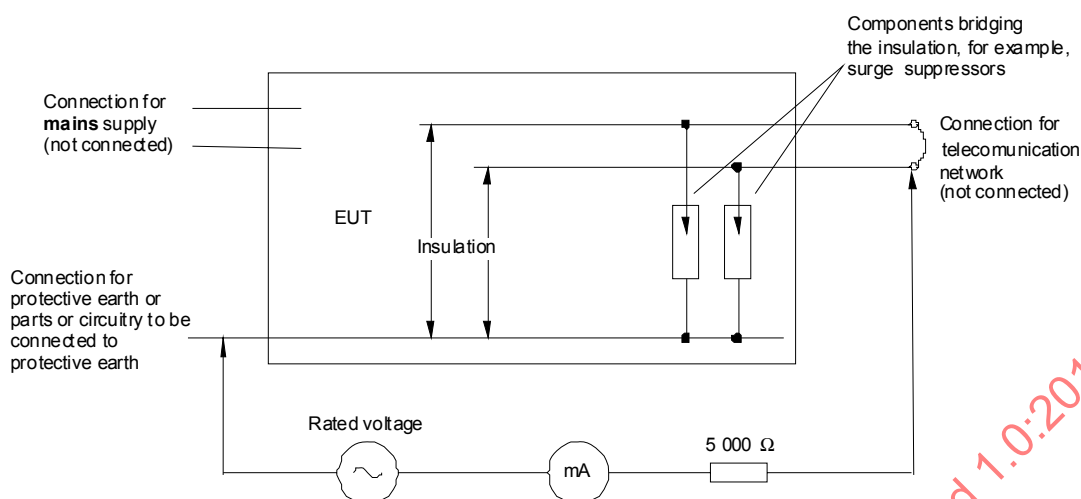


Figure 37 – Test for separation between a telecommunication network and earth

5.5 Components as safeguards

5.5.1 General

This subclause specifies applications of components that serve as (electrical) **safeguards** or that bridge **safeguards**.

NOTE See Annex G for the qualification of safety components.

If a component bridges a **safeguard**, then it shall also comply with all the requirements for that **safeguard** as applicable.

5.5.2 Components as basic safeguard and supplementary safeguard

5.5.2.1 General requirements

For components used as a **basic safeguard**, the insulation shall comply with **basic insulation**.

For components used as a **supplementary safeguard**, the insulation shall comply with **supplementary insulation**.

Components may be used as a **basic safeguard** or **supplementary safeguard**, but only if used within their ratings.

5.5.2.2 Capacitors and RC units as a basic safeguard and a supplementary safeguard

Capacitors and RC units may be used as **basic safeguards**. If capacitors and RC units are used as **basic safeguards** then they shall comply with the requirements for **basic insulation** between their terminations for the total **working voltage** across the insulation and shall comply with the requirements as specified in Clause G.15.

NOTE 1 RC units may consist of discrete components.

The requirements of Clause G.15 do not apply to the **basic insulation** provided between:

- ES3 isolated from the **mains** and protective earth; and
- ES2 and protective earth; and

- ES2 and ES1.

The test of 5.4.11.1 still applies to the above capacitors.

Capacitors and RC units may be used as a **supplementary safeguard**. If capacitors and RC units are used as a **supplementary safeguard** then they shall comply with the requirements for **supplementary insulation** between their terminations for the total **working voltage** across the insulation and shall comply with the safety requirements as specified in Clause G.15.

For a capacitor used as a **basic safeguard** or as a **supplementary safeguard**, the peak impulse test voltage of the capacitor shall be at least equal to the **required withstand voltage**.

If a **basic safeguard** or a **supplementary safeguard** consists of more than one capacitor, all of the following applies:

- under **single fault conditions**, the voltage on each of the remaining individual capacitors shall not exceed the voltage rating of the relevant individual capacitors;
- the sum of the peak impulse test voltages of all capacitors shall be not less than the **required withstand voltage**;
- the sum of the r.m.s. test voltages of all capacitors shall be not less than the highest of the required test voltage of Table 31, Table 32 and Table 33.

NOTE 2 It is common practice to have the same rated capacitance value and same rated voltage for all capacitors in series.

NOTE 3 In Norway, due to the IT power system used, capacitors are required to be rated for the applicable line-to-line voltage (230 V).

Class X capacitors may be used as **basic safeguards** in circuits isolated from the **mains** but shall not be used as:

- a **basic safeguard** in circuits connected to the **mains**; or
- a **supplementary safeguard**.

5.5.2.3 Safeguards against capacitor discharge

For an **ordinary person**, where a capacitor voltage is **accessible**, or becomes **accessible** upon disconnection of a connector (for example, the **mains** connector), either

- the combination of capacitance and voltage shall comply with ES1 limits of Table 7, or
- the circuit shall be provided with a means for discharging the capacitor to ES1 limits of Table 7 within 2 s.

For an **instructed person**, where a capacitor voltage is **accessible**, or becomes **accessible** upon disconnection of a connector (for example, the **mains** connector), either

- the combination of capacitance and voltage shall comply with ES2 limits of Table 7 or
- the circuit shall be provided with a means for discharging the capacitor to ES2 limits of Table 7 within 2 s.

NOTE The limits apply both to the capacitor itself and to the circuit that charges it.

5.5.2.4 Transformers as a basic safeguard and a supplementary safeguard

Insulation of transformers used as a **basic safeguard** shall comply with **basic insulation** requirements or with the safety requirements of the relevant IEC standard described in Clause G.7. Insulation of transformers used as a **supplementary safeguard** shall comply with

supplementary insulation requirements and Clause G.7 or with the safety requirements of the relevant IEC standard described in Clause G.7.

5.5.2.5 Optocouplers as basic safeguard and supplementary safeguard

Insulation of optocouplers used as a **basic safeguard** shall comply with **basic insulation** requirements or with the safety requirements of the IEC standard (see Clause G.16). Insulation of optocouplers used as a **supplementary safeguard**, shall comply with **supplementary insulation** requirements or with the safety requirements of the IEC standard (see Clause G.16).

5.5.2.6 Relays as a basic safeguard and a supplementary safeguard

Insulation of relays used as a **basic safeguard** shall comply with **basic insulation** requirements or with the safety requirements of the IEC standard as described in Clause G.17.

Insulation of relays used as a **supplementary safeguard** shall comply with **supplementary insulation** requirements or with the safety requirements of the IEC standard as described in Clause G.17.

5.5.2.7 Resistors as a basic safeguard and a supplementary safeguard

Resistors may be used as a **basic safeguard**. If resistors are used as a **basic safeguard**, then they shall comply with the **clearance** and **creepage distance** requirements for **basic insulation** between its terminations for the total **working voltage** across the insulation.

Resistors may be used as a **supplementary safeguard**. If resistors are used as a **supplementary safeguard**, they shall comply with the **clearance** and **creepage distance** requirements for **supplementary insulation** between their terminations for the total **working voltage** across the insulation.

Basic insulation or **supplementary insulation** may be bridged by one resistor or by a group of two or more resistors in series under the following conditions.

The resistor or group of resistors shall comply with the minimum **clearances** of 5.4.2 and the minimum **creepage distances** of 5.4.3 for **basic insulation** or **supplementary insulation** as applicable for the total **working voltage** across the resistor or group. For a group of resistors, see Figure O.4.

If a single resistor is used, it shall pass the resistor test of G.14.2.

If a group of resistors is used, the **clearance** and **creepage distance** are assessed as if each resistor were short-circuited in turn, unless the group passes the resistor test of G.14.2.

NOTE In Finland, Norway and Sweden, resistors bridging **basic insulation** in **class I pluggable equipment type A** must comply with G.14.3.

5.5.2.8 SPD as a basic safeguard

An SPD may be used as a **basic safeguard** provided that one side of the SPD is earthed according to 5.6.8.2.

A MOV used as a **basic safeguard** shall comply with the requirements of Clause G.10.

5.5.2.9 Other components as a basic safeguard between ES1 and ES2

Any type of component may be used as a **basic 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.

Components bridging **basic insulation** serving as a **basic safeguard** between ES1 and ES2 shall meet the applicable electric strength test in accordance with 5.4.11.1.

5.5.3 Components as a reinforced safeguard

5.5.3.1 General requirements

For components used as a **reinforced safeguard**, the insulation shall comply with **reinforced insulation**.

A component used as a **reinforced safeguard** shall be used within its rating.

5.5.3.2 Capacitors and RC units

Capacitors and RC units may be used as a **reinforced safeguard** provided they comply with the requirements for **reinforced insulation** between their terminations for the total **working voltage** across the insulation. The capacitors and RC units shall comply with IEC 60384-14 as given in Clause G.15.

Class X capacitors shall not be used as a **reinforced safeguard**.

If a **reinforced safeguard** consists of more than one capacitor, all of the following applies:

- under **single fault conditions**, the voltage on each of the remaining individual capacitors shall not exceed the voltage rating of the relevant individual capacitors;
- the sum of the peak impulse test voltages of all capacitors shall be not less than twice the **required withstand voltage**;
- the sum of the r.m.s. test voltages of all capacitors shall be not less than the highest of the required test voltage of Table 31, Table 32 and Table 33.

5.5.3.3 Transformers

Transformers used as a **reinforced safeguard** shall comply with the requirements of **reinforced insulation** and Clause G.7.

5.5.3.4 Optocouplers

Insulation of optocouplers used as a **reinforced safeguard** or **double safeguard** shall comply with **reinforced insulation** requirements or with the safety requirements of the IEC standard described in Clause G.16.

5.5.3.5 Relays

Insulation of relays used as a **reinforced safeguard** or **double safeguard** shall comply with **reinforced insulation** requirements or with the safety requirements of the IEC standard as described in Clause G.17.

5.5.3.6 Resistors

Resistors may be used as a **reinforced safeguard** provided they comply with the **clearance** and **creepage distance** requirements for **reinforced insulation** between their terminations for the total **working voltage** across the insulation.

Double insulation or **reinforced insulation** may be provided by one resistor or by a group of two or more resistors in series, under the following conditions:

- the resistor or group of resistors shall comply with the minimum **clearances** of 5.4.2; and
- the minimum **creepage distances** of 5.4.3 for **reinforced insulation**, as applicable for the total **working voltage** across the resistor or group. For a group of resistors, see Figure O.4.

If a single resistor is used, it shall pass the resistor test of G.14.2.

If a group of resistors is used, the **clearance** and **creepage distance** are assessed as if each resistor were short-circuited in turn, unless the group passes the resistor test of G.14.2.

5.5.4 Insulation between the mains and an external circuit consisting of a coaxial cable

Except as specified below, the insulation between the **mains** and the terminal or lead provided for the connection to a coaxial cable including the resistor bridging this insulation, if any, shall pass either:

- the voltage surge test of G.14.3.2 for equipment intended to be connected to a coaxial cable connected to an outdoor antenna; or
- the impulse test of G.14.3.3 for equipment intended to be connected to another coaxial cable.

If the insulation and the bridging resistor are subject to overvoltages from both an outdoor antenna and another coaxial cable, they shall pass the tests of G.14.3.2 and G.14.3.3.

The above requirement does not apply to the insulation and to the resistor bridging the insulation, if any, in any of the following equipment:

- indoor use equipment, provided with a built-in (integral) antenna and not provided with a connection to a coaxial cable; or
- equipment connected to a reliable earth in accordance with 5.6.8.3.

Compliance is checked by inspection and, if necessary, by the voltage surge test of G.14.3.2 or impulse test of G.14.3.3 as referenced in G.14.3.

NOTE **Clearances** are determined by the requirements of 5.4.2. It may be necessary to increase the **clearances** between **mains** and circuits isolated from the **mains** intended for connection to an antenna or a coaxial cable.

5.5.5 Components and parts that may bridge insulation

5.5.5.1 Requirement

Where a component or part could bridge insulation where failure of that insulation would result in class 2 energy sources or class 3 energy sources becoming **accessible**, the component or part shall withstand the test of Clause T.2.

5.5.5.2 Compliance

*During the test, no short-circuit shall occur. After the test, no **equipment safeguards** shall be defeated.*

5.6 Protective conductor

5.6.1 General requirements

This subclause specifies the general, performance and size requirements for **protective conductors** that serve as a **basic safeguard** or a **supplementary safeguard** or a **reinforced safeguard**.

Protective conductors and their terminations shall not have excessive resistance (see 5.6.6.4).

The current-carrying capacity of **protective conductors** shall be adequate for the duration of the fault current under **single fault conditions**.

Protective conductors shall not contain switches or overcurrent protective devices.

Protective bonding conductors shall be such that disconnection (for example, 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 disconnection also breaks the supply to that part or unit at the same time.

Protective conductors shall make contact earlier and disconnect later than the supply connections in each of the following:

- a connector (on a cable) or a connector attached to a part or a subassembly that can be removed by other than a **skilled person**;
- a plug on a power supply cord;
- an appliance coupler.

NOTE It is recommended that this construction also be applied when it is expected that the **skilled person** will replace powered parts and assemblies while the equipment is operational.

For low current-carrying **protective conductors**, only the requirements of 5.6.3 and the test of 5.6.4 are required.

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

5.6.2 Corrosion

Conductive parts in contact at the main protective earthing terminal, protective bonding terminals and connections shall be selected in accordance with Annex N so that the potential difference between any two different metals is 0,6 V or less.

Compliance is checked by inspection.

5.6.3 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, if provided, may be transparent;
- a **protective bonding conductor** in assemblies such as ribbon cables, bus bars, printed wiring, etc., may be of any colour provided that no misinterpretation of the use of the conductor is likely to arise.

Compliance is checked by inspection.

5.6.4 Test for low current-carrying protective conductors

For a part receiving its power from an **external circuit**, the test current is 1,5 times the maximum current available from the **external circuit**, for a duration of 120 s.

For parts connected to the **protective bonding conductor** to limit the transients or to limit **touch current** to an **external circuit** and that do not exceed an ES2 level during **single fault conditions**, the test is conducted in accordance with 5.6.6.4.2. The relevant test method and criteria of either a), b), c) or d) shall be applied based on the power source assumed.

Compliance is checked by measuring the voltage drop or resistance as applicable between the main protective earthing terminal and the point in the equipment that is required to be earthed.

5.6.5 Protective conductors used as a basic safeguard between ES1 and ES2

5.6.5.1 General

This subclause specifies the general, performance and size requirements for **protective conductors** that serve as a **basic safeguard** between ES1 and ES2.

5.6.5.2 Fault current-carrying protective conductors

5.6.5.2.1 General

This subclause specifies the application of **protective conductors** that serve as a **basic safeguard** but may have to carry fault currents.

5.6.5.2.2 Requirements

Protective conductors may serve as **basic safeguards** between ES1 and ES2:

- for **accessible** conductive parts not exceeding an ES2 level during **single fault conditions**;
- to maintain the integrity of parts at ES1 level during **normal operating conditions** provided that parts do not exceed an ES2 level during **single fault conditions**;
- to maintain the integrity of parts at an ES2 level during **normal operating conditions** provided that parts do not exceed an ES2 level during **single fault conditions**.

The size of the **protective earthing conductors** shall comply with 5.6.6.2 and for **protective bonding conductors** with 5.6.6.3.

5.6.5.2.3 Compliance

Compliance is checked by inspection and measurement of **protective earthing conductor** and **protective bonding conductor** sizes in accordance with 5.6.6.2 or 5.6.6.3 as applicable.

5.6.6 Protective conductors used as a supplementary safeguard

5.6.6.1 General

Protective conductors may serve as a **supplementary safeguard**:

- for parts that might otherwise assume an ES3 level during **single fault conditions** (if a **supplementary safeguard** was not provided), or
- to limit transient voltages that might affect **basic insulation** for parts that could not exceed an ES2 level during **single fault conditions**, or
- to limit **touch current** to an **external circuit**.

5.6.6.2 Size of protective earthing conductors and terminals

Protective earthing conductors shall comply with the minimum conductor sizes in Table 34.

Terminals that are used in a connection of a **protective earthing conductor** shall comply with the minimum terminal sizes in Table 36.

*Compliance is checked by inspection and measurement of **protective bonding conductor** sizes in accordance with Table 34 and terminal sizes in Table 36, as applicable.*

Table 34 – Sizes of conductors

Rated current of equipment A up to and including	Minimum conductor sizes	
	Nominal cross-sectional area mm ²	AWG [cross-sectional area in mm ²] see NOTE 2
6	0,75 ^a	18 [0,8]
10	1,00 (0,75) ^b	16 [1,3]
16	1,50 (1,0) ^c	14 [2]
25	2,5	12 [3]
32	4	10 [5]
40	6	8 [8]
63	10	6 [13]
80	16	4 [21]
100	25	2 [33]
125	35	1 [42]
160	50	0 [53]
190	70	000 [85]
230	95	0000 [107]
		kcmil [cross-sectional area in mm ²] see NOTE 2
260	120	250 [126]
300	150	300 [152]
340	185	400 [202]
400	240	500 [253]
460	300	600 [304]

NOTE 1 IEC 60320-1 specifies acceptable combinations of appliance couplers and flexible cords, including those covered by items a, b and c. However, a number of countries have indicated that they do not accept all of the values listed in Table 34, particularly those covered by items a, b and c.

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.

NOTE 3 For higher currents see the IEC 60364 series.

^a For **rated current** up to 3 A, a nominal cross-sectional area of 0,5 mm² may be used in some countries provided that the length of the cord does not exceed 2 m.

^b The value in parentheses applies to detachable power supply cords fitted with the connectors rated 10 A in accordance with IEC 60320-1 (types C13, C15, C15A and C17) provided that the length of the cord does not exceed 2 m.

^c The value in parentheses applies to detachable power supply cords fitted with the connectors rated 16 A in accordance with IEC 60320-1 (types C19, C21 and C23) provided that the length of the cord does not exceed 2 m.

5.6.6.3 Size of protective bonding conductors and terminals

Protective bonding conductors and their terminals shall comply with one of the following:

- the minimum conductor sizes in Table 34 and terminal sizes in Table 36; or
- the requirements of 5.6.6.4 and also, if the **protective current rating** of the circuit is more than 16 A, with the minimum conductor sizes in Table 35 and terminal sizes that are not more than one size smaller than in Table 36; or
- the requirements of 5.6.6.4 and also, if the **protective current rating** of the circuit does not exceed 16 A; either
 - with the minimum conductor sizes in Table 35 and terminal sizes that are not more than one size smaller than in Table 36; or
 - with the limited short-circuit test of Annex R;
- for components only, be not smaller than the conductors supplying power to the component.

NOTE 1 The value of **protective current rating** (above) is used in Table 35 and in the test of 5.4.5.2.

Where the source is the **mains** supply, the **protective current rating** of the circuit is the rating of the overcurrent protective device provided in, or as part of the equipment. Where the overcurrent protective device is so provided, then:

- for **pluggable equipment type A**, the **protective current rating** is the rating of an overcurrent protective device provided external to the equipment (for example, in the building wiring, in the **mains** plug or in an equipment rack) to protect the equipment, with a minimum of 16 A;

NOTE 2 In most countries, 16 A is considered to be suitable as the **protective current rating** of the circuit.

NOTE 3 In Canada and the USA, the **protective current rating** of the circuit is taken as 20 A.

NOTE 4 In the UK and Ireland the **protective current rating** is taken to be 13 A, this being the largest rating of fuse used in the **mains** plug.

- for **pluggable equipment type B**, and **permanently connected equipment** the **protective current rating** is the maximum rating of the overcurrent protective device specified in the equipment installation instructions to be provided external to the equipment.

Where the source is an external supply having the maximum current inherently limited by the internal source impedance (such as an impedance protected transformer) the **protective current rating** of the circuit is the highest current available from that supply into any load. Where the maximum current from the external supply source is limited by electronic components in the source, the **protective current rating** shall be taken as the maximum output current with any resistive load including a short circuit measured 60 s after the application of the load if the current is limited by impedance or the current limiting device is a fuse, a circuit breaker or a PTC device, or 5 s in other cases.

The current limiting device or the overcurrent protective device (fuse, a circuit breaker or a PTC device) shall not be connected in parallel with any other component that could fail to a low-resistance state.

Where the source is a circuit within the equipment, the **protective current rating** of the circuit is:

- the rating of the overcurrent protective device if the current is limited by an overcurrent protective device; or
- the maximum output current, if the current is limited by the source impedance of the supply. The output current is measured with any resistive load including a short circuit measured 60 s after the application of the load if current is limited by impedance or the current limiting device is a fuse, a circuit breaker or a PTC device, or 5 s in other cases.

The current limiting device or the overcurrent protective device (fuse, a circuit breaker or a PTC device) shall not be connected in parallel with any other component that could fail to a low-resistance state.

Table 35 – Minimum protective bonding conductor size of copper conductors

Protective current rating of the circuit under consideration A up to and including	Minimum conductor sizes	
	Cross-sectional area mm ²	AWG or kcmil [cross-sectional area in mm ²]
6	0,5	20 [0,519]
10	0,75	18 [0,8]
13	1,0	16 [1,3]
16	1,25	16 [1,3]
25	1,5	14 [2]
32	2,5	12 [3]
40	4,0	10 [5]
63	6,0	8 [8]
80	10	6 [13]
100	16	4 [21]
125	25	2 [33]
160	35	1 [42]
190	50	0 [53]
230	70	000 [85]
260	95	0000 [107]
		kcmil [cross-sectional area in mm²]
300	120	250 [126]
340	150	300 [152]
400	185	400 [202]
460	240	500 [253]
NOTE AWG 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 (diameter in mils) ² . These terms are commonly used to designate wire sizes in North America.		

Compliance is checked by inspection and measurement of **protective bonding conductor** sizes and terminal sizes.

5.6.6.4 Resistance of protective conductors and their terminations

5.6.6.4.1 Requirements

Protective conductors and their terminations shall not have excessive resistance. **Protective conductors** that meet the minimum conductor sizes in Table 34 throughout their length and whose terminals all meet the minimum sizes in Table 36 are considered to comply without test.

Table 36 – Sizes of terminals for protective conductors

Rated current A up to and including	Conductor size mm ² (from Table 34)	Minimum nominal thread diameter mm		Area of cross section mm ²	
		Pillar type or stud type	Screw type ^a	Pillar type or stud type	Screw type ^a
10	1	3,0	3,5	7	9,6
16	1,5	3,5	4,0	9,6	12,6
25	2,5	4,0	5,0	12,6	19,6
32	4	4,0	5,0	12,6	19,6
40	6	5,0	5,0	19,6	19,6
63	10	6,0	6,0	28	28
80	16	7,9	7,9	49	49

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

For **rated currents** above 80 A, the **protective earthing conductor** shall be attached to special connectors, or suitable clamping means (for example, an upturned spade or closed loop pressure type; clamping unit type; saddle clamping unit type; mantle clamping unit type; etc.) that is secured by a screw and nut mechanism to the metal chassis of the equipment. The sum of the cross-sectional areas of the screw and the nut shall not be less than three times the cross-sectional area of the conductor size in Table 34 or Table 35 as applicable.

The terminals shall comply with IEC 60998-1 and IEC 60999-1 or IEC 60999-2.

5.6.6.4.2 Compliance and test method

*This subclause specifies the test requirements for **protective bonding conductors** that do not comply with the size requirements of Table 34 and Table 36.*

*Compliance is checked by inspection, measurement and, for **protective bonding conductors** that do not meet the minimum conductor sizes in Table 34 throughout their length or whose terminals do not all meet the minimum sizes in Table 36, 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, the conductor may be included 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 that 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 may only be used 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:

- a) For equipment powered from the **mains**, if the **protective current rating** of the circuit under test is 16 A or less, the test current is 200 % of the **protective current rating** applied for 120 s.

The resistance of the **protective bonding conductor**, calculated from the voltage drop, shall not exceed 0,1 Ω . After the test, the **protective bonding conductor** shall not be damaged.

- b) For equipment powered from the **mains**, if the **protective current rating** of the circuit under test exceeds 16 A, the test current is 200 % of the **protective current rating** or 500 A, whichever is less, and the duration of the test is as shown in Table 37.

Table 37 – Test duration, mains connected equipment

Protective current rating of the circuit A up to and including	Duration of the test min
30	2
60	4
100	6
200	8
over 200	10

The voltage drop in the **protective bonding conductor** for test currents up to 500 A shall not exceed 2,5 V. For equipment requiring branch circuit fusing over 250 A, the measured potential voltage drop multiplied by the required fusing and divided by 250 shall not exceed 2,5 V. After the test, the **protective bonding conductor** shall not be damaged.

- c) As an alternative to b) above, the tests are based on the time-current characteristic of the overcurrent protective device that limits the fault current in the **protective bonding conductor**. This device is either one provided in the EUT or specified in the installation instructions to be provided external to the equipment. The tests are conducted at 200 % of the **protective current rating**, for the duration corresponding to 200 % on the time-current characteristic. If the duration for 200 % is not given, the nearest point on the time-current characteristic may be used.

The voltage drop in the **protective bonding conductor** shall not exceed 2,5 V. After the test, the **protective bonding conductor** shall not be damaged.

- d) For equipment powered from a d.c. supply system, if the **protective current rating** of the circuit under test exceeds 16 A, the test current and duration are as specified by the manufacturer.

The voltage drop in the **protective bonding conductor** shall not exceed 2,5 V. After the test, the **protective bonding conductor** shall not be damaged.

5.6.7 Protective earthing conductors serving as a double or reinforced safeguard

5.6.7.1 General

This subclause specifies requirements for enhanced **protective earthing conductors** and their terminations (for example, when the **touch current** exceeds the ES2 limits in Table 4, see also 5.7.6).

Protective conductors serving as a **double safeguard** or **reinforced safeguard** shall comply with the applicable requirements of 5.6.1, 5.6.3 and 5.6.6.

5.6.7.2 Requirements for protective earthing conductors serving as a reinforced safeguard

A **reinforced safeguard protective earthing conductor** may be employed on **pluggable equipment type B** or on **permanently connected equipment** only and shall:

- be included in and protected by a sheathed supply cord not lighter than heavy duty:
 - PVC sheathed flexible cord according to IEC 60227-1 (designations 60227; IEC 52 or IEC 53) or
 - rubber-sheathed flexible cord according to IEC 60245-1 (designations 60245; IEC 53, IEC 57 or IEC 58);
- or
- have a minimum conductor size not less than 10 mm² (to resist mechanical damage); or
- be protected by a conduit and have a minimum size in accordance with Table 38.

NOTE For **mains** supply cords, see also Clause G.9.

Table 38 – Protective earthing conductor sizes for reinforced safeguards for permanently connected equipment

Protection provided by	Minimum protective earthing conductor size mm ²
Non-metallic flexible conduit	4 ^a
Metallic flexible conduit	2,5 ^a
Non-flexible metal conduit	1,5 ^a
^a The protective earthing conductor is installed by a skilled person .	

5.6.7.3 Requirements for terminations

The terminations shall have reliable securement and shall comply with Table 36.

5.6.7.4 Compliance

Compliance is checked by inspection and measurement.

5.6.8 Reliable earthing

5.6.8.1 General

This subclause specifies situations where the equipment connection to earth is considered reliable (for example, when a SPD is provided in accordance with 5.5.2.8).

5.6.8.2 Reliable earthing for protection

For **mains** connected equipment connected to **external circuits** indicated in Table 16, ID numbers 11, 12, 13, 14, 15, 16 and 17, earthing is considered reliable for the following:

- **permanently connected equipment**; or
- **pluggable equipment type B**; or
- **stationary pluggable equipment type A**, that is intended to be used in a location having equipotential bonding (such as a telecommunication centre, a dedicated computer room or a **restricted access area**) and has installation instructions that require verification of the **protective earthing connection** of the socket-outlet by a **skilled person**; or

- **stationary pluggable equipment type A** that has provision for a permanently connected **protective earthing conductor**, including instructions for the installation of that conductor to building earth by a **skilled person**.

NOTE See also Note to 5.4.13.1.

5.6.8.3 Reliable earthing when the basic safeguard between ES1 and ES2 is provided by earthing ES1

For equipment connected to an **external circuit**, such as a indicated in Table 16, ID numbers 11, 12, 13, 14, 15, 16 and 17, earthing is considered reliable for the following:

- **permanently connected equipment**; or
- **pluggable equipment type A** and **pluggable equipment type B**, that have provision for a permanently connected **protective earthing conductor**, including instructions for the installation of that conductor to building earth by a **skilled person**.

NOTE See also Note to 5.4.13.1.

5.7 Prospective touch voltage, touch current and protective conductor current

5.7.1 General

This subclause specifies the equipment test environment, the equipment configuration, the equipment earthing, the equipment supply system connections, and the measurement processes for measurement of **prospective touch voltage**, **touch current**, and **protective conductor current**.

5.7.2 Measuring devices and networks

For measurements of **touch current**, the instrument used for measuring U_2 and U_3 specified in Figures 4 and 5 respectively in IEC 60990:1999 shall indicate peak voltage. If the **touch current** waveform is sinusoidal, an r.m.s. indicating instrument may be used.

NOTE 1 The effect of the instrument impedance on the measured voltage should be negligible.

NOTE 2 Many commercial **touch current** instruments provide a direct reading of the r.m.s. value of weighted current, thereby not requiring a calculation from voltage to current. Some commercial **touch current** instruments also provide a direct reading of the peak value of weighted current.

5.7.3 Equipment set-up, supply connections and earth connections

The equipment set-up, equipment supply connections and equipment earthing shall be in accordance with Clause 4 and 5.3 and 5.4 of IEC 60990:1999.

Equipment provided with a connection to earth separate from the **protective conductor** shall be tested with that connection disconnected.

Systems of interconnected equipment with separate connections to the **mains** shall have each equipment tested separately.

Systems of interconnected equipment with one connection to the **mains** shall be tested as a single equipment.

NOTE Systems of interconnected equipment are specified in more detail in Annex A of IEC 60990:1999.

Equipment that is designed for multiple connections to the **mains**, where only one connection is required at a time, shall have each connection tested while the other connections are disconnected.

Equipment that is designed for multiple connections to the **mains**, where more than one connection is required, shall have each connection tested while the other connections are connected, with the **protective earthing conductors** connected together. If the **touch current** exceeds the limit in 5.2.2.2, the **touch current** shall be measured individually.

5.7.4 Unearthed conductive accessible parts

5.7.4.1 Unearthed conductive parts accessible to ordinary persons

All unearthed conductive parts **accessible** to **ordinary persons** shall be tested first for **prospective touch voltage** with respect to earth and with respect to other unearthed conductive parts **accessible** to **ordinary persons**.

If the **prospective touch voltage** exceeds the ES1 limits in 5.2.2.2, such parts shall be tested for **touch current** in accordance with 5.1.1 and 6.2.1 of IEC 60990:1999. The **touch current** shall not exceed the ES1 limits in 5.2.2.2.

If the **prospective touch voltage** or **touch current** do not exceed the ES1 limits in 5.2.2.2, then the part shall be additionally tested for **prospective touch voltage**

- following simulated or actual fault of the applicable **basic safeguard**, and
- following simulated or actual fault of the applicable **supplementary safeguard**.

Safeguard faults are introduced one at a time; the **basic safeguard** and the **supplementary safeguard** are not faulted at the same time.

If the **prospective touch voltage** does not exceed the ES2 limits in 5.2.2.2, the test is concluded.

If the **prospective touch voltage** exceeds the ES2 limits in 5.2.2.2, such parts shall be tested for **touch current** in accordance with 6.2.2 of IEC 60990:1999, except 6.2.2.7. The **touch current** shall not exceed the ES2 limits in 5.2.2.2.

NOTE 1 For parts connected to a common point, only one such part need be tested.

NOTE 2 If the unearthed **accessible** parts are isolated from the **mains** so that the fault conditions specified in 6.2.2 of IEC 60990:1999 do not alter the **prospective touch voltage** or **touch current**, then the fault condition tests need not be performed.

5.7.4.2 Unearthed conductive parts accessible only to instructed persons

All unearthed conductive parts **accessible** only to **instructed persons** shall be tested first for **prospective touch voltage** with respect to earth and with respect to other unearthed conductive parts **accessible** to **instructed persons**.

If the **prospective touch voltage** does not exceed the ES2 limits in 5.2.2.2, the test is concluded.

If the **prospective touch voltage** exceeds the ES2 limits in 5.2.2.2, such parts shall be tested for **touch current** in accordance with 5.1.2 and 6.2.2 of IEC 60990:1999, except 6.2.2.7. The **touch current** shall not exceed the ES2 limits in 5.2.2.2.

NOTE For parts connected to a common point, only one such part need be tested.

5.7.5 Earthed accessible conductive parts

At least one earthed **accessible** conductive part shall be tested for **touch current** following supply connection faults in accordance with 6.1 and 6.2.2 of IEC 60990:1999, except 6.2.2.7. Except as permitted in 5.7.6, the **touch current** shall not exceed the ES2 limits in 5.2.2.2.

Subclause 6.2.2.2 of IEC 60990:1999 does not apply to equipment with a switch or other **disconnect device** that disconnects all poles of the supply.

NOTE An appliance coupler is an example of a **disconnect device**.

5.7.6 Protective conductor current

The **protective conductor current** shall be measured in accordance with Clause 8 of IEC 60990:1999.

Except as specified below, the **protective conductor current** shall not exceed the ES2 limits in 5.2.2.2.

If the **protective conductor current** exceeds the ES2 limits in 5.2.2.2, the current shall not exceed 5 % of the measured input current, and the construction of the **protective conductor** circuit and its connections shall comprise a **reinforced safeguard** (see 5.6.7.2).

The input current is measured under the same conditions as the **touch current**.

Where the **protective conductor current** exceeds the ES2 limits of Table 4, an **instructional safeguard** shall be affixed to the equipment adjacent to the equipment supply connection in accordance with Clause F.5. The **instructional safeguard** shall indicate high **touch current**, and shall require connection of the **protective conductor** prior to connection of the supply voltage with the following or equivalent wording:

CAUTION High touch current. Connect to earth before connecting to supply.

5.7.7 Prospective touch voltage and touch current due to external circuits

For **external circuits** connected to a coaxial cable, the manufacturer shall provide instructions to connect the shield of the coaxial cable to building earth in accordance with 6.2 g) and 6.2 l) of IEC 60728-11:2005.

NOTE For Norway and Sweden, see NOTE 1 to Table 16.

5.7.8 Summation of touch currents from external circuits

This subclause determines when a permanently connected **protective earthing conductor** is required for **pluggable equipment type A** or **pluggable equipment type B**, should the **mains** connection be disconnected.

This subclause only applies to equipment with **external circuits** such as described in Table 16, ID numbers 11, 12, 13, 14, 15, 16, and 17.

NOTE These types of **external circuits** are typically telecommunication networks.

The summation of **touch currents** from equipment that provides multiple **external circuits**, shall not exceed the limits for ES2 (see Table 4).

In this subclause, the following abbreviations are used:

- I_1 : **touch current** received from other equipment via a network at an **external circuit** of the equipment;

- $S(I_1)$: summation of **touch current** received from other equipment at all such **external circuit** of the equipment;
- I_2 : **touch current** due to the **mains** of the equipment.

It shall be assumed that each **external circuit** receives 0,25 mA (I_1) from the other equipment, unless the actual current from the other equipment is known to be lower.

The following requirements, a) or b) as applicable, shall be met:

a) Equipment with earthed **external circuit**

For equipment in which each **external circuit** is connected to a terminal for the **protective earthing conductor** of the equipment, the following items 1), and 2) shall be considered:

- 1) If $S(I_1)$ (not including I_2) exceeds ES2 limits of Table 4:
 - the equipment shall have provision for a permanent connection to protective earth in addition to the **protective earthing conductor** in the power supply cord of **pluggable equipment type A** or **pluggable equipment type B**; and
 - the installation instructions shall specify the provision of a permanent connection to protective earth with a cross-sectional area of not less than 2,5 mm², if mechanically protected, or otherwise 4,0 mm²; and
 - provide a marking in accordance with 5.7.6 and Clause F.3.
- 2) Such equipment shall comply with 5.7.6. The value of I_2 shall be used to calculate the 5 % input current limit per phase specified in 5.7.6.

Compliance with item a) is checked by inspection and if necessary by test.

If the equipment has provision for a permanent protective earth connection in accordance with item 1) above, it is not necessary to make any measurements, except that I_2 shall comply with the relevant requirements of 5.7.

Touch current tests, if necessary, are made using the relevant measuring instrument described in IEC 60990:1999, Figure 4, or any other instrument giving the same results. A capacitively coupled a.c. source of the same line frequency and phase as the a.c. **mains** is applied to each **external circuit** so that 0,25 mA, or the actual current from other equipment if known to be lower, is available to flow into that **external circuit**. The current flowing in the earthing conductor is then measured.

b) Equipment whose **external circuit** have no reference to protective earth

If each **external circuit** does not have a common connection, the **touch current** for each **external circuit** shall not exceed ES2 limits of Table 4.

If all **external circuits** or any groups of such ports have a common connection, the total **touch current** from each common connection shall not exceed ES2 limits of Table 4.

Compliance with item b) is checked by inspection and if there are common connection points, by the following test.

*A capacitively coupled a.c. source of the same frequency and phase as the a.c. **mains** is applied to each **external circuit** so that 0,25 mA, or the actual current from the other equipment if known to be lower, is available to flow into that **external circuit**. Common connection points are tested in accordance with 5.7.3, whether or not the points are accessible.*

6 Electrically-caused fire

6.1 General

This subclause specifies **safeguards** to reduce the likelihood of injury or property damage arising from an electrically-caused fire originating from within the equipment.

6.2 Classification of power sources (PS) and potential ignition sources (PIS)

6.2.1 General

This subclause describes how to classify the different power sources and the **PIS** that may exist in the equipment.

Electrical sources of heating can be classified into available power levels PS1, PS2 and PS3 (see 6.2.2.4, 6.2.2.5 and 6.2.2.6) that may cause resistive heating of both components and connections. These power sources are based on available energy to a circuit.

Within a power source, a **PIS** may arise due to arcing of either broken connections or opening of contacts (**arcing PIS**) or from components dissipating more than 15 W (**resistive PIS**).

Depending on the power source classification of each circuit, one or more **safeguards** are required either to reduce the likelihood of ignition or to reduce the likelihood of spread of fire beyond the equipment.

6.2.2 Power source circuit classifications

6.2.2.1 General

An electric circuit is classified PS1, PS2, or PS3 based on the electrical power available to the circuit from the power source.

NOTE A power source may be an identifiable power supply and its associated load circuits, or a functional circuit that serves as a power source to another circuit.

The electrical power source classification shall be the maximum power measured under each of the following conditions:

- for load circuits: a power source under **normal operating conditions** as specified by the manufacturer into a worst-case load circuit fault (see 6.2.2.2);
- for power source circuits: a worst-case power source fault into the specified normal load circuit (see 6.2.2.3).

The power is measured at points X and Y in Figure 38 and Figure 39.

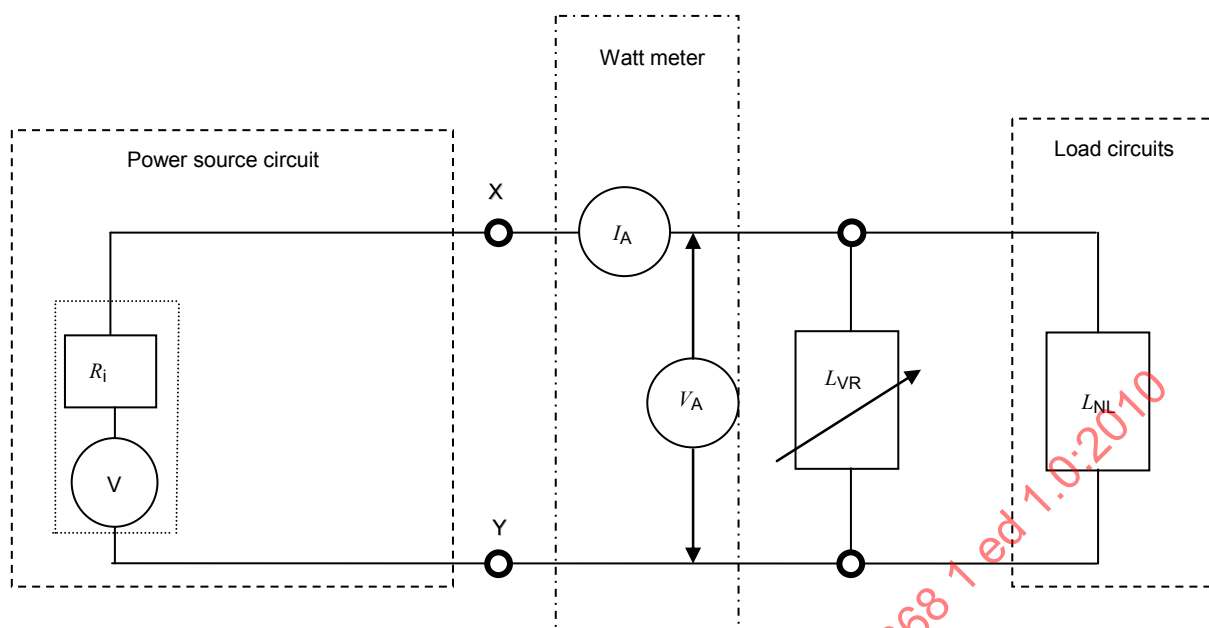
6.2.2.2 Power measurement for worst-case load fault

With reference to Figure 38:

- *the measurement may be performed without the load circuit L_{NL} connected, unless the maximum power is dependent on the connection of the load;*
- *at points X and Y, insert a wattmeter (or a voltmeter, V_A , and a current meter, I_A);*
- *connect a variable resistor, L_{VR} as shown;*
- *adjust the variable resistor, L_{VR} , for maximum power. Measure the maximum power and classify the power source according to 6.2.2.4, 6.2.2.5 or 6.2.2.6.*

If an overcurrent protective device or circuit operates during the test, the measurement shall be repeated at the point just below the trip current.

NOTE When evaluating accessories connected via cables to the equipment, the impedance of the cable may be taken into account in the determination of PS1 or PS2 on the accessory side.

**Key**

- V voltage source
- R_i internal resistance of the power source
- I_A current from the power source
- V_A voltage at the points where determination of PS power is made.
- L_{VR} variable resistor load
- L_{NL} normal load

Figure 38 – Power measurement for worst-case load fault**6.2.2.3 Power measurement for worst-case power source fault**

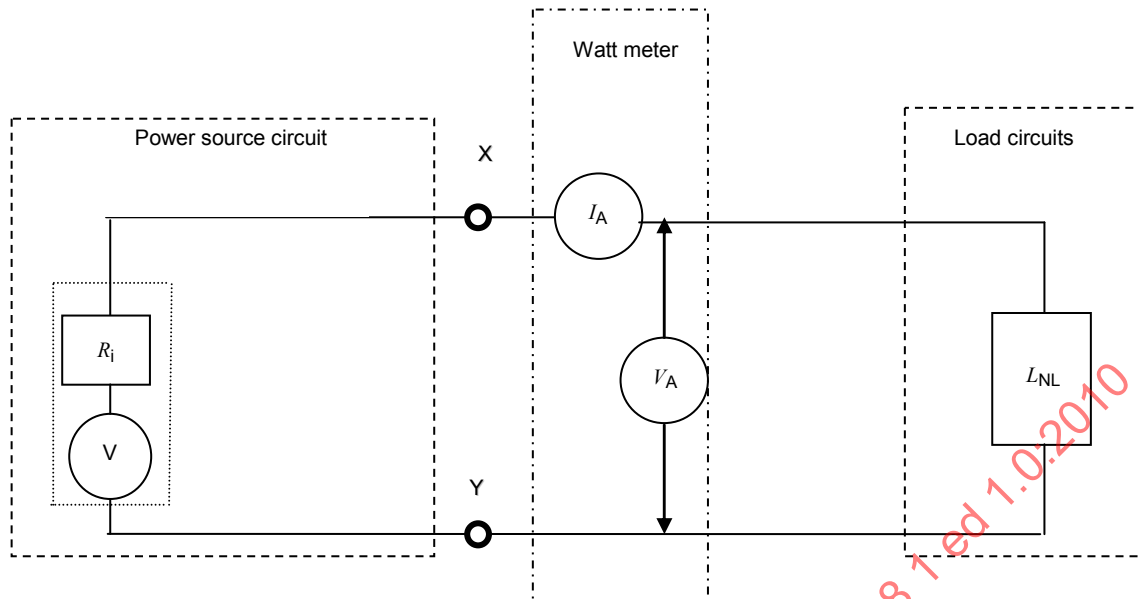
With reference to Figure 39

- At points X and Y, insert a wattmeter (or a voltmeter, V_A , and a current meter, I_A).
- Within the power source circuit, simulate any **single fault condition** that will result in maximum power to the circuit being classified. All relevant components in the power source circuits shall be short-circuited or disconnected one at a time at each measurement.
- Measure the maximum power as specified and classify circuits supplied by the power source according to 6.2.2.4, 6.2.2.5 or 6.2.2.6.

If an overcurrent protective device or circuit operates during the test, the measurement shall be repeated at the point just below the trip current.

NOTE 1 To avoid damage to the components of the normal load, a resistor (equal to the normal load) may be substituted for the normal load.

NOTE 2 Experimentation may be necessary to identify the single component fault that produces maximum power.



Key

- V voltage source
- R_i internal resistance of the power source
- I_A current from the power source
- V_A voltage at the points where determination of PS power is made.
- L_{NL} normal load

Figure 39 – Power measurement for worst-case power source fault

6.2.2.4 PS1

PS1 is a circuit where the power source, (see Figure 40) measured according to 6.2.2, does not exceed:

- 500 W measured during the first 3 s; and
- 15 W measured after 3 s.

For the purpose of this standard, the power available from **external circuits** described in Table 16, ID numbers 11, 12, 13 and 14, are considered to be PS1.

6.2.2.5 PS2

PS2 is a circuit where the power source, (see Figure 40) measured according to 6.2.2:

- exceeds PS1 limits; and
- does not exceed 100 W measured after 5 s.

6.2.2.6 PS3

PS3 is a circuit whose power source exceeds PS2 limits, or any circuit whose power source has not been classified (see Figure 40).

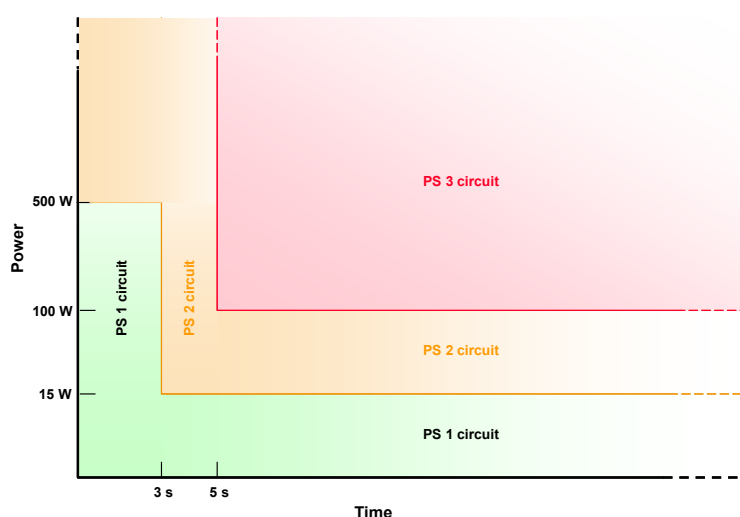


Figure 40 – Illustration of power source classification

6.2.3 Classification of potential ignition sources

6.2.3.1 Arcing PIS

Determination of an **arcing PIS** is performed under **normal operating conditions** unless otherwise specified.

An **arcing PIS** is a location with the following characteristics:

- an open circuit voltage (measured after 3 s) across an open conductor or opening electrical contact exceeding 50 V (peak) a.c. or d.c.; and
- the product of the peak of the open circuit voltage (V_p) and the measured r.m.s. current (I_{rms}) exceeds 15 (that is, $V_p \times I_{rms} > 15$) for any of the following:
 - a contact, such as a switch or connector;
 - a termination, such as one made by a crimp, spring or solder termination;
 - opening of a conductor, such as a printed wiring board trace, as a consequence of a **single fault condition**. This condition does not apply if electronic protection circuits or additional constructional measures are used to reduce the likelihood that such a fault becomes an **arcing PIS**.

An **arcing PIS** is considered not to exist in a PS1 because of the limits of the power source.

NOTE 1 An open conductor in an electric circuit includes those interruptions that may occur in conductive patterns on printed boards.

Reliable or redundant connections are not considered to be an **arcing PIS**.

Redundant connections are any kind of two or more connections in parallel, where in the event of the failure of one connection, the remaining connections are still capable of handling the full power.

Reliable connections are connections that are considered not to open.

NOTE 2 Examples of connections that could be considered reliable are:

- holes of solder pads on a printed board that are through-metallized;
- tubular rivets/eyelets that are additionally soldered;
- machine-made or tool-made crimp or wire-wrap connections.

NOTE 3 If other means are used to avoid the occurrence of an **arcing PIS** and such means have proven to be satisfactory, they could be used as well.

NOTE 4 Connection failure due to thermal fatigue phenomena could be prevented by selection of components with a coefficient of thermal expansion similar to that of the printed board material. Attention should be paid to the location of the component with respect to the fibre direction of the board material.

6.2.3.2 Resistive PIS

Determination of a **resistive PIS** is performed under **normal operating conditions** unless otherwise specified.

A **resistive PIS** is any part in a PS2 or PS3 circuit that:

- has a power capability to dissipate more than 15 W measured after 30 s of normal operation; or

NOTE During the first 30 s there is no limit.

- under **single fault conditions**:
 - has a power exceeding 100 W measured during the 30 s immediately after the introduction of the fault if electronic circuits, regulators or PTC devices are used; or
 - has an available power exceeding 15 W measured 30 s after the introduction of the fault

and in which the part may ignite due to excessive power dissipation or ignite adjacent materials or components.

A **resistive PIS** is considered not to exist in a PS1 because of the limits of the power source.

6.3 Safeguards against fire under normal operating conditions and abnormal operating conditions

6.3.1 Requirements

Under **normal operating conditions** and **abnormal operating conditions**, the following **basic safeguards** are required:

- ignition shall not occur; and
- no part of the equipment shall attain a temperature value greater than 90 % of the auto-ignition temperature limit, in Celsius, of the part as defined by ISO 871. When the auto-ignition temperature of the material is not known, the temperature shall be limited to 300 °C; and

NOTE 1 This standard currently does not contain requirements for flammable liquids and dust.

- **combustible materials** for components and other parts outside **fire enclosures** (including **electrical enclosures**, **mechanical enclosures** and decorative parts), shall have a **material flammability class** of at least:
 - **HB75** if the thinnest significant thickness of this material is <3 mm, or
 - **HB40** if the thinnest significant thickness of this material is ≥3 mm, or
 - **HBF**.

NOTE 2 Where an **enclosure** also serves as a **fire enclosure**, the requirements for **fire enclosures** apply.

These requirements do not apply to:

- parts with a size of less than 1 750 mm³;
- supplies, **consumable materials**, media and recording materials;
- parts that are required to have particular properties in order to perform intended functions, such as synthetic rubber rollers and ink tubes;

- gears, cams, belts, bearings and other parts that would contribute negligible fuel to a fire, including, labels, mounting feet, key caps, knobs and the like.

6.3.2 Compliance

*Compliance is checked by inspection of the data sheets and by test under **normal operating conditions** according to Clause B.2 and under **abnormal operating conditions** according to Clause B.3. The temperatures of materials are measured continuously until thermal equilibrium has been attained.*

NOTE See B.1.7 for details on thermal equilibrium.

*Temperature limiting **basic safeguards** that comply with the applicable requirements of this standard or the applicable safety device standard shall remain in the circuit being evaluated.*

6.4 Safeguards against fire under single fault conditions

6.4.1 General

This subclause defines the possible **safeguard** methods that can be used to reduce the likelihood of ignition or spread of fire under **single fault conditions**.

There are two methods of providing protection. Either method may be applied to different circuits of the same equipment under the following conditions:

- **Reduce the likelihood of ignition:** Equipment is so designed that under **single fault conditions** no part shall have sustained flaming. This method can be used for any circuit in which the available steady state power to the circuit does not exceed 4 000 W. The appropriate requirements and tests are detailed in 6.4.2 and 6.4.3.
 - **Pluggable equipment type A** is considered not to exceed the steady state value of 4 000 W.
 - **Pluggable equipment type B** and **permanently connected equipment** are considered not to exceed the steady state value of 4 000 W if the product of the nominal **mains** voltage and the **protective current rating** of the installation overcurrent protective device ($V_{\text{mains}} \times I_{\text{max}}$) does not exceed 4 000 W.
- **Control fire spread:** Selection and application of **supplementary safeguards** for components, wiring, materials and constructional measures that reduce the spread of fire and, where necessary, by the use of a second **supplementary safeguard** such as a **fire enclosure**. This method can be used for any type of equipment. The appropriate requirements are detailed in 6.4.4, 6.4.5 and 6.4.6.

6.4.2 Reduction of the likelihood of ignition under single fault conditions in PS1 circuits

No **supplementary safeguards** are needed for protection against PS1. A PS1 is not considered to contain enough energy to result in materials reaching ignition temperatures.

6.4.3 Reduction of the likelihood of ignition under single fault conditions in PS2 circuits and PS3 circuits

6.4.3.1 General

This subclause defines the **supplementary safeguards** needed to reduce the likelihood of ignition under **single fault conditions** in PS2 circuits and PS3 circuits where the available power does not exceed 4 000 W (see 6.4.1).

6.4.3.2 Requirements

The likelihood of ignition can be reduced by employing the following **supplementary safeguards** as applicable:

- flaming shall not occur beyond 5 s;
- providing separation from an **arcing PIS** or a **resistive PIS** as specified in 6.4.7;
- using protective devices that comply with Clause G.2 to Clause G.5 or the relevant IEC component standards for such devices;
- using components that comply with Clauses G.7, G.8 or the relevant IEC component standard;
- for components associated with the **mains**, using components that comply with the relevant IEC component standards and requirements of other parts of this standard.

NOTE Examples of components associated with the **mains** are the supply cord, appliance couplers, EMC filtering components, switches, etc.

The opening of a conductor on a printed board, except as specified in this subclause, shall not be used as a **safeguard**.

Conductors of a printed board of **V-1 class material** may open under **overload condition** provided that the open circuit is not an **arcing PIS**. Conductors on a printed board material that has no **material flammability class** or is classed lower than **V-1 class material** shall not open.

Under a **single fault condition**, the peeling of conductors on a printed board shall not result in the failure of any **supplementary safeguard** or **reinforced safeguard**.

6.4.3.3 Test method

The conditions of Clause B.4, that 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 two more times with replacement components in order to check that sustained flaming does not occur.

*The equipment is operated under **single fault conditions** and the temperatures of materials are measured continuously until thermal equilibrium has been attained.*

*If a conductor opens during a simulated **single fault condition**, the conductor shall be bridged and the simulated **single fault condition** shall be continued. In all other cases, where an applied **single fault condition** results in interruption of the current before steady state has been reached, the temperatures are measured immediately after the interruption. The circuit shall still comply with this subclause.*

NOTE 1 See B.1.7 for details on thermal equilibrium.

NOTE 2 The **single fault condition** tests may identify a situation applicable to another clause of this standard.

NOTE 3 Consideration of auto ignition temperatures of surrounding materials of the heat source should be taken into account. Temperature rise can be observed after interruption of the current due to thermal inertia.

If the temperature is limited by fuses complying with the IEC 60127 series, the following test is carried out, if necessary, in relation to the characteristic of the fuse.

*The fuse-link is short-circuited and the current that would have passed through the fuse-link under the relevant **single fault condition** is measured.*

- *If the fuse-link current remains less than 2,1 times the current rating of the fuse-link, the temperatures are measured after a steady state has been attained.*
- *If the current either immediately reaches 2,1 times the current rating of the fuse-link or more, or reaches this value after a period of time equal to the maximum pre-arcing time for the relevant current through the fuse-link under consideration, 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 under consideration 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 board conductors are tested by applying the relevant **single fault conditions** of B.4.4.*

6.4.3.4 Compliance

Compliance is checked by inspection, tests and measurements.

6.4.4 Control of fire spread in PS1 circuits

No **supplementary safeguards** are needed for protection against PS1. A PS1 is not considered to contain enough energy to result in materials reaching ignition temperatures.

6.4.5 Control of fire spread in PS2 circuits

6.4.5.1 General

This subclause describes the **supplementary safeguards** needed to reduce the likelihood of fire spread in PS2 circuits to nearby **combustible materials**.

6.4.5.2 Requirements

A **supplementary safeguard** is required to control the spread of fire from any possible **PIS** to other parts of the equipment as given below.

For conductors and devices that constitute a **PIS** the following apply:

- printed boards shall be made of **V-1 class material**;
- wire insulation and tubing shall comply with IEC 60332-1-2, IEC 60332-2-2 or IEC/TS 60695-11-21;
- devices subject to arcing or changing contact resistance (for example, pluggable connectors) shall comply with one of the following:
 - have materials made of **V-1 class material**; or
 - comply with the flammability requirements of the relevant IEC component standard; or
 - be mounted on material made of **V-1 class material** and be of a volume not exceeding 1 750 mm³.

Battery cells and battery packs shall comply with all of the requirements of Annex M.

All other components in a PS2 circuit shall:

- be mounted on **V-1 class material**; or
- be made of **V-2 class material**, **VTM-2 class material** or **HF-2 class foamed material**; or
- have a mass of **combustible material** of less than 4 g, provided that when the part is ignited, the fire does not spread to another part; or
- be separated from **PIS** by the requirements of 6.4.7; or
- comply with the requirements of the relevant IEC component standard; or
- motors complying with Clause G.8; or
- transformers complying with Clause G.7; or

- be in a sealed **enclosure** of 0,06 m³ or less, consisting totally of non-**combustible material** and having no ventilation openings.

The following materials shall be separated from a **PIS** according to the requirements of 6.4.7, or the materials shall not ignite during **single fault conditions** as specified in 6.4.3.3:

- supplies, **consumable materials**, media and recording materials;
- parts that are required to have particular properties in order to perform intended functions, such as synthetic rubber rollers and ink tubes.

6.4.5.3 Compliance

Compliance is checked by testing or by inspection of the equipment and material data sheets.

6.4.6 Control of fire spread in a PS3 circuit

6.4.6.1 General

This subclause defines the **supplementary safeguards** needed to reduce the likelihood of fire spread in PS3 circuits to nearby **combustible materials**.

6.4.6.2 Requirements

Fire spread in PS3 circuits shall be controlled as specified for PS2 circuits in 6.4.5 and by providing a **fire enclosure** as specified in 6.4.8.

Within the **fire enclosure**, **combustible materials** that are not part of a PS2 or PS3 circuit shall comply with the flammability test of Clause S.1 or be made of **V-2 class material**, **VTM-2 class material** or **HF-2 class foamed material**. These requirements do not apply to:

- parts with a size of less than 1 750 mm³;
- supplies, **consumable materials**, media and recording materials;
- parts that are required to have particular properties in order to perform intended functions, such as synthetic rubber rollers and ink tubes;
- gears, cams, belts, bearings and other parts that would contribute negligible fuel to a fire, including, labels, mounting feet, key caps, knobs and the like;
- tubing for air or fluid systems, containers for powders or liquids and foamed plastic parts, provided that they are of **HB75 class material** if the thinnest significant thickness of the material is < 3 mm, or **HB40 class material** if the thinnest significant thickness of the material is ≥ 3 mm, or **HBF class foamed material**.

A **fire enclosure** is not necessary for the following components and materials:

- wire insulation and tubing complying with IEC 60332-1-2, IEC 60332-2-2 or IEC/TS 60695-11-21;
- components, including connectors, complying with the requirements of 6.4.8.1.1, and that fill an opening in a **fire enclosure**;
- plugs and connectors forming part of a power supply cord or interconnecting cable complying with 6.5, Clause G.9 and Clause G.20;
- motors complying with Clause G.8;
- transformers complying with Clause G.7.

6.4.6.3 Compliance

Compliance is checked by inspection of the material data sheets or by test or both.

6.4.7 Separation of combustible materials from a PIS

6.4.7.1 General

This subclause specifies the minimum separation requirements between a **PIS** and **combustible materials** in order to reduce the likelihood of sustained flaming or spread of fire. This can be achieved by either separation by distance (6.4.7.2) or separation by a barrier (6.4.7.3).

Separation requirements from a PIS to a **fire enclosure** are specified in 6.4.8.3.

6.4.7.2 Separation by distance

Combustible material, except the material on which the **PIS** is mounted, shall be separated from an **arcing PIS** or a **resistive PIS** according to Figure 41, Figure 42, Figure 43 and Figure 44.

Base material of printed boards, on which an **arcing PIS** is located, shall be made of **V-1 class material**, **VTM-1 class material** or **HF-1 class foamed material**.

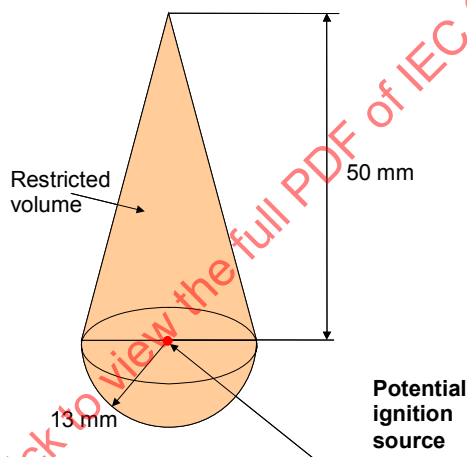
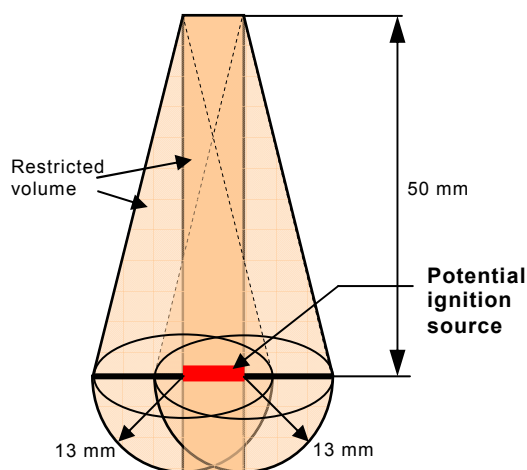


Figure 41 – Minimum separation requirements from an arcing PIS



NOTE This figure can be used for:

- an **arcing PIS** that consists of tracks or areas on printed boards;
- the **resistive PIS** areas of components. Measurements are made from the nearest power dissipating element of the component involved. If in practice it is not readily possible to define the power dissipating part, then the outer **enclosure** of the component is used.

Figure 42 – Extended separation requirements from a PIS

When the airflow across a circuit is moving due to air moving devices, the vertical orientation of the restricted volumes described in Figure 41, Figure 42 and Figure 44 shall be rotated to reflect the effect of the airflow on the flame path. When determining the restricted volumes for each figure, each cone shall be rotated (tilted) around the **PIS** location from 0° (vertical orientation, shown in Figure 43) to 45° in the direction of the forced airflow.

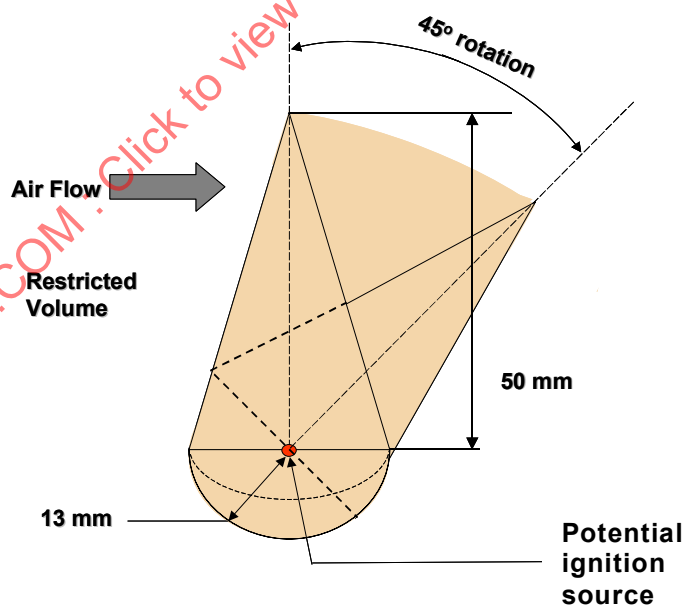


Figure 43 – Rotated separation requirements due to forced air flow

When the distance between a **PIS** and **combustible materials** is less than specified in Figure 41, Figure 42 and Figure 43 as applicable, the **combustible materials** shall:

- have a mass of less than 4 g provided that when the part is ignited, the fire does not spread to another part; or

- comply with the following flammability requirements:
 - requirements of the relevant IEC component standard; or
 - be made of **V-1 class material**, **VTM-1 class material** or **HF-1 class foamed material**, or comply with IEC 60695-11-5. Severities are identified in Clause S.2.

6.4.7.3 Separation by a fire barrier

Combustible material shall be separated from an **arcing PIS** or a **resistive PIS** by a fire barrier as defined in 6.4.8.1.1 (see Figure 44).

Printed boards are not considered to be a fire barrier against an **arcing PIS** located on the same board. Printed boards complying with 6.4.8 may be considered to be a fire barrier against an **arcing PIS** located on a different board.

Printed boards can be considered to be a fire barrier against a **resistive PIS** provided that the following conditions are met:

- the printed board shall:
 - comply with the flammability test Clause S.1 as used in the application; or
 - be made of **V-1 class material**, **VTM-1 class material** or **HF-1 class foamed material**;
- within the restricted volume, no materials rated less than **V-1 class material** shall be mounted on the same side of a printed board as the **resistive PIS**;
- within the restricted volume, the printed board shall have no PS2 conductors or PS3 conductors (except for the conductors that supply the circuit under consideration). This applies to any side of the printed board as well as the inner layer of the printed board.

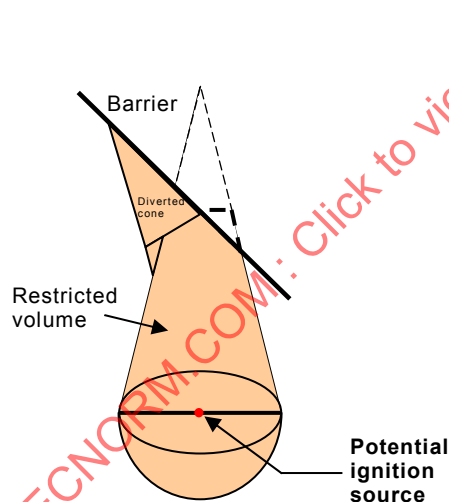


Figure 44a – Illustration showing an angled barrier

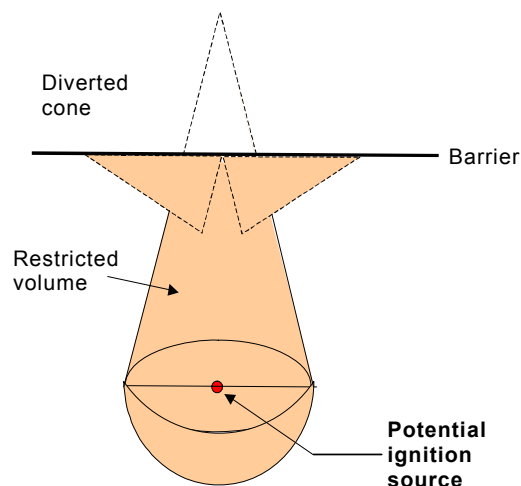


Figure 44b – Illustration showing a horizontal barrier

NOTE 1 The volume of the flame is nearly constant; consequently the shape of the flame is dependent upon the position and the shape of the barrier. It should be taken into account that different shapes of barriers might give different flame shapes. The restricted area and separation requirements need to be adapted accordingly by the user of the standard.

NOTE 2 Dimensions are identical to Figure 41 and Figure 42 but, except as required in 6.4.8.3, the distance of the barrier from the **PIS** is not significant.

Figure 44 – Deflected separation requirements from a PIS when a fire barrier is used

6.4.7.4 Compliance

Compliance is checked by inspection or measurement or both.

6.4.8 Fire enclosures and fire barriers

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**.

6.4.8.1 Fire enclosure and fire barrier material properties

6.4.8.1.1 Requirements for a fire barrier

A fire barrier shall comply with the requirements of Clause S.1.

These requirements do not apply provided that the material is:

- made of non-**combustible material** (for example, metal, glass, ceramic, etc.); or
- made of **V-1 class material** or **VTM-1 class material**.

6.4.8.1.2 Requirements for a fire enclosure

For circuits where the available power does not exceed 4 000 W (see 6.4.1), a **fire enclosure** shall comply with the requirements of Clause S.1.

For circuits where the available power exceeds 4 000 W, a **fire enclosure** shall comply with the requirements of Clause S.5.

These requirements do not apply provided that the material is:

- made of non-**combustible material** (for example, metal, glass, ceramic, etc.); or
- made of
 - **V-1 class material** if the available power does not exceed 4 000 W; or
 - **5VA class material** or **5VB class material** if the available power exceeds 4 000 W.

Material for components that fill an opening in a **fire enclosure** or that is intended to be mounted in such opening shall:

- comply with the flammability requirements of the relevant IEC component standard; or
- be made of **V-1 class material**; or
- comply with Clause S.1.

6.4.8.1.3 Compliance

Compliance is checked by inspection of applicable data sheets or test.

*The **material flammability class** is checked for the thinnest significant thickness used.*

6.4.8.2 Constructional requirements for a fire enclosure and a fire barrier

6.4.8.2.1 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 to the **PIS**.

The openings to which these properties apply are relative to the site or location of the **PIS** and of **combustible materials**. The locations of openings relative to the flame property are shown in Figure 45 and Figure 46.

Regardless of the equipment orientation, the flame orientation property of the **PIS** is always vertical, unless the equipment contains a forced airflow. Where the equipment has two or more **normal operating condition** orientations, opening properties apply to each possible orientation and airflow direction.

NOTE When the forced airflow across a **PIS** is moving due to air moving devices, the vertical orientation of the volume described in Figure 42 is rotated (tilted) around the **PIS** location from 0° (vertical orientation shown in the figure) to 45° in the direction of the forced airflow (see also Figure 43).

6.4.8.2.2 Fire barrier dimensions

A fire barrier shall have dimensions sufficient to prevent ignition of the edges of the barrier. The edges of the fire barriers shall extend to beyond the fire cone (see Figure 44).

6.4.8.2.3 Top openings and top opening properties

Top opening properties of a **fire enclosure** and a fire barrier shall apply to openings above a **PIS** as shown in Figure 45.

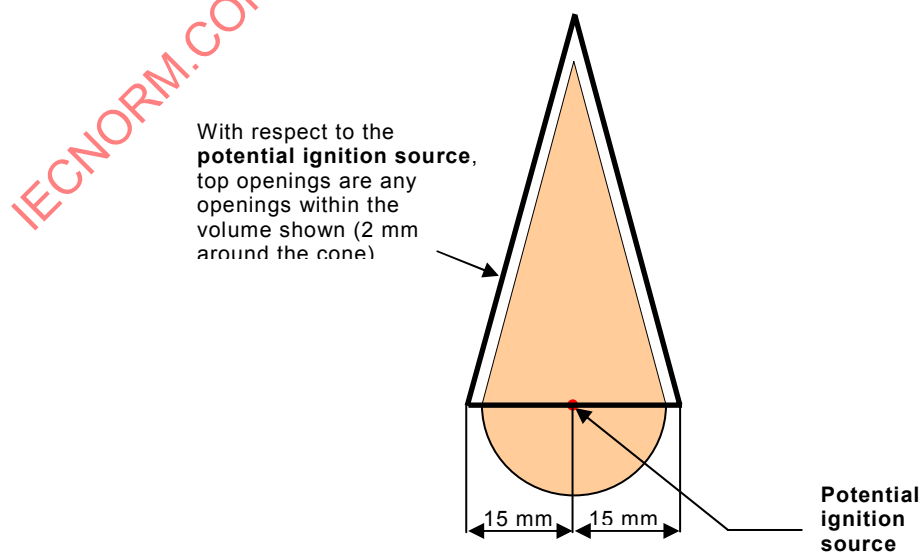
NOTE Any openings within the zone as shown in Figure 45 are regarded to be top openings, including side openings.

Top openings that fall within the volume defined in Figure 45 shall comply with the following test.

*The test is conducted using the needle-flame burner as specified in Clause S.2 placed vertically in a draft-free location. The distance between the inner side of the top openings and the centre of the burner tube is 7 mm ± 1 mm. The sample is placed in its normal operating position. 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.*

In case of openings having different dimensions, the test shall be conducted on one opening of each group of the top openings with the same dimensions.



NOTE Dimensions of the cone are identical to Figure 41 and Figure 42.

Figure 45 – Top openings

No test is required provided that the openings do not exceed:

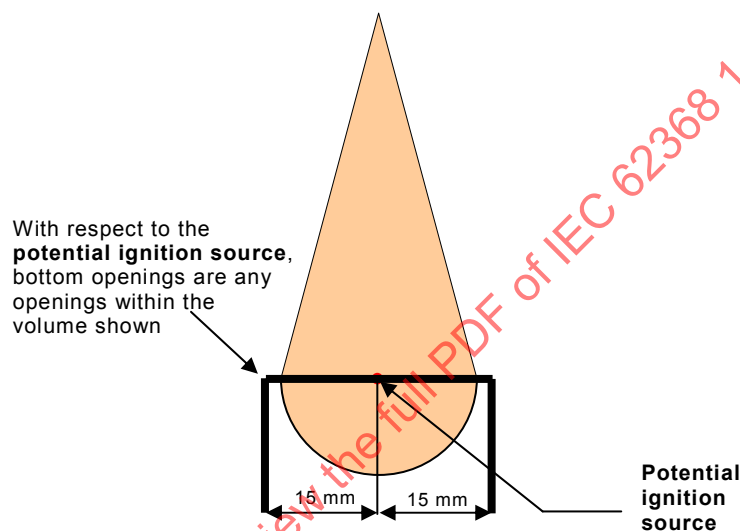
- 5 mm in any dimension, or
- 1 mm in width regardless of length.

6.4.8.2.4 Bottom openings and bottom opening properties

Bottom opening properties of a **fire enclosure** and a fire barrier shall apply to openings that are located in the volume as shown in Figure 46.

NOTE Any openings within the zone as shown in Figure 46 are regarded to be bottom openings, including side openings.

Bottom openings are those openings below a **PIS** and within 30 mm diameter cylinder extending indefinitely below the **PIS**.



NOTE Dimensions of the cone are identical to Figure 41 and Figure 42.

Figure 46 – Bottom openings

Bottom openings shall comply with Clause S.3.

No test is necessary provided that one of the following conditions is met:

- a) the bottom openings do not exceed:
 - 3 mm in any dimension, or
 - 1 mm in width regardless of length;
- b) under components and parts meeting the requirements for **V-1 class material**, or **HF-1 class foamed material** or under components that pass the needle-flame test of IEC 60695-11-5 using a 30 s flame application, bottom openings shall not exceed:
 - 6 mm in any dimension, or
 - 2 mm in width regardless of length;
- c) the bottom openings do not exceed a 2 mm by 2 mm mesh of at least 0,45 mm diameter metal wire.

Where the risk of flaming liquids escaping the equipment exists, the bottom of the **fire enclosure** shall comply with Table 39.

Table 39 – 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 floor standing on a non-combustible surface need not be provided with a **fire enclosure** bottom. Such equipment shall be marked in accordance with Clause F.5 in a clearly visible location with the following or equivalent wording:

RISK OF FIRE Install only on concrete or other non-combustible floor

6.4.8.2.5 Integrity of the fire enclosure

If part of a **fire enclosure** consists of a door or cover that 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 **safety interlock** requirements in Annex K;
- 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 operating conditions**;
- c) a door or cover intended only for occasional use by the **ordinary person**, such as for the installation of accessories, may be removable provided that instructions for correct removal and reinstallation of the door or cover are available.

6.4.8.2.6 Compliance

Compliance is checked by inspection of applicable data sheets and, where necessary, by test.

6.4.8.3 Separation of a PIS from a fire enclosure and a fire barrier

A **fire enclosure** or fire barrier made of **combustible material** shall:

- a) have a minimum distance of 13 mm to an **arcing PIS**; and
- b) have a minimum distance of 5 mm to a **resistive PIS**.

Smaller distances are allowed provided that the part of the **fire enclosure** or fire barrier within the required separation distance complies with one of the following:

- the **fire enclosure** or fire barrier meets the needle-flame test according to IEC 60695-11-5. Severities are identified in Clause S.2. After the test, the **fire enclosure** or fire barrier material shall not have formed any holes that are bigger than allowed in 6.4.8.2.3 or 6.4.8.2.4 as appropriate; or
- the **fire enclosure** or fire barrier is made of **V-0 class material**.

6.5 Internal and external wiring

6.5.1 General

This subclause specifies requirements to reduce the likelihood of fire from internal and external wiring in PS2 circuits and PS3 circuits.

6.5.2 Requirements

In PS2 circuits or PS3 circuits, the insulation on internal or external wiring shall pass the test methods described below.

For conductors with cross-sectional area greater than 0,5 mm², the test methods in IEC 60332-1-2 and IEC 60332-1-3 shall be used.

For conductors of 0,5 mm² or less in area, the test methods in IEC 60332-2-1 and IEC 60332-2-2 shall be used.

NOTE For both internal and external wiring, the test method described in IEC/TS 60695-11-21 may be used instead of the test methods in IEC 60332-1-2, IEC 60332-1-3, IEC 60332-2-1 or IEC 60332-2-2.

6.5.3 Compliance

The insulated conductor or cable shall be acceptable if:

- *the distance between the lower edge of the top support and the onset of charring is greater than 50 mm; and*
- *the filter paper has not ignited during the test duration; and*
- *charring extends downwards to a point less than 540 mm from the lower edge of the top support.*

If the insulated conductor or cable fails the first test, two more tests shall be carried out. If the second and third tests are acceptable, the insulated conductor or cable shall be deemed acceptable.

NOTE These requirements are currently contained within the referenced standards as informative annexes.

6.5.4 Requirements for interconnection to building wiring.

Equipment intended to provide power over the wiring system to remote equipment shall limit the output current to a value that does not cause damage to the wiring system, due to overheating, under any external load condition. The maximum continuous current from the equipment shall not exceed a current limit that is suitable for the minimum wire gauge specified in the equipment installation instructions.

NOTE 1 This wiring is not usually controlled by the equipment installation instructions, since the wiring is often installed independent of the equipment installation.

PS2 circuits or PS3 circuits that provide power and that are intended to be compatible with LPS to **external circuits** (see Annex Q) shall have their output power limited to values that

reduce the likelihood of ignition within building wiring or external devices located in a different room.

Compliance is checked with Clauses Q.1 and Q.2.

NOTE 2 Circuits to provide power to devices or external components that are intended for use in the same room as the equipment under test are not subject to this requirement. See 6.7 for connection to secondary equipment.

External paired conductor cable circuits, such as those described in Table 16, ID numbers 11, 12, 13 and 14 having a minimum wire diameter of 0,4 mm, shall have the current limited to 1,3 A.

NOTE 3 Time/current characteristics of type gD and type gN fuses specified in IEC 60269-2 comply with the above limit. Type gD or type gN fuses rated 1 A, would meet the 1,3 A current limit.

Compliance is checked with Clause Q.3.

6.5.5 Compliance

Compliance is checked by test, inspection and where necessary by the requirements of Annex Q.

6.6 Likelihood of fire due to entry of foreign objects

This subclause specifies **safeguards** that reduce the likelihood of fire due to the entry of conductive foreign objects into the equipment.

Conductive foreign objects shall not cause bridging of PS2 circuits or PS3 circuits. Top and side openings above those circuits, located at a height of less than 1,8 m above the floor, shall comply with Annex P.

If the entry of a foreign object can result in bridging of PS2 circuits or PS3 circuits, one of the following shall be applied:

- internal barrier(s) shall be provided to deflect the objects away from the relevant circuits; or
- openings in the equipment above the relevant circuits shall be located more than 1,8 m above the floor; or
- the construction above the relevant circuits shall comply with Annex P.

Compliance is checked by inspection or according to Annex P.

6.7 Safeguards against fire due to the connection of secondary equipment

This subclause specifies requirements to reduce the likelihood of fire due to connection of secondary equipment.

Where it is unknown that the connected equipment or accessories (for example, a scanner, mouse, keyboard, DVD drive, CD ROM drive or joystick) are likely to comply with this standard, the delivered power shall be limited to PS2.

Compliance is checked by inspection or measurement.

7 Chemically-caused injury

7.1 General

This clause specifies **safeguards** to reduce the likelihood of injury due to exposure to chemicals. The requirements are not intended to be the only means to reduce the likelihood of chemically-caused injury.

7.2 Reduction of exposure to hazardous chemicals

The exposure to **hazardous chemicals** shall be reduced. Reduction of exposure to **hazardous chemicals** shall be controlled by using containment of the **hazardous chemicals**. Containers shall be sufficiently robust and shall not be damaged or degraded by the contents over the lifetime of the product.

Compliance is checked by

- the examination of the effects the chemical has on the material of the container, and
- any relevant tests of Annex T following which there should be no leakage from the container.

7.3 Ozone exposure

For equipment that produces ozone, the installation and operating instructions shall indicate that precaution must be taken to ensure that the concentration of ozone is limited to a safe value.

NOTE 1 Currently, the recommended long term exposure limit for ozone is $0,1 \times 10^{-6}$ ($0,2 \text{ mg/m}^3$) calculated as an 8 h time-weighted average concentration. Time-weighted average is the average level of exposure over a given time period.

NOTE 2 Ozone is heavier than air.

Compliance is checked by inspection of instructions or accompanying documents.

7.4 Use of PPE

Where **safeguards**, such as containment of a chemical, are not practical, **PPE** shall be specified in the accompanying documents.

Suitable **PPE** should be chosen taking into account the recommendations given by the manufacturer.

Compliance is checked by inspection of instructions or accompanying documents.

7.5 Use of instructional safeguards and instructions

Where a chemical is capable of causing an injury, **instructional safeguards** as specified in ISO 7010 and instructions shall be applied to the equipment in accordance with Clause F.5.

Compliance is checked by inspection of instructions or accompanying documents.

7.6 Batteries

Batteries shall comply with Annex M.

8 Mechanically-caused injury

8.1 General

This clause specifies **safeguards** to reduce the likelihood of injuries such as cuts, bruises, broken bones, etc., due to transfer of energy from a mechanical energy source to a body part.

Mechanical injury is due to relative motion between the body and **accessible** parts of the equipment, or due to parts ejected from the equipment colliding with a body part.

NOTE 1 In some cases, the person may be the source of the kinetic energy.

NOTE 2 Where not specifically mentioned in this clause, the words “products” and “equipment” also cover carts, stands and carriers used with these products or equipment.

8.2 Mechanical energy source classifications

8.2.1 General classification

Various categories of mechanical energy sources are given in Table 40.

Table 40 – Classification for various categories of mechanical energy sources

Line	Category	MS1	MS2	MS3
1	Sharp edges and corners	Does not cause pain or injury ^b	Does not cause injury ^b but may be painful	May cause injury ^c
2	Moving parts	Does not cause pain or injury ^b	Does not cause injury ^b but may be painful	May cause injury ^c
3	Moving fan blades ^a See Figure 47.	$\frac{RPM}{15\ 000} + \frac{K\ Factor}{2\ 400} \leq 1$	$\frac{RPM}{22\ 000} + \frac{K\ Factor}{3\ 600} \leq 1$ >MS1; and	>MS2
4	Loosening, exploding or imploding parts.	NA	NA	Examples ^d
5	Equipment mass	≤7 kg	7 kg < mass ≤ 25 kg	>25 kg
6	Wall/ceiling mount	Equipment mass ≤7 kg mounted <2 m ^e	Equipment mass >7 kg mounted <2 m ^e	All equipment mounted ≥2 m

^a The K factor is determined from the formula $K = 6 \times 10^{-7} (m\ r^2\ N^2)$ where m is the mass (kg) of the moving part of the fan assembly (blade, shaft and rotor), r is the radius (mm) of the fan blade from centre line of the motor (shaft) to the tip of the outer area likely to be contacted, N is the rotational speed (rpm) of the fan blade.

In the end product, the fan maximum operational voltage can be different than the rated voltage of the fan and this difference should be taken into account.

^b The phrase “Does not cause injury” means that a doctor or hospital emergency attention is not needed.

^c The phrase “May cause injury” means that a doctor or hospital emergency attention may be needed.

^d The following equipment constructions are examples considered MS3:

- high speed removable plastic solid media such as used in CD drives or DVD drives, capable of rotational speed greater than 8 000 rpm; and
- CRTs having a maximum face dimension exceeding 160 mm; and
- lamps in which the pressure exceeds 0,2 MPa when cold or 0,4 MPa when operating are considered high pressure lamps, and shall be classed MS3.

^e Manufacturer's installation instructions shall state that the equipment is only suitable for mounting at heights < 2 m.

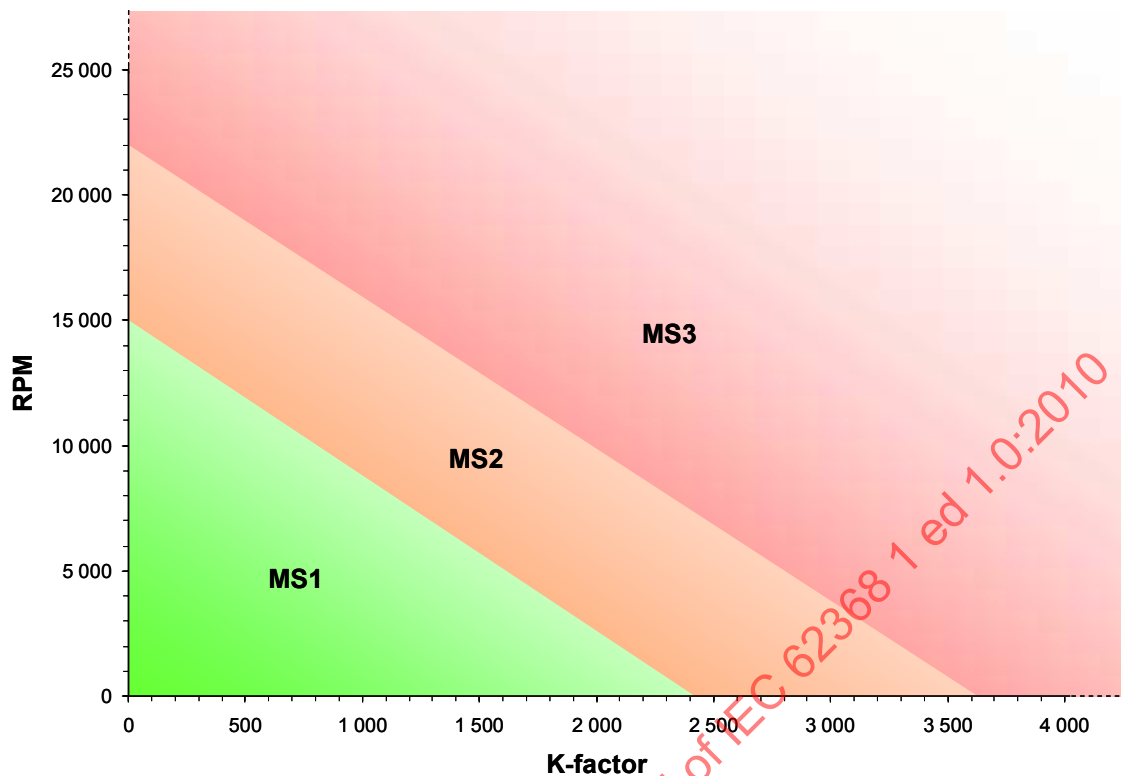


Figure 47 – Illustration showing MS limits for moving fan blades

8.2.2 MS1

MS1 is a mechanical energy source with levels not exceeding MS1 limits under **normal operating conditions** and **abnormal operating conditions** and not exceeding MS2 under **single fault conditions**.

NOTE MS1 may be **accessible** to an **ordinary person**.

8.2.3 MS2

MS2 is a mechanical energy source with levels not exceeding MS2 limits under **normal operating conditions**, **abnormal operating conditions**, and **single fault conditions**, but is not MS1.

NOTE MS2 may be **accessible** to an **instructed person**, and under **single fault conditions**, to an **ordinary person**.

8.2.4 MS3

MS3 is a mechanical energy source with levels exceeding MS2 limits under **normal operating conditions**, **abnormal operating conditions** and **single fault conditions**, or any mechanical energy source declared to be treated as MS3 by the manufacturer.

NOTE Parts classed MS3 may be **accessible** to a **skilled person**.

8.3 Protection against mechanical energy sources

8.3.1 General

This subclause specifies general protection requirements for parts **accessible** to **ordinary persons**, **instructed persons**, and **skilled persons**.

Table 41 gives a summary of the required **safeguards**.

Table 41 – Summary of required safeguards

Person	Number of safeguards required to be interposed between an energy source and a person		
	MS1	MS2	MS3
Ordinary person	0 ^a	1 ^b	2 ^c
Instructed person	0	0	2 ^d
Skilled person	0	0	0 or 1 ^e
^a See 4.3.2.1 and 8.3.2. ^b See 4.3.2.2, 4.3.2.3 and 8.3.2. ^c See 4.3.2.4 and 8.3.2. ^d See 4.3.3.2, 4.3.3.3 and 8.3.3. ^e See 4.3.4.3 and 8.3.4.			

8.3.2 Protection of ordinary persons

No **safeguards** need be interposed between MS1 and an **ordinary person**.

At least one **safeguard** shall be interposed between MS2 and an **ordinary person**.

Except as specified in 8.4.2 and 8.5.2, at least one **equipment basic safeguard** and one **equipment supplementary safeguard** shall be interposed between MS3 and an **ordinary person**.

8.3.3 Protection of instructed person

No **safeguards** need be interposed between MS1 or MS2 and an **instructed person**. However, for MS2 that is not obvious, an **instructional safeguard** shall be provided.

Except as specified in 8.4.2 and 8.5.2, at least one **equipment basic safeguard** and one **equipment supplementary safeguard** shall be interposed between MS3 and an **instructed person**.

8.3.4 Protection of skilled persons

No **safeguards** need to be interposed between MS1, MS2 or MS3 and a **skilled person**. However, for MS3 that is not obvious, an **instructional safeguard** shall be provided.

In addition, other MS3 parts not actively being serviced shall be located or guarded so that unintentional contact with such parts during service operations is an unlikely result in the **skilled person** involuntary recoiling from class 2 or class 3 energy sources being serviced.

NOTE Recoil might occur where the **skilled person** may partially or fully enter inside large equipment for servicing.

8.4 Safeguards against parts with sharp edges and corners

8.4.1 Requirements

This subclause specifies **safeguards** that reduce the likelihood of injury by parts with sharp edges and corners in **accessible** areas of the equipment.

Engineering judgement shall be used to class a mechanical energy source as MS1, MS2 or MS3 according to Table 40, line 1.

Except as provided in 8.4.2, an appropriate **safeguard** shall be provided as given in Table 41.

8.4.2 Instructional safeguard

Where an **accessible** sharp edge or corner is required for the function of the equipment:

- any potential limited exposure shall not be life threatening, and
- the sharp edge or corner shall be obvious to an **ordinary person** or an **instructed person** when exposed, and
- the sharp edge shall be guarded as much as practicable, and
- an **instructional safeguard** shall be used to minimise unintentional contact.

The **instructional safeguard** for the **accessible** sharp edge or corner shall be in accordance with Clause F.5 and shall be fixed to the equipment and located in proximity to the sharp edge or corner and contain a relevant graphical symbol or text with the following or similar appropriate wording:

WARNING Sharp edges present. Do not touch.
--

8.4.3 Compliance

*Compliance is checked by inspection and, if necessary, by test of Annex V. During and after the application of the force, the sharp edge or corner shall not be **accessible**.*

8.5 Safeguards against moving parts

8.5.1 Requirements

This subclause specifies **safeguards** that reduce the likelihood of injury by moving parts in **accessible** areas of the equipment (for example, pinch points, meshing gears and parts that may start moving due to unexpected resetting of a control device).

Engineering judgement shall be used to class a mechanical energy source as MS1, MS2 or MS3 according to Table 40, line 2.

The phrase “moving parts” in this subclause includes moving fan blades. Moving fan blades are classified according to Table 40, line 3.

NOTE 1 The ability of a part to cause injury is not solely dependent upon the kinetic energy it possesses. Consequently, the classification used in this standard can only be based on typical experience and engineering judgement.

NOTE 2 Examples of factors influencing the energy transfer to a body part include shape of the surface that strikes the body part, elasticity, velocity and the mass of equipment and body part.

A **mechanical enclosure** or barrier used as an **equipment safeguard** shall be so constructed that MS2 or MS3 parts are not **accessible** to an **ordinary person** and that MS3 parts are not **accessible** to an **instructed person**.

Where the likelihood exists that fingers, jewellery, clothing, hair, etc., can be drawn into parts (for example, gears), an **equipment safeguard** shall be provided to prevent injury.

If the **safeguard** is a **safety interlock**, it shall comply with the requirements in Annex K. The movement of the part shall be reduced to MS1 before the part is **accessible**.

An MS3 fan that is arranged, located, enclosed or guarded in such a way that the possibility of contact with the moving parts of the fan is unlikely by an **ordinary person** during **ordinary**

person servicing, or by an **instructed person** during **instructed person** servicing, shall be provided with an **instructional safeguard** as specified in 8.5.2.

8.5.2 MS2 or MS3 part required to be accessible for the function of the equipment

If a moving MS2 or MS3 part is required to be **accessible** to an **ordinary person** or an **instructed person** for the function of the equipment:

- any exposure shall not be life threatening; and
- the moving part shall be obvious when exposed; and
- the moving part shall be guarded as much as practicable; and
- an **instructional safeguard** shall be used to minimise unintentional contact; and
- for MS3, a manually activated stopping device shall be clearly visible and placed in a prominent position within 750 mm of the MS3 part.

If the location of a MS3 moving part may not be obvious to a **skilled person**, such as intermittent movement, an **instructional safeguard** shall be provided to minimise unintentional contact. A manually activated stopping device shall be clearly visible and placed in a prominent position within 750 mm of the MS3 part.

Instructional safeguards for a moving part shall be in accordance with Clause F.5 and shall be fixed to the equipment located in proximity to the moving part and contain a relevant

graphical symbol (such as  for moving fan blades) or text with the following or similar appropriate wording:

WARNING Hazardous moving parts. Keep body parts out of the motion path.
--

8.5.3 Compliance

The accessibility of moving parts shall be checked by inspection, and if necessary according to Annex V. Selection of the probe will depend on the application.

*Compliance is checked by inspection of the construction and available data, and where necessary, by the relevant tests of Annex T for **enclosures** and barriers.*

Compliance of thermoplastic stability is checked by the test according to Clause T.8, followed by the test of Annex V. Alternatively, compliance can be shown by examination of the construction and available material data.

8.5.4 Special categories of equipment comprising moving parts

8.5.4.1 Large data storage equipment

The requirements of IEC 60950-23 are additional to the relevant requirements in this standard.

Large equipment is typically of such a size that a person may enter completely. Systems may also include similar equipment having areas containing moving parts into which only a complete limb or head may enter. These requirements apply to a three dimensional envelope of 0,75 m³ or more within reach of the moving part.

The following references in IEC 60950-23 shall be treated as follows:

- replace IEC 60950-1:2005, 2.8 by Annex K;

- replace IEC 60950-1:2005, 2.8.6 by Clause K.4;
- replace "SERVICE PERSON" by "**skilled person**";
- replace "OPERATOR ACCESS AREA" by "areas **accessible** by an **ordinary person** as determined by Annex V".

NOTE An example of these systems is a self-contained data storage system.

8.5.4.2 Equipment having an electromechanical device for destruction of media

8.5.4.2.1 General requirements

This subclause specifies **equipment safeguards** to protect persons, including children, for equipment intended to mechanically destroy various media by means of moving parts that draw the media into the equipment. The media destruction device within this equipment is classed as MS3.

NOTE 1 Examples of this type of equipment include household use and home-office use document shredding and similar media destruction devices, as determined by the nature of their power source.

For equipment for use in locations where children are not likely to be present, see Clause F.4.

NOTE 2 This equipment design typically applies to commercial or industrial equipment expected to be installed in locations where only adults are normally present.

Equipment shall be provided with **safeguards** so that MS3 moving parts are not **accessible** to the appropriate jointed test probe of Annex V and the wedge probe of Figure V.4. Requirements for **safety interlocks** are according to Annex K, except that where a moving part cannot be reduced to the appropriate energy class within 2 s, the **safety interlock** shall continue to prevent access.

8.5.4.2.2 Instructional safeguards against moving parts

An **instructional safeguard** shall be provided in accordance with Clause F.5, adjacent to the media feed opening, alerting **ordinary persons** to the following:

- the equipment is not intended for use by children (this product is not a toy);
- avoid touching the media feed opening with the hands, clothing or hair.

For equipment installed where children are likely to be present, the instructions shall contain a statement recommending the equipment be unplugged when not in use for an extended period of time.

8.5.4.2.3 Disconnection from the supply

An isolating switch complying with Annex L shall be provided to disconnect power to MS3 moving parts. A switch with an "OFF" position, that removes all power from the MS3 moving part is acceptable. The switch shall be located where it is easily **accessible** to the user whose body part or clothes may be caught.

The "ON" and "OFF" positions of a two-position switch shall be marked in accordance with F.3.5.2.

For a multi-position switch, the "OFF" position of the switch shall be marked in accordance with F.3.5.2, and the other positions shall be marked with appropriate words or symbols.

8.5.4.2.4 Test method

For strip-cut type media destruction devices and the like, the wedge probe of Figure V.4 is applied with a force up to 45 N.

For cross-cut type media destruction devices and the like, the wedge probe is applied with a force up to 90 N. The force is applied in any direction relative to the opening.

NOTE Media destruction devices are typically identified as either strip-cut type or cross-cut type. A strip-cut media destruction device shreds the media into long strips using a motor-based shredding mechanism. A cross-cut media destruction device shreds the media two or more ways into tiny particles, typically using a more powerful motor and more complex shredding mechanism.

*Any **enclosure** or guard that can be removed or opened by an **ordinary person** or an **instructed person** shall be removed or opened prior to application of the probes.*

8.5.4.2.5 Compliance

Compliance is checked in accordance with V.1.2 and V.1.5. Depending on whether the equipment is a strip-type media destruction device or cross-cut media destruction device, the wedge probe of Figure V.4 is applied with the forces specified in this subclause. The wedge probe shall not contact any moving part.

*Where the equipment is provided with a **safety interlock**, compliance is checked according to Annex K, except where a moving part cannot be reduced to the appropriate energy class within 2 s, the **safety interlock** shall continue to prevent access.*

8.5.5 Protection of persons against loosening, exploding or imploding parts

8.5.5.1 Protection against MS3 parts

Where the equipment contains high speed parts, pressurized surfaces or the like, **safeguards** shall be provided to prevent the parts or fragments such as broken media and glass from injuring persons.

The following equipment constructions are examples considered MS3:

- high speed removable plastic solid media such as used in CD drives or DVD drives, capable of rotational speed greater than 8 000 rpm; and
- CRTs having a maximum face dimension exceeding 160 mm; and
- lamps, in which the pressure exceeds 0,2 MPa when cold or 0,4 MPa when operating, are considered high pressure lamps and shall be classed MS3.

Compliance is checked in accordance with 8.5.5.2.1, 8.5.5.2.2 and Annex U, as applicable.

To contain any other loose or broken parts, a **double safeguard** or **reinforced safeguard** shall be sufficiently robust to

- contain the parts; or
- attenuate the energy of the parts to MS1 level.

Compliance is checked by inspection, or, if necessary, by test. The test force to the inside of the enclosure, if necessary, shall be 1,25 times that of the calculated force from a broken or loose part.

8.5.5.2 Requirements and test methods

8.5.5.2.1 Mechanical enclosure requirements for rotating solid media

8.5.5.2.1.1 General

This subclause assesses containment of damaged solid media classified as MS3 in accordance with 8.5.5.1 that may shatter during **normal operating conditions**. The movable

media door and tray assembly are tested in accordance with 8.5.5.2.1.2 to assess the size of the potential gap during the static force test where media fragments may be expelled.

8.5.5.2.1.2 Test methods

The size of the gap 'X' between the media door or tray assembly and the enclosure is measured while the following force is applied.

A force of $F \pm 10\%$ is applied to the inside of the cover at the most unfavourable location. The formula for calculating the static force to be applied is:

$$F = S \times (mv^2) / R_o$$

where

- F is the force in Newtons to be applied;
- S = 0,250 when no deflector is used (considered worst case fractional size of fragment mass);
- S = 0,125 when a deflector is used (considered worst case fractional size of fragment mass);
- m is the mass in kilograms of the media;
- v is the velocity in metres per second of the outside diameter of the media;
- R_o is the outer radius in metres of the media.

NOTE 1 The entire mass of the media is as specified by the manufacturer.

NOTE 2 Typical CD and DVD media will be within this range.

- For a CD (in accordance with IEC 60908)
 - thickness: 1,20 mm $\begin{smallmatrix} +0,3 \\ -0,1 \end{smallmatrix}$ mm,
 - mass: 14 g to 33 g.
- For a DVD (in accordance with ECMA-267)
 - thickness: 1,20 mm $\begin{smallmatrix} +0,3 \\ -0,06 \end{smallmatrix}$ mm,
 - mass: 13 g to 20 g.

8.5.5.2.1.3 Compliance

Compliance is checked by inspection and, if necessary, by the following tests in accordance with Figure 48 or Figure 49, as appropriate.

*Where a media deflector is not used, the cover on the door shall not break, separate from the drive or flex such as to create an opening greater than 'X' mm measured between any part of the media door and the nearest outer **enclosure** surface through which media fragments could be expelled. A cylindrical probe or feeler gauge shall be used to measure the opening (see Figure 48). 'X' is the smallest thickness in millimetres of the media specified by the manufacturer.*

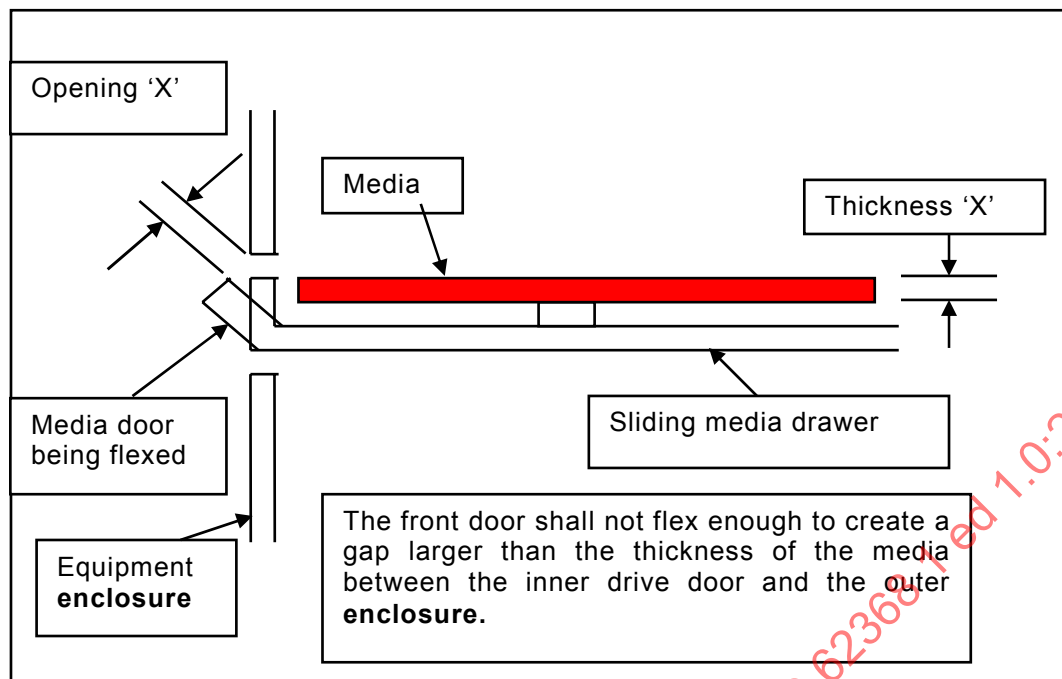


Figure 48 – Example for determining opening 'X' without a deflector

Where a media deflector is used, the cover on the door/deflector combination shall not break, separate from the drive or flex such as to create an opening through which media fragments could be expelled (see Figure 49).

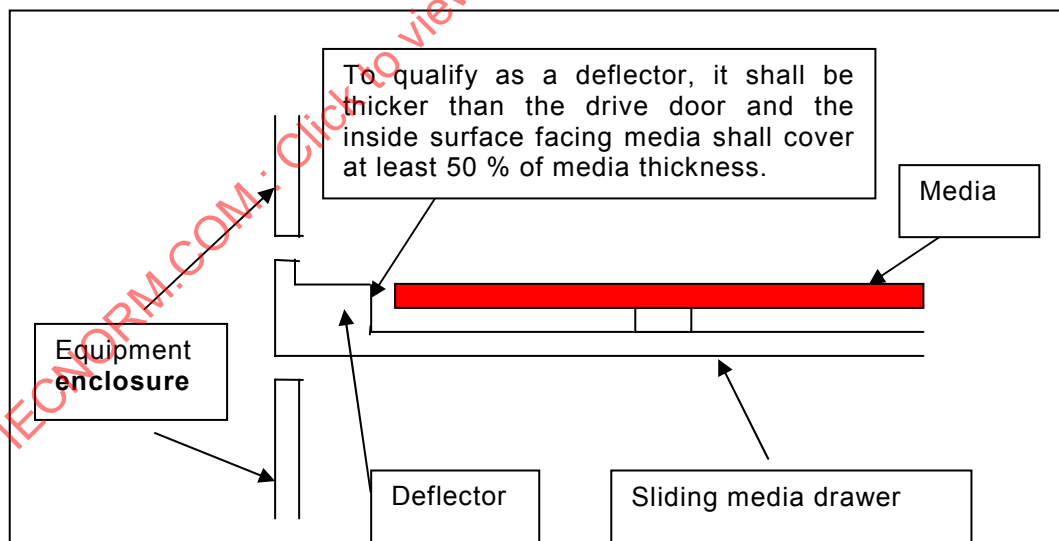


Figure 49 – Example for determining opening 'X' with a deflector

8.5.5.2.2 High pressure lamps

8.5.5.2.2.1 General

The containment mechanism for high pressure lamps that are considered MS3 shall have adequate strength to contain an **explosion** of the lamp so as to reduce the likelihood of injury

to an **ordinary person** or **instructed person** during normal use, or lamp assembly replacement, as appropriate.

Particles are considered MS1 parts if they are contained within the lamp assembly or equipment **enclosure** as tested in accordance with 8.5.5.2.2.2.

Particles are considered MS2 parts if they are less than 0,8 mm in the longest axis.

Particles are considered MS3 parts if they are equal to or greater than 0,8 mm in the longest axis.

8.5.5.2.2.2 Test methods

For the protection against the effects of a high pressure lamp failure, the following test is performed as follows:

- *lamp assemblies considered MS3 parts during field replacement are tested separate from the equipment;*
- *lamp assemblies only considered MS3 parts during operation, may be tested separately, or as normally installed in the equipment, or both.*

*An **explosion** of the lamp is stimulated by mechanical impact, electronic pulse generator or similar method. The lamp shall operate for at least 5 min to obtain operational temperature and pressure. To evaluate the rupture results for potential debris area and particle size, a dark sticky mat (or another adequate method) of adequate size is placed near the exhaust vent of the equipment. The equipment opening shall be oriented to maximize potential for particles to be expelled from the product horizontally across the dark sticky mat. After the rupture, the glass particles generated are measured using a magnified glass piece with a 0,1 mm resolution. The test shall be conducted to simulate the worst case operating position specified in the instructions.*

NOTE It is recommended to have the sticky mat a dark blue colour for easier inspection of potential glass debris.

An example of an electronic pulse generator method is given in Figure D.3.

The charge is increased in steps of 5 J until the lamp ruptures are repeatable.

8.5.5.2.2.3 Compliance

Compliance is checked by physical inspection or, if necessary, by the tests of 8.5.5.2.2.2.

*When tested, inspect the dark sticky mat for glass particles. No MS3 particle shall be found and no MS2 particles shall be found beyond 1 m of the **enclosure** opening.*

8.6 Stability of equipment

8.6.1 Requirements

This subclause specifies performance requirements that reduce the likelihood of MS2 or MS3 equipment becoming physically unstable to the point of tip over.

Classification of products for the purposes of assessing equipment stability is to be done according to Table 40, line 5.

Free standing MS2 or MS3 equipment shall be subjected to the stability test of 8.6.2.2 at an angle of 10°.

NOTE Examples of this type of equipment include some loudspeaker systems and some audio systems.

Free standing MS2 or MS3 equipment, having controls that are accessed during normal use or having a display with moving images, shall be tested according to the floor standing tests of 8.6.2 and the non-floor standing tests of 8.6.3 as appropriate.

Floor standing MS2 or MS3 equipment that is fixed to the building structure shall be subjected to the horizontal force test of 8.7.2 only.

Individual units that are designed to be mechanically fixed together on site and are not used individually, or **stationary equipment**, shall be assessed by inspection after installation according to the manufacturer's instructions and, if necessary, tested according to 8.6.2.2.

Where thermoplastic materials are involved in the construction, the relevant mechanical tests shall be conducted after the stress relief test in Clause T.8 when the equipment has cooled to room temperature.

Non-floor standing MS3 equipment, tested according to 8.6.3.1 and 8.6.3.2, shall have an **instructional safeguard** in accordance with Clause F.5, elements 3 and 4, located in the instructions for installation or use, containing the following information or equivalent:

WARNING

Never place the equipment in an unstable location. The equipment may fall, causing serious personal injury or death. Many injuries, particularly to children, can be avoided by taking simple precautions such as:

- Using cabinets or stands recommended by the manufacturer of the equipment.
- Only using furniture that can safely support the equipment.
- Ensuring the equipment is not overhanging the edge of the supporting furniture.
- Not placing the equipment on tall furniture (for example, cupboards or bookcases) without anchoring both the furniture and the equipment to a suitable support.
- Not standing the equipment on cloth or other materials placed between the equipment and supporting furniture.
- Educating children about the dangers of climbing on furniture to reach the equipment or its controls.

8.6.2 Static stability for floor standing equipment

8.6.2.1 Requirements

This subclause addresses the stability of equipment that can be handled, moved or relocated during intended use or installation.

The MS2 or MS3 equipment shall not tip over when installed according to the installation instructions, or during relocation.

The equipment shall be blocked, if necessary, by means of a stop of the smallest dimensions possible to keep it from sliding or rolling during the test. During the tests, containers, if any, are to contain the amount of substance within their rated capacity that will result in the most disadvantageous condition.

Compliance is checked by inspection or, if necessary, by test. The equipment shall not tip over.

8.6.2.2 Static stability test

*All doors, drawers, casters, adjustable feet and other appurtenances, if used by an **ordinary person**, are arranged in any combination that results in the least stability. Equipment provided with multi-positional features shall be tested in the least favourable position based on the equipment construction. However, if the casters are intended only to transport the unit, and if the installation instructions require adjustable feet to be lowered after installation, then the adjustable feet (and not the casters) are used in this test.*

- a) *MS3 equipment shall not tip over when a force equal to 20 % of the weight of the unit, but not more than 250 N, is applied in any direction, except upwards, to any point on the equipment in such a way as to produce the maximum overturning moment, at a height not exceeding 1,5 m from the floor. The test force shall be discontinued if the equipment remains stable after being tilted 15° from vertical. Alternatively, the equipment shall be tipped at any angle up to and including 15° from the vertical.*
- b) *MS3 equipment shall not tip over when a constant downward force of 800 N is applied at the point of leverage for a maximum moment to any point of any horizontal surface of at least 125 mm by at least 200 mm, at any height up to 1 m from the floor. The 800 N force is applied by means of a suitable test apparatus having a flat surface of approximately 125 mm by 200 mm. The downward force is applied with the complete flat surface of the test **tool** in contact with the equipment; the test apparatus need not be in full contact with uneven surfaces (for example, corrugated or curved surfaces). Equipment having a shape or a flexibility of the surface that is not likely to be used as a step or a ladder are exempt from the test.*

NOTE Examples are products in combination with a cart or stand or products with protrusion or recess where the construction is obviously not to be used as a step or ladder.

*Where MS3 equipment is subject to periodic maintenance or routinely serviced or repaired at its intended use location, the doors, drawers, etc. or any other adjustment means **accessible** to an **instructed person** or **skilled person** shall be arranged in any combination specified by the servicing instructions that results in the least stability. The test of a) above is repeated if necessary.*

8.6.2.3 Relocation stability test

*Floor standing equipment expected to be moved or relocated by **ordinary persons** and having wheels with a minimum diameter of less than 100 mm shall have all doors, drawers, casters, adjustable feet and other appurtenances arranged in any combination that results in the least stability. A unit provided with multi-positional features shall be tested in the least favourable position based on the equipment construction.*

*Floor standing equipment expected to be moved or relocated by an **instructed person** or a **skilled person** and having wheels with a minimum diameter of less than 100 mm shall have all doors, drawers, etc., positioned in accordance with the manufacturer's instructions. A unit provided with multi-positional features shall be tested in the least favourable position based on the equipment construction.*

Floor standing MS2 or MS3 equipment shall not tip over when tilted to an angle of 10° from its normal upright position in any direction. If the equipment is such that when it is tilted through an angle of 10° when standing on a horizontal plane, a part of it not normally in contact with the supporting surface would touch the horizontal plane, the equipment is placed on a horizontal support so that contact does not occur with the horizontal surface and the combination is tilted in the most unfavourable direction through an angle of 10°. Alternatively, the equipment may be placed on a plane and is rotated through an angle of 360° about its normal vertical axis while tilted at 10°.

NOTE The test on the horizontal support may be necessary (for example, for equipment provided with small feet, casters or the like).

8.6.3 Non-floor standing equipment having controls that are accessed during normal use or having displays with moving images

8.6.3.1 Glass slide test

*MS2 or MS3 equipment (except for floor standing equipment) likely to be used in the home or similar installation environments where they may be **accessible** to children, is placed on a clean, dry, glass covered horizontal surface so that only the supporting feet are in contact with the glass. The glass-covered surface is then tilted in the most unfavourable direction through an angle of 10°.*

During the tests, the equipment shall not slide or tip over.

8.6.3.2 Horizontal force test

8.6.3.2.1 General

This subclause addresses the risk of children being attracted to MS2 or MS3 equipment likely to be elevated above the floor with normally **accessible** controls or displays with moving images resulting in their attempt to climb onto devices that may tip over easily. This requirement does not apply to other equipment.

NOTE Equipment with front mounted user controls and moving images are considered to increase the frequency of children being attracted to displays and thereby increasing the likelihood of the child attempting to climb or move the equipment.

8.6.3.2.2 Test method

MS2 or MS3 equipment is to be placed on a horizontal non-skid surface with all doors, drawers, casters, adjustable feet and other movable parts arranged in any combination that results in the least stable condition. The equipment shall be blocked, if necessary, by means of a stop of the smallest dimensions possible, to keep it from sliding or rolling when subjected to one of the following tests:

- a) an externally applied horizontal force of 13 % of the weight of the equipment or 100 N, whichever is less, is applied in a horizontal direction to that point on the equipment that will result in the least stability. The force shall not be applied more than 1,5 m above supporting surface; or*
- b) the equipment shall be moved through any angle of tilt up to and including 15° from the vertical.*

During the test, the equipment shall not tip over.

8.7 Equipment mounted to a wall or ceiling

8.7.1 General

This subclause specifies how to minimise the likelihood of injury caused by equipment falling due to failure of the mounting means.

The mounting means of MS2 or MS3 equipment intended for wall or ceiling mounting shall be capable of vertically supporting four times the weight of the equipment, and also lateral stress. The mounting hardware shall either be provided with the equipment, or described in detail in the user instructions (for example, length of screws and type of mounting surface suitable for the installation, etc.). Classification of equipment for the purposes of assessing wall mounting means is to be done according to Table 40, line 6.

8.7.2 Test method

The equipment is mounted in accordance with the manufacturer's instructions and mounting means positioned, when possible, to represent the most severe stress on the supports.

A downward force, in addition to the weight of the equipment, is applied downwards through the centre of gravity for 60 s. The additional force shall be equal to three times the weight of the equipment, but not less than 50 N in total. The equipment and its associated mounting means shall remain secure during the test.

In addition, for wall mounted equipment, a horizontal force of 50 N is applied laterally for 60 s.

8.7.3 Compliance

Compliance is checked by inspection of the construction and of available data or, where necessary, by the test of 8.7.2.

8.8 Handle strength test method

8.8.1 General

This subclause specifies how to reduce the likelihood of injury from a handle failure causing the equipment to fall for other than MS1 equipment having only one handle.

This subclause applies to a handle that is declared by the manufacturer for the purpose of lifting or carrying the equipment.

For the purposes of this subclause, the equipment is classified according to Table 40, line 5.

8.8.2 Compliance and test method

The equipment shall pass the following test:

A weight shall be uniformly applied over a 75 mm width at the centre of the handle, without clamping.

The weight shall be the equipment weight plus an additional weight as specified below:

- for MS1 equipment, with two or more handles, a weight that exerts a force of three times the weight of the equipment;*
- for MS2 equipment, a weight that exerts a force of three times the weight of the equipment;*
- for MS3 equipment with a mass 50 kg or less, a weight that exerts a force of two times the weight of the equipment or 75 kg, whichever is greater;*
- for MS3 equipment with a mass greater than 50 kg, a weight that exerts a force of one times the weight of the equipment or 100 kg, whichever is greater.*

The additional weight shall be started at zero and gradually increased so that the test value is attained in 5 s to 10 s and maintained for 60 s. When more than one handle is provided, the force shall be distributed between the handles. The distribution of the forces shall be determined by measuring the percentage of the equipment's weight sustained by each handle with the equipment in the intended carrying position. When MS2 equipment is furnished with more than one handle, and it can be considered capable of being carried by only one handle, each handle shall be capable of sustaining the total force.

*As a result of the test, the handle, its securing means, or that portion of the **enclosure** to which it is secured, shall not break, crack, or detach from the equipment.*

8.9 Wheels or casters attachment requirements

8.9.1 General

This subclause specifies how to reduce the likelihood of MS3 and some MS2 equipment, including carts, stands and similar carriers that support the equipment, from tipping over during movement. For the purposes of this subclause, the equipment is classified according to Table 40, line 5.

8.9.2 Test method

*Wheels or casters on MS3 equipment, or their supporting cart, stand or similar carrier, intended to be moved as part of its **normal operating conditions**, shall be capable of withstanding a pull of 20 N without being damaged or pulled free from its securing means. The pull force is to be applied by a weight, or a steady pull, to the wheel or caster for a period of 1 min in any direction made possible by the construction.*

8.10 Carts, stands, and similar carriers

8.10.1 General

This subclause specifies how to minimise the risk of tipping, material breakdown, or mismatching of cart, stand or similar carrier relevant to the mounted equipment.

The equipment shall be stable with the cart, stand or similar carrier. For the purposes of this subclause, the MS classifications of Table 40, line 5 are applied using the combined mass of both the equipment and the carts or stands specified with the equipment.

All carts and stands specified for use with the equipment shall be subjected to the applicable tests described in the following subclauses. A cart, stand or carrier shall be subjected to the applicable tests alone and again with the equipment specified by the manufacturer placed on the cart or stand.

MS3 equipment, including their supporting carts, stands and similar carriers that support the equipment, that are not moved as part of its **normal operating conditions**, shall comply with the horizontal force test of 8.6.3.2.

MS2 or MS3 equipment more than 1 m in height, including equipment mounted on their specified cart, stand or carrier, shall comply with the relocation stability test in 8.6.2.3 except that the tip angle becomes 15°. If equipment is provided with wheels or casters that allow the equipment to only move in limited directions, the test is only applied in those directions (for example, an electronic white board).

8.10.2 Marking and instructions

A cart, stand or similar carrier that is specified by the manufacturer for use with specific equipment, but is packaged and marketed separately from the equipment, shall be provided with an **instructional safeguard** in accordance with Clause F.5.

Elements 2, 3 and 4 as appropriate shall include the manufacturer's name, distinctive catalogue designation of equipment to be supported, model or series, and equipment name; and the following statement or equivalent text:

CAUTION This (cart, stand or carrier) is intended for use only with (manufacturer's name), (model number or series), (equipment name). Use with other equipment may result in instability causing injury.
--

When it is not feasible to include a specific equipment model number or series designation on the cart, stand or similar carrier, this information shall be provided in the instructions.

Equipment only intended and shipped for use with a specific cart, stand or similar carrier, shall be provided with an **instructional safeguard** in accordance with Clause F.5.

Elements 2, 3 and 4 as appropriate shall include:

CAUTION This (equipment name) is for use only with (manufacturer's name), (model number or series), (cart, stand or carrier). Use with other (carts, stands, or carriers) may result in instability causing injury.
--

8.10.3 Cart, stand or carrier loading test and compliance

*A cart, stand or carrier shall be constructed so that permanent deformation or damage that is capable of resulting in injury to a person, does not occur when it is subjected to a force of 220 N applied for 1 min to any grippable or leverage point **accessible** to a child.*

To determine compliance, the force is applied through the end of a 30 mm diameter circular cylinder. The force is to be applied to a shelf drawer, dowel rung support, or equivalent part that is within 750 mm from the floor and will support some or all of a child's weight. The force is to be applied for 1 min with the cart or stand at room temperature. The part shall not collapse or break so as to expose sharp edges or produce pinch points that are capable of resulting in injury.

In addition, a cart, stand or other carrier shall be constructed so that permanent deformation or damage that is capable of resulting in injury to persons does not occur when each supporting surface is individually loaded with:

- *the manufacturer's intended load plus 440 N for the surface intended to support a display with moving images; or*
- *four times the manufacturer's intended load or 100 N, whichever is greater but not to exceed 440 N, is applied to all applicable surfaces.*

A dedicated storage area intended to accommodate specific accessories such as media tapes, discs, etc. shall be fully loaded to the rated load.

The weight is to be applied for 1 min on each supporting surface, with the other supporting surfaces unloaded.

8.10.4 Cart, stand or carrier impact test

When tested as described below, a cart, stand or carrier shall not produce a risk of injury to persons.

A single 7 J impact is to be applied to any part of the cart or stand and the test method is to be as described in Clause T.6. However, a cart, stand or carrier made of glass shall be tested instead according to T.9.1.

8.10.5 Mechanical stability

A cart, stand or carrier, including floor standing, by itself, and where applicable in combination with its intended MS2 or MS3 equipment, shall be subjected to the applicable tests described in 8.6.2.3 and 8.6.3.2.

For the purposes of these tests, the weight shall be considered as the total weight of the equipment plus the weight of the cart, stand or carrier. The equipment shall be installed according to the manufacturer's instructions and the horizontal force shall be applied to either the cart, stand or carrier or intended equipment to produce a maximum overturning moment on the equipment at a point up to a maximum height of 1,5 m above the floor level.

If during the tests of 8.6.2.3 and 8.6.3.2 the equipment starts to slide or tip relative to the cart, stand or carrier, only the horizontal force test shall be repeated by reducing the force to 13 % of the weight of the equipment alone, or 100 N, whichever is less.

The equipment and cart or stand shall not tip over.

8.10.6 Thermoplastic temperature stability

An equipment, cart, stand or carrier using thermoplastic materials in its construction shall withstand the test of Clause T.8, without any shrinkage, warpage, or other distortion of the thermoplastic materials that results in the equipment failing to comply with 8.10.3, 8.10.4 and 8.10.5.

8.11 Mounting means for rack mounted equipment

8.11.1 Requirements

This subclause applies to the mounting means of MS2 and MS3 equipment installed in a rack, that can be extended away from the rack for installation, service and the like. This requirement does not apply to equipment fixed in place, equipment subassemblies or racks having a top installation position less than 1 m in height from the supporting surface.

For the purpose of this subclause, the mechanical mounting means will be referred to as slide-rail. This subclause specifies requirements for the slide-rail to reduce the likelihood of injury by retaining the equipment in a safe position and not allowing the slide-rails to buckle, means of attachment to break, or the equipment to slide past the end of the slide-rails.

NOTE 1 Slide-rails include bearing slides, friction slides or other equivalent mounting means.

NOTE 2 Slide-rail constructions of integrated parts/units of the end product (for example, pullout paper trays in copiers/printers) are not considered to be rack mounted equipment.

Classification of products for the purposes of assessing equipment stability is to be done according to Table 40, line 5.

Such slide-rails shall have end stops that prevent the equipment from unintentionally sliding off the mounting means.

8.11.2 Mechanical strength test, variable *N*

The slide-rail shall be installed in a rack with the equipment, or equivalent setup in accordance with the manufacturer's instructions. With the equipment in its extended position, a force in addition to the weight of the equipment is to be applied downwards through the centre of gravity for 1 min by means of a suitable test apparatus providing contact over a circular plane surface 30 mm in diameter. If applying this force could damage the equipment, a metal plate or other means of distributing the force may be placed under the test apparatus. The total force shall be calculated based on the mass of the equipment plus an additional mass as determined below.

NOTE This additional force is intended to take into account other items or devices that may be stacked on top of the installed rack mounted equipment while in the extended position during installation of other equipment.

For slide-rail mounted equipment where the slide-rails are mounted horizontally on each side of the equipment, the total force applied to the slide-rails shall be equal to the greater of the following two values:

- 150 % of the equipment mass plus 330 N,
- 150 % of the equipment mass, plus an additional mass, where the additional mass is equal to the equipment mass or 530 N, whichever is less.

For slide-rail mounted equipment where the slide-rails are mounted vertically on the top and bottom of the equipment in the rack, the total force applied to the slide-rails shall be 150 % of the equipment mass, with a minimum force of 250 N and a maximum force of 530 N.

*If the supporting surface is intended to be a shelf, then the distribution of force over a metal plate under the test apparatus does not apply. The manufacturer shall state the maximum load that is intended to be placed on the shelf in order to determine the force that needs to be applied to the shelf. An **instructional safeguard** shall be provided on the shelf to indicate the maximum weight that can be added to the shelf. The force test shall be conducted at 125 % of the maximum weight stated by the manufacturer. The force is to be applied directly by means of the test apparatus providing contact over a circular plane surface 30 mm in diameter.*

8.11.3 Mechanical strength test, 250 N, including end stops

The slide-rail mounted equipment is installed in a rack in accordance with the manufacturer's instructions. A 250 N static force is applied to the slide-rail mounted equipment, in every direction except upward to include the most unfavourable position of the slide-rail mounted equipment, for a period of 1 min. The force is applied to the slide-rail mounted equipment in its fully extended (service) position as well as its normally recessed (operating) position by means of a suitable test instrument providing contact over a circular plane surface 30 mm in diameter. The force is applied with the complete flat surface of the test instrument in contact with the equipment. The test instrument need not be in full contact with uneven surfaces (for example corrugated or curved surfaces).

NOTE Additional requirements for a dynamic force test on end stops are being considered at this time.

8.11.4 Compliance

Compliance is checked by inspection and available manufacturer's data. If data is not available, then the tests according to 8.11.2 and 8.11.3 are conducted.

The equipment and its associated slide-rails shall remain secure during the tests. One complete cycle of travel on its slide-rails after completion of each test shall be performed. If the mounting means is not able to perform one complete cycle without binding, a force of 100 N shall be applied horizontally to the front of the equipment at its centre point with the intent to completely retract the equipment into the rack. Should the equipment fail to fully retract, the mounting means shall not bend or buckle to any extent that could introduce an injury. End stops shall retain the equipment in a safe position and shall not allow the equipment to slide past the end of the slide-rails.

8.12 Telescoping or rod antennas

A telescoping or rod antenna shall be provided with a minimum 6,0 mm diameter button or ball on the end. An antenna end piece and the sections of a telescoping antenna shall be secured in such a manner as to prevent removal.

Compliance is checked by inspection and the test of Clause T.10.

9 Thermal burn injury

9.1 General

This clause specifies safeguards to reduce the likelihood of skin burn injury as the result of conduction of thermal energy from parts of equipment.

9.2 Thermal energy source classifications

9.2.1 General

This subclause describes the different energy sources and defines their limits under **normal operating conditions** and **abnormal operating conditions** at normal room ambient of 25 °C. **Single fault conditions** are not considered.

9.2.2 TS1

TS1 is a thermal energy source with levels not exceeding TS1 limits in Table 42 under **normal operating conditions**, and not exceeding TS2 limits in Table 42 under **abnormal operating conditions**. If, under **abnormal operating conditions**, the equipment continues to function, TS1 does not exceed the TS2 limits specified for contact durations less than 1 s. Where the malfunction of the equipment is evident, no limits apply.

NOTE TS1 may be **accessible** to an **ordinary person**.

9.2.3 TS2

TS2 is a thermal energy source with levels exceeding TS1 limits under **normal operating conditions** but not exceeding TS2 limits in Table 42 under **normal operating conditions** and **abnormal operating conditions**. If, under **abnormal operating conditions**, the equipment continues to function, the TS2 limits specified for contact durations less than 1 s apply. Where the malfunction of the equipment is evident, no limits apply.

NOTE TS2 may be **accessible** to an **instructed person**, and under **single fault conditions**, to an **ordinary person**.

TS2 may be **accessible** to **ordinary persons** if an **instructional safeguard** is in place.

9.2.4 TS3

TS3 is a thermal energy source with levels exceeding the appropriate TS2 limits in Table 42 under **normal operating conditions** and **abnormal operating conditions**, or any thermal energy source declared to be TS3.

NOTE Parts and surfaces classed TS3 may be **accessible** to a **skilled person**.

9.2.5 Touch temperature levels

Table 42 – Touch temperature limits

	Accessible parts ^a	Maximum temperature (T_{max}) °C			
		Metal	Glass, porcelain and vitreous material	Plastic and rubber ^b	Wood
TS1	Handles, knobs, grips, etc., and external surfaces held in normal use (>1 min) ^c	48	48	48	48
TS1	Handles, knobs, grips, etc., and external surfaces held for short periods of time or touched occasionally (>10 s and <1 min) ^c	51	56	60	60
TS1	Handle, knobs, grips etc., and external surfaces touched occasionally for very short periods (>1 s and <10 s) ^c	60	71	77	107
TS1	External surfaces that need not be touched to operate the equipment (<1 s) ^c	70 ^d	80 ^d	94 ^d	140
The limits for TS2 are 10 K higher than the TS1 limits.					
^a Except for handles, knobs, grips etc., the following parts inside the equipment need not comply with this table provided an instructional safeguard in accordance with Clause F.5 is provided on or near the hot part (see 9.4.2): – a part that does not need to be touched to operate the equipment and if unintentional contact with the part is unlikely; – internal parts of the equipment requiring heat for the intended function (for example, a document laminator, thermal print head, fuser heater, etc.) provided the parts are unlikely to be touched by an ordinary person under normal operating conditions. ^b For each material, account shall be taken of the data for that material to determine the appropriate maximum temperature. ^c Time of contact shall be determined by the manufacturer. For outside parts of metal that are covered with plastic material of at least 0,3 mm thick, a temperature rise which corresponds to the permissible temperature limit of the plastic and rubber is allowed. ^d For the following areas and external surfaces, the temperature limit is 100 °C unless a higher limit is specified above: – an area on the external surface of the equipment that has no dimension exceeding 50 mm, and that is not likely to be touched in normal use; or – accessible surfaces of the equipment requiring heat for the intended function (for example, equipment that contains a document laminator, thermal print head, fuser heater, etc.), and that are not likely to be touched in normal use; or – heatsinks and metallic parts directly covering heatsinks, except those on surfaces incorporating switches or controls handled during normal use. For these areas and parts, an instructional safeguard in accordance with Clause F.5 shall be provided on or near the hot part.					

9.3 Protection against thermal energy sources

9.3.1 General

This subclause specifies protection requirements for parts **accessible** to **ordinary persons**, **instructed persons**, and **skilled persons**.

9.3.2 Protection of an ordinary person

9.3.2.1 Protection of an ordinary person against TS1

No **safeguard** need be interposed between TS1 and an **ordinary person**.

9.3.2.2 Protection of an ordinary person against TS2

At least one **safeguard** shall be interposed between TS2 and an **ordinary person**. This **safeguard** may be:

- an **equipment safeguard** such as thermal insulation; or
- an **instructional safeguard** in accordance with Clause F.5.

For use of **instructional safeguards**, see 9.4.2.

9.3.2.3 Protection of an ordinary person against TS3

At least one equipment **basic safeguard** and one **supplementary safeguard** shall be interposed between TS3 and an **ordinary person**.

NOTE The **supplementary safeguard** may be an **instructional safeguard**.

9.3.2.4 Compliance

Compliance is checked by inspection.

9.3.3 Protection of an instructed person

9.3.3.1 Protection of an instructed person against TS2

No **equipment safeguard** need be interposed between TS2 and an **instructed person**.

9.3.3.2 Protection of an instructed person against TS3

At least one equipment **basic safeguard** and one **supplementary safeguard** shall be interposed between TS3 and an **instructed person**.

NOTE The **supplementary safeguard** may be an **instructional safeguard**.

Compliance is checked by inspection.

9.3.4 Protection of a skilled person

Parts and surfaces classed TS3 shall be provided with an **equipment safeguard** or provided with an **instructional safeguard** so that unintentional contact with such parts and surfaces during service operations is unlikely to cause the **skilled person** to recoil into other class 3 energy sources (see Figure 19).

Compliance is checked by inspection.

9.4 Requirements for safeguards

9.4.1 Equipment safeguard

9.4.1.1 Requirements

An **equipment safeguard** shall limit the transfer of thermal energy (source temperature) under **normal operating conditions** and **abnormal operating conditions** or limit accessibility to a thermal energy source to a touch temperature as specified by the TS classification according to Table 42.

Temperature limits are applied only for those **abnormal operating conditions** where the equipment continues to function and the **abnormal operating condition** is not obvious. If the equipment stops functioning, then the limits are not applicable.

9.4.1.2 Test method and compliance

This test is run with the room ambient conditions as defined in B.1.7, except that the room ambient temperature shall be 25 °C.

*The equipment shall be operated in a manner the manufacturer determines likely to result in elevated thermal conditions of **accessible** surfaces and parts.*

NOTE This may not be the condition of maximum input current or wattage but the condition that delivers the highest thermal level to the part in question.

*Compliance is checked by measuring the steady state temperature of **accessible** surfaces.*

9.4.2 Instructional safeguard

An **instructional safeguard** shall be provided in accordance with Clause F.5 and be comprised of

- the symbol , IEC 60417-5041 (2002); or
- the following statement or equivalent text:

CAUTION
Hot surface. Do not touch.

Compliance is checked by inspection.

10 Radiation

10.1 General

This clause specifies how to reduce the likelihood of exposure of persons to injurious levels of both ionising and non-ionising electromagnetic radiation. This clause also provides protection against hearing impairment from excessive sound levels that may be produced by electronic equipment.

10.2 Radiation energy source classifications

10.2.1 RS1

RS1 has levels not exceeding RS1 limits under **normal operating conditions** and **abnormal operating conditions** and not exceeding RS2 limits under **single fault conditions**. When a person is exposed to RS1, the energy is undetectable to detectable but not painful.

NOTE An **ordinary person** may be exposed to RS1.

10.2.2 RS2

RS2 has levels not exceeding RS2 limits under **normal operating conditions**, **abnormal operating conditions** and under **single fault conditions**, but is not RS1. When a person is exposed to RS2, the energy may be detectable to painful. Exposure to RS2 is acceptable within given exposure limits and related short time periods (dose rates).

NOTE An **instructed person** may be exposed to RS2. Under **single fault conditions**, an **ordinary person** may also be exposed to RS2.

10.2.3 RS3

RS3 has levels exceeding RS2 limits, or any energy source declared to be RS3. When a person is exposed to RS3, the energy, even at short exposure (instantaneous power or power density), is considered injurious.

NOTE A **skilled person** may have access to RS3 with appropriate **instructional safeguards** and **skill safeguards** in place. National regulations limit the radiation level and exposure time where a **skilled person** is working live where RS3 may be present.

10.3 Requirements for electromagnetic radiation

10.3.1 Protection of persons from non-ionising radiation

10.3.1.1 General

This subclause specifies safeguards to reduce the risk of harmful effects of non-ionising radiation to all persons.

NOTE Diodes emitting coherent light (such as super luminescent diodes) should be treated as a laser.

10.3.1.2 Non-ionising radiation from lasers

10.3.1.2.1 Requirements

Equipment containing one or more lasers (including laser diodes) shall comply with IEC 60825-1, IEC 60825-2 or IEC 60825-12 as applicable.

Where a laser of class 3R, 3B or 4 is present, a **tool** shall be required to gain access.

10.3.1.2.2 Compliance

Radiation energy classification is determined by

- *measuring according to the IEC 60825 series, or*
- *checking the available manufacturer's data sheet.*

Compliance is checked to the applicable standard(s) within the IEC 60825 series.

NOTE 1 As of the date of this standard, the applicable standards are IEC 60825-1, IEC 60825-2 and IEC 60825-12.

*Equipment that does not exceed the accessible emission limit for Class 1 under all conditions of operation, maintenance and failure is not required to have a laser warning **instructional safeguard** or laser explanatory label. Such equipment is exempt (see Clause 1 of IEC 60825-1:2007).*

NOTE 2 Accessible emission limit is defined in IEC 60825-1:2007, 3.3.

10.3.1.3 Non-ionising optical radiation from lamps and lamp systems (including LEDs)

10.3.1.3.1 General

Equipment containing lamps or lamp systems that produce optical radiation in excess of the limits specified in IEC 62471 in the wavelength range 200 nm to 3 000 nm, as specified by the lamp manufacturer, shall be provided with **safeguards** to eliminate unnecessary optical radiation exceeding the limits specified in IEC 62471. Low power applications of LEDs need not comply with IEC 62471.

NOTE 1 General purpose incandescent and fluorescent lamps, with ordinary glass envelopes, are not considered to emit significant UV radiation.

NOTE 2 Some examples of low power applications of LEDs that are exempt from the above requirements are those used as:

- indicating lights;
- infra-red devices such as used in home entertainment devices;
- infra-red devices for data transmission such as used between computers and computer peripherals;
- optocouplers; and
- other similar low power devices.

NOTE 3 If optical radiation is broadband visible and IR-A radiation and the luminance of the source does not exceed 10^4 cd/m², it is expected that the radiation does not exceed the exposure limits given in 4.3 of IEC 62471:2006 (see 4.1 of IEC 62471:2006).

NOTE 4 For UV-C limits (wavelengths between 180 nm and 200 nm), the value of IEC 62471 for 200 nm is used.

The marking requirements in Clause F.5 are not required for a door or cover that is provided with a **safety interlock** switch that disconnects power to the UV lamp when the door or cover is opened, or any other mechanism that prevents UV radiation from being **accessible**.

In IEC 62471,

- the exempt group is RS1,
- risk group 1 and risk group 2 are RS2,
- risk group 3 is RS3.

10.3.1.3.2 Requirements

Except for the following condition of a) or b), optical radiation shall either

- be contained by the **enclosure** of the lamps and lamp system or the **enclosure** of the equipment; or
- not exceed the relevant limits for the exempt group given in IEC 62471 for **normal operating conditions** (for example, 8 h exposure for UV radiation).

NOTE 1 Lamp systems containing lamps covered by 6.1.1 of IEC 62471:2006 are exempt from the above requirements.

NOTE 2 The exempt group is described in 6.1.1 of IEC 62471:2006.

a) For UV radiation:

Equipment that produces visible light that is only emitted through a glass focusing lens having a 90 % UV attenuation up to 400 nm is exempt if there are no other openings through which visible radiation is emitted.

NOTE 3 Glass with a thickness of 2 mm usually complies with this requirement.

Higher UV exposure levels are acceptable for shorter periods (up to 100 s for RS2) for maintenance and cleaning operations, if it is necessary for the UV lamp to be on during these operations. However, optical radiation shall not exceed the limits for risk group 2 (moderate risk) given in IEC 62471. The relevant exposure limits for the reduced time intervals for these operations shall be stated in the instructions.

Doors and covers that, when open, would allow access to RS2 shall have an **instructional safeguard** provided in accordance with Clause F.5 and be comprised of:

- the symbol , consisting of IEC 60417-5751 (2002) combined with the triangle shaped warning sign from ISO 3864-2, or

- the following statement or equivalent text:

WARNING Turn off the UV lamp before opening.

If the UV radiation symbol is used on the equipment, both the symbol and an **instructional safeguard** similar to the above marking shall appear together in the instructions. Where a symbol is used, its meaning shall be explained in the instructions.

If **skilled persons** are likely to be exposed to higher emissions than those specified above, in an area only **accessible** to **skilled persons**, and it is necessary for the equipment to remain energized while being serviced, an **instructional safeguard** shall be provided in accordance with Clause F.5 and be comprised of:

- the symbol , consisting of IEC 60417-5751 (2002) combined with the triangle shaped warning sign from ISO 3864-2, or
- the following statement or equivalent text:

WARNING Use UV radiation eye and skin protection during servicing.

The marking shall be located where readily visible during the servicing operation. The **instructional safeguard** shall be visible prior to opening the means of access to the RS3.

If the UV radiation symbol is used on the equipment, both the symbol and an **instructional safeguard** similar to the above marking shall appear together in the servicing instructions.

b) For visible radiation:

If the emission of high levels of visible radiation is required for the equipment's intended function, an **instructional safeguard** shall be provided in accordance with Clause F.5 and be comprised of:

- the symbol , consisting of IEC 60417-5012 (2002) combined with the triangle shaped warning sign from ISO 3864-2, or
- the following statement or equivalent text:

WARNING Do not stare into beam.
--

Higher exposure levels are acceptable for shorter periods of time for maintenance and cleaning operations, if it is necessary for the lamp to be on during these operations, however optical radiation shall not exceed the limits for risk group 2 (moderate risk) given in IEC 62471. The relevant limits are those for the expected time intervals for these operations, which shall be stated in the instructions.

For doors and covers that when open would allow higher emissions than those specified above to be **accessible**, an **instructional safeguard** shall be provided in accordance with Clause F.5 and be comprised of:

- the symbol , consisting of IEC 60417-5012 (2002) combined with the triangle shaped warning sign from ISO 3864-2, or

- the following statement or equivalent text:

WARNING Turn off the lamp before opening.

The **instructional safeguard** shall be in accordance with Clause F.5. The above marking is not required for a door or cover that is provided with a **safety interlock** switch that disconnects power to the lamp when the door or cover is opened, or any other mechanism that prevents visible radiation from being **accessible**.

If the visible radiation symbol is used on the equipment, both the symbol and an **instructional safeguard** similar to the above marking shall appear together in the instructions. Where a symbol is used, its meaning shall be explained in the instructions.

If **skilled persons** are likely to be exposed to higher emissions than those specified above, and it is necessary for the equipment to remain energized while being serviced, an **instructional safeguard** shall be provided in accordance with Clause F.5 and be comprised of:

- the symbol , consisting of IEC 60417-5012 (2002) combined with the triangle shaped warning sign from ISO 3864-2, or
- the following statement or equivalent text:

WARNING Use eye protection during servicing.
--

The marking shall be located where readily visible during the servicing operation.

If the visible radiation symbol is used on the equipment, both the symbol and an **instructional safeguard** similar to the above marking shall appear together in the service instructions.

10.3.1.3.3 Compliance

Compliance is checked by evaluation of available data sheets, by inspection and, if necessary, by measurement.

NOTE For guidance on measuring techniques, see IEC 62471.

10.3.2 Non-ionizing radiation from radio frequencies in the range 0 Hz to 300 GHz

These types of radiation are not covered by this standard.

NOTE 1 National regulations apply.

NOTE 2 In the member countries of CENELEC, the amount of non-ionizing radiation is regulated by European Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz).

NOTE 3 For intentional radiators, ICNIRP guidelines should be taken into account for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz). For hand-held and body-mounted devices, attention is drawn to IEC 62209-1 and IEC 62209-2.

10.3.3 Protection of persons from ionizing radiation (X-radiation)

10.3.3.1 General

This subclause defines the level of ionising radiation to reduce the risk of injury to persons, and describes the method of measurement for ionising radiation.

10.3.3.2 Requirements

Equipment shall not generate ionising radiation at levels that are injurious to persons. For an **ordinary person** and an **instructed person**, the limits of RS1 shall not be exceeded. For **skilled persons**, the limits of RS2 shall not be exceeded.

An **equipment safeguard** shall be interposed between all persons and a RS2 or RS3. In addition, if a **skilled person** may be exposed to RS2, then an **instructional safeguard** is required.

10.3.3.3 Compliance

*For RS1, at any point 50 mm from the surface of the area **accessible to ordinary persons** and **instructed persons**, the dose-rate shall not exceed 36 pA/kg (5 μ Sv/h, or 0,5 mR/h).*

NOTE 1 This value is consistent with International Commission on Radiation Protection (ICRP) Publication 60.

*For RS2, for protection of a **skilled person**, an additional measurement is made with any part of the cabinet, case, and chassis removed per maintenance instructions (CRT exposed) at the maximum test voltage applicable and under the conditions in accordance with 10.3.3.4. At any point 100 mm from the outer surface of any component of the equipment, the dose-rate shall not exceed 185 pA/kg (25 μ Sv/h, or 2,5 mR/h).*

NOTE 2 In the member countries of CENELEC, the amount of ionizing radiation is regulated by European Council Directive 96/29/Euratom of 13 May 1996. This Directive requires that at any point 100 mm from the surface of the equipment, the dose-rate shall not exceed 1 μ Sv/h (0,1 mR/h) taking account of the background level. For complete requirements refer to the above Directive.

NOTE 3 In the USA, the measuring conditions in the U.S. Code of Federal Regulations Title 21 Part 1020 are as given below (for complete requirements, refer to the above regulations).

Measurements are made with the equipment under test connected to the following source of supply:

- 130 V if the **rated voltage** is between 110 V and 120 V;
- 110 % of the **rated voltage**, if the **rated voltage** is not between 110 V and 120 V.

During the measurements:

- all user and service **accessible** controls are adjusted to combinations that produce maximum x-radiation emissions; and
- **abnormal operating conditions** of any component or circuit malfunction causing an increase of x-radiation emissions are to be simulated.

NOTE 4 In Canada, the measuring conditions in the Consolidated Regulations of Canada, c.1370 are as given below (for complete requirements refer to the above regulations).

Measurements are made with the equipment under test connected to the following source of supply:

- 127 V if the **rated voltage** is between 110 V and 120 V;
- 110 % of the **rated voltage**, if the **rated voltage** is not between 110 V and 120 V.

During the measurements all user and service **accessible** controls are adjusted to combinations that produce maximum x-radiation emissions.

10.3.3.4 Test method

Equipment that is likely to produce ionizing radiation is checked by measuring the amount of radiation. Account is taken of the background level.

The amount of radiation is determined by means of a radiation monitor of the ionizing chamber type with an effective area of 1 000 mm² or by measuring equipment of other types giving equivalent results.

*Measurements are made with the equipment under test operating at the most unfavourable supply voltage (see B.2.3) and with controls for an **ordinary person** and an **instructed person**, and controls for a **skilled person** that are not locked in a reliable manner, adjusted so as to give maximum radiation whilst maintaining the equipment operative for normal use.*

NOTE 1 Soldered joints and fixing by application of paint, epoxy, or similar materials are considered reliable locking means.

*Moreover, the measurement shall be made under any **abnormal operating condition** and **single fault conditions** that can cause an increase of the high-voltage, provided an intelligible picture is maintained for 5 min, at the end of which the measurement is made and averaged over 5 min.*

During the measurements, an intelligible picture is to be maintained.

A picture is considered to be intelligible if the following conditions are met:

- *a scanning amplitude of at least 70 % of the usable screen for both width and height;*
- *a minimum luminance of 50 cd/m² with locked blank raster provided by a test generator;*
- *not more than 12 flashovers in a 1 h period;*
- *a horizontal resolution corresponding to at least 1,5 MHz in the centre with a similar vertical degradation.*

NOTE 2 In the USA and Canada, an intelligible picture is in synchronization while covering 60 % of the viewable screen area.

10.3.4 Protection of materials from lamps that produce UV radiation

Materials that are exposed to UV radiation from a lamp in the equipment shall be sufficiently resistant to degradation to the extent that safety is not affected.

NOTE Metals, glass and ceramic materials do not need to be assessed.

Compliance is checked by the tests in Annex C.

10.4 Protection against acoustic energy sources

10.4.1 General

This subclause specifies **safeguard** requirements for protection from acoustic energy sources that are closely coupled to the ear, for all persons.

NOTE In Australia the limits in AS/ACIF S004 apply for telecommunications-network-connected equipment.

10.4.2 Requirements

The following shall comply with the requirements of 10.4.3:

small battery powered equipment whose purpose is to listen to recorded or broadcasted sound, that uses wired headphones or earphones that can be worn in or on or around the ears, and that allows the user to walk around.

NOTE 1 Examples are portable mini-disk or CD players, MP3 audio players or similar equipment.

NOTE 2 Other equipment is under consideration.

10.4.3 Protection of ordinary persons

An **instructional safeguard** shall be provided in accordance with Clause F.5, using the following wording or similar:

To prevent possible hearing damage, do not listen at high volume levels for long periods. As a guide to setting the volume level, check that you can still hear your own voice, when speaking normally while listening with the headphones.
--

NOTE The **instructional safeguard** indicates that exposure to an acoustic energy source over extended periods may cause injury. The **instructional safeguard** provides sufficient information to enable the consumer to understand the effect of listening to loud sound levels.

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Annex A (informative)

Examples of equipment within the scope of this standard

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

Generic product type	Specific example of generic type
Banking equipment	Monetary processing machines including automated teller (cash dispensing) machines (ATM)
Consumer electronic equipment (including professional audio, video and musical instrument equipment)	Receiving equipment and amplifiers for sound and/or vision, supply equipment intended to supply other equipment covered by the scope of this standard, electronic musical instruments, and electronic accessories such as rhythm generators, tone generators, music tuners and the like for use with electronic or non-electronic musical instruments, audio and/or video educational equipment, video projectors, video cameras and video monitors, video games, juke boxes, record and optical disc players, tape and optical disc recorders, antenna signal converters and amplifiers, antenna positioners, Citizen's Band equipment, equipment for imagery, electronic light effect equipment, intercommunication equipment using low voltage mains as the transmission medium, cable head-end receivers, multimedia equipment, electronic flash equipment
Data and text processing machines and associated equipment	Data preparation equipment, data processing equipment, data storage equipment, personal computers, plotters, printers, scanners, text processing equipment, visual display units
Data network equipment	Bridges, data circuit terminating equipment, data terminal equipment, routers
Electrical and electronic retail equipment	Cash registers, point of sale terminals including associated electronic scales
Electrical and electronic office machines	Calculators, copying machines, dictation equipment, document shredding machines, duplicators, erasers, micrographic office equipment, motor-operated files, paper trimmers (punchers, cutting machines, separators), paper jogging machines, pencil sharpeners, staplers, typewriters
Other information technology equipment	Photoprinting equipment, public information terminals, multimedia equipment
Postage equipment	Mail processing machines, postage machines
Telecommunication network infrastructure equipment	Billing equipment, multiplexers, network powering equipment, network terminating equipment, radio base stations, repeaters, transmission equipment, telecommunication switching equipment
Telecommunication terminal equipment	Facsimile equipment, key telephone systems, modems, PABXs, pagers, telephone answering machines, telephone sets (wired and wireless)

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

Annex B

(normative)

Normal operating condition tests, abnormal operating condition tests and single fault condition tests

B.1 General

B.1.1 Introduction

This annex specifies various tests and test conditions applicable to the equipment.

B.1.2 Test applicability

If it is evident that a particular test is not applicable, or not necessary after inspection of available data, the test shall not be made. Tests in this standard shall be conducted only if safety is involved.

In order to establish whether or not a test is applicable, the circuits and construction shall be carefully investigated to take into account the consequences of possible faults. The consequence of a fault may or may not require the use of a **safeguard** to reduce the likelihood of injury or fire.

B.1.3 Type of test

Except where otherwise stated, tests specified are **type tests**.

B.1.4 Test samples

Unless otherwise specified, the sample under test shall be representative of the actual equipment or shall be the actual equipment.

As an alternative to conducting tests on the complete equipment, tests may be conducted separately on circuits, components or sub-assemblies outside the equipment, provided that inspection of the equipment and circuit arrangements ensure 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 could be destructive, a model may be used to represent the condition to be evaluated.

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

B.1.5 Measurement of voltages to earth

Where the standard specifies a voltage between a conductive part and earth, all of the following earthed parts are considered:

- the protective earthing terminal (if any); and
- any other conductive part required to be connected to protective earth (for example, see 5.6); and
- any conductive part that is earthed within the equipment for functional reasons.

Parts that will be earthed in the application by connection to other equipment, but are unearthed in the equipment as tested, shall be connected to earth at the point by which the highest voltage is obtained.

When measuring a voltage between earth and a conductor in a circuit that will not be earthed in the intended application of the equipment, a non-inductive resistor of $5\,000\ \Omega \pm 10\%$ shall be connected across the voltage measuring instrument.

The voltage drop in the **protective earthing conductor** of the power supply cord, or in an earthed conductor in other external wiring, is not included in the measurements.

B.1.6 Compliance by inspection of relevant data

Where in this standard compliance of materials, components or subassemblies is checked by inspection or by testing of properties, compliance may be confirmed by reviewing any relevant data or previous test results that are available instead of carrying out the specified **type tests**.

B.1.7 Temperature measurement conditions

The test measurement set-up shall reproduce the most severe equipment 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 $25\ ^\circ\text{C}$ when the equipment is operating. However, the manufacturer may specify a different maximum ambient air temperature.

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

With reference to those tests that are to be continued until steady state temperatures are attained, thermal equilibrium is considered to exist if the temperature rise does not exceed $3\ \text{K}$ in $30\ \text{min}$. If the measured temperature is at least 10% less than the specified temperature limit, thermal equilibrium is considered to exist if the temperature rise does not exceed $1\ \text{K}$ in $5\ \text{min}$.

Unless a particular method is specified, temperatures of windings shall be determined either by the thermocouple method or by any other method giving the average temperature of the winding wires such as the resistance method.

B.2 Normal operating conditions

B.2.1 General

Except where specific test conditions are stated elsewhere and where it is clear that there is a significant impact on the results of the test, the tests shall be conducted under the most unfavourable **normal operating conditions** taking into account the following parameters:

- supply voltage;
- supply frequency;
- environmental conditions (for example, the manufacturer's rated maximum ambient temperature);
- physical location of equipment and position of movable parts, as specified by the manufacturer;
- operating mode, including external loading due to interconnected equipment;
- adjustment of a control.

For audio amplifiers and equipment containing an audio amplifier, additional test conditions apply, see Annex E.

B.2.2 Supply frequency

In determining the most unfavourable supply frequency for a test, different frequencies within the **rated frequency** range shall be taken into account (for example, 50 Hz and 60 Hz) but consideration of the tolerance on a **rated frequency** (for example, 50 Hz $\pm$ 0,5 Hz) is not necessary.

B.2.3 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 % for a.c. **mains** and +20 % and –15 % for d.c. **mains** only.

Where a test subclause does not require the most unfavourable supply voltage (by not making a specific reference to B.2.3), the supply voltage is the value of the **rated voltage** or any value in the **rated voltage range**.

B.2.4 Normal operating voltages

The following voltages shall be considered:

- normal operating voltages generated in the equipment, including repetitive peak voltages such as those associated with switch mode power supplies;
- normal operating voltages generated external to the equipment, including ringing signals received from **external circuits** as indicated in Table 16, ID numbers 11, 12, 13 and 14.

Externally generated **mains transient voltages** and **external circuit** transient voltages shall not be considered:

- when determining **working voltages**, because such transients have been taken into account in the procedures for determining minimum **clearances** (see 5.4.2);
- when classifying circuits in the equipment as ES1, ES2 and ES3 (see 5.2).

B.2.5 Input test

In determination of the input current or input power, the following variables shall be considered:

- 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 that is **accessible** to an **ordinary person**, up to the value specified by the manufacturer;
- for equipment containing an audio amplifier, see Annex E;
- for displays with moving images, the following settings shall apply:
 - the 'Three vertical bar signal' shall be used as defined in 3.2.1.3 of IEC 60107-1:1997; and

- user **accessible** picture controls shall be adjusted so as to obtain the maximum power consumption; and
- sound settings shall be as defined in Clause E.1 of this standard.

Artificial loads may be used to simulate such loads during testing.

In each case, the readings are taken when the input current or input power has stabilized. If the current or power varies during the normal operating cycle, the steady-state current or power is taken as the mean indication of the value, measured on a recording r.m.s. ammeter or power meter, during a representative period.

Compliance is checked by measuring the input current or input power of the equipment under the following conditions:

- where equipment has more than one **rated voltage**, the input current or input power is measured at each **rated voltage** and at each tolerance of the **rated voltage**;
- where equipment has one or more **rated voltage ranges**, the input current or input power is measured at each end of each **rated voltage range** and at the tolerance of each end of each **rated voltage range**
 - where a single value of **rated current** or **rated power** is marked, it is compared with the higher value of input current or input power measured in the associated **rated voltage range**, but excluding the tolerances on the voltages,
 - where two values of **rated current** or **rated power** are marked, separated by a hyphen, they are compared with the two values measured in the associated **rated voltage range** but excluding the tolerances on the voltages.

The measured input current or input power under **normal operating conditions**, but at the **rated voltage** or at any voltage within the **rated voltage range**, shall not exceed the **rated current** or **rated power** by more than 10 %.

B.2.6 Operating temperature measurement conditions

B.2.6.1 General

Temperatures measured on the equipment shall conform to B.2.6.2 or B.2.6.3, as applicable, all temperatures being in degrees Celsius (°C); where

- T is the temperature of the given part measured under the prescribed test conditions;
- $T_{\max}$ is the maximum temperature specified for compliance with the test;
- T_{amb} is the ambient temperature during test;
- T_{ma} is the maximum ambient temperature specified by the manufacturer, or 25 °C, whichever is greater.

B.2.6.2 Operating temperature dependent heating/cooling

For equipment where the amount of heating or cooling is designed to be dependent on temperature (for example, the equipment contains a fan that has a higher speed at a higher temperature), the temperature measurement is made at the least favourable ambient temperature within the manufacturer's specified operating range. In this case:

T shall not exceed $T_{\max}$.

NOTE 1 In order to find the highest value of T for each component, it may be necessary to conduct several tests at different values of T_{amb} .

NOTE 2 The least favourable value of T_{amb} may be different for different components.

Alternatively, the temperature measurement may be made under ambient conditions with the heating/cooling device at its least effective setting or with the device defeated.

B.2.6.3 Operating temperature independent heating/cooling

For equipment where the amount of heating or cooling is not designed to be dependent on ambient temperature, the method in B.2.6.2 may be used. Alternatively, the test is performed at any value of T_{amb} within the manufacturer's specified operating range. In this case:

T shall not exceed $(T_{max} + T_{amb} - T_{ma})$.

During the test, T_{amb} should not exceed T_{ma} unless agreed by all parties involved.

B.2.7 Battery charging under normal operating conditions

Under **normal operating conditions**, the **maximum charging current**, **upper limit charging voltage**, **lowest charging temperature** and the **highest charging temperature** shall comply with the requirements of Annex M as applicable.

B.3 Simulated abnormal operating conditions

B.3.1 General

When applying simulated **abnormal operating conditions**, parts, supplies, and media shall be in place if they are likely to have an effect on the outcome of the test.

Each **abnormal operating condition** shall be applied in turn, one at a time.

Faults that are the direct consequence of the **abnormal operating condition** are deemed to be a **single fault condition**.

The equipment, installation, instructions, and specifications shall be examined to determine those **abnormal operating conditions** that might reasonably be expected to occur.

As a minimum, the following examples of **abnormal operating conditions** shall be considered, as applicable, in addition to those mentioned in B.3.2 to B.3.7:

- for paper handling equipment, a paper jam;
- for equipment with controls **accessible** to an **ordinary person**, adjustment of the controls, both individually and collectively, for worst-case operating conditions;
- for audio amplifiers with controls **accessible** to an **ordinary person**, adjustment of the controls, both individually and collectively, for worst-case operating conditions, without applying the conditions specified in Annex E;
- for equipment with moving parts **accessible** to an **ordinary person**, a moving parts jam;
- for equipment with media, incorrect media, incorrect size media, and incorrect media quantity;
- for equipment with replenishable liquids or liquid cartridges, or replenishable materials, liquids or materials spilled into the equipment.

Before introducing any of the above **abnormal operating conditions**, the equipment shall be operating under **normal operating conditions**.

B.3.2 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 (thick, stiff paper or thin cardboard) of 200 g/m² 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° and smaller than 60° 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 are no requirements for blocking openings in the bottom of the equipment.

B.3.3 DC mains polarity test

If the connection to the d.c. **mains** is not polarized and the connection is **accessible** to an **ordinary person**, then the possible influence of polarity shall be taken into account when testing equipment designed for d.c.

B.3.4 Setting of voltage selector

Equipment to be supplied from the **mains** and provided with a voltage setting device to be set by the **ordinary person** or an **instructed person**, is tested with the **mains** voltage setting device at the most unfavourable position.

B.3.5 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.3.6 Reverse battery polarity

If it is possible for an **ordinary person** to insert replaceable batteries with reversed polarity, the equipment is tested in all possible configurations with one or more batteries reversed (see also Annex M).

B.3.7 Audio amplifier abnormal operating conditions

Abnormal operating conditions for audio amplifiers are specified in Clause E.2.

B.3.8 Compliance during and after abnormal operating conditions

*During an **abnormal operating condition** that does not lead to a **single fault condition**, all **safeguards** shall remain effective. After restoration of **normal operating conditions**, all **safeguards** shall comply with applicable requirements.*

*If an **abnormal operating condition** leads to a **single fault condition**, Clause B.4 applies.*

B.4 Simulated single fault conditions

B.4.1 General

When applying simulated **single fault conditions**, parts, supplies, and media shall be in place if they are likely to have an effect on the outcome of the test.

The introduction of any **single fault condition** shall be applied in turn one at a time. Faults, that are the direct consequence of the **single fault condition**, are deemed to be part of that **single fault condition**.

The equipment, circuit diagrams and component specifications are examined to determine those **single fault conditions** that might reasonably be expected to occur.

The following **single fault conditions** shall be considered:

- an **abnormal operating condition** that results in a **single fault condition**. For example, an **ordinary person** overloading external output terminals, or an **ordinary person** incorrectly setting a selector switch;
- a **basic safeguard** failure or a **supplementary safeguard** failure;
- except for **safeguard** components (that is, components complying with Clause G.13), a component failure simulated by short-circuiting any two leads and open-circuiting any one lead of the component;
- when required by B.4.4, a failure of **functional insulation**.

B.4.2 Temperature controlling device

Except for temperature controlling **safeguards**, according to Clauses G.2 to G.5, any single device or component of a circuit controlling the temperature during temperature measurement shall be open-circuited or short-circuited, whichever is more unfavourable.

Temperatures shall be measured according to B.1.7.

B.4.3 Motor tests

B.4.3.1 Blocked motor test

Motors are blocked or the rotor is locked in the end product if it is obvious that such an action will result in an increase in internal ambient temperature of the equipment (for example, locking the rotor of the fan motor to stop air flow).

B.4.3.2 Compliance

Compliance is checked by inspection and examination of the available data or by testing according to Clause G.8.

B.4.4 Short circuit of functional insulation

B.4.4.1 Short circuit of clearances for functional insulation

Unless the **clearance** for **functional insulation** complies with the **clearance** for **basic insulation** or with the electric strength test of Table 31 for **basic insulation**, **clearances** for **functional insulation** shall be short-circuited.

B.4.4.2 Short circuit of creepage distances for functional insulation

Unless the **creepage distance** for **functional insulation** complies with the **creepage distance** for **basic insulation** or with the electric strength test of 5.4.11.1 for **basic insulation**, **creepage distances** for **functional insulation** shall be short-circuited.

B.4.4.3 Short circuit of functional insulation on coated printed boards

Unless the **functional insulation** complies with the separation distance of Table G.12 or with the electric strength test of 5.4.11.1 for **basic insulation**, **functional insulation** on a coated printed board shall be short-circuited.

B.4.5 Short circuit and interruption of electrodes in tubes and semiconductors

Electrodes in electronic tubes and leads of semiconductor devices shall be short-circuited, or if applicable, interrupted. One lead at a time is interrupted or any two leads connected together in turn. See B.4.1 for exceptions to this test.

B.4.6 Short circuit or disconnection of passive components

Resistors, capacitors, windings, loudspeakers, VDRs and other passive components shall be short-circuited or disconnected, whichever is more unfavourable.

These **single fault conditions** do not apply to:

- PTC thermistors complying with IEC 60730-1:1999, Clauses 15, 17, J.15 and J.17;
- a PTC providing IEC 60730-1 Type 2.A.L. action;
- short circuit between the input and output terminations of optocouplers that comply with the relevant **clearances**, **creepage distances** and distance through insulation requirements of this standard;
- short circuit between the input and output of transformers that comply with the relevant **clearances** and **creepage distances** requirements of this standard;
- resistors complying with the tests of 5.5.3.6 and 5.5.4;
- capacitors complying with IEC 60384-14 and assessed according to 5.5.3.2 of this standard;
- components complying with the safety requirements of relevant IEC component standards or complying with Annex G.

B.4.7 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 **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-offs** are not short-circuited.*

*In circuits not directly connected to the **mains** and in circuits supplied by a d.c. power distribution system, 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 an **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 (for example, burn-out) or to other consequences of the simulated fault condition, whichever is shorter.*

B.4.8 Compliance during and after single fault conditions

*During and after a **single fault condition**, a class 1 energy source or class 2 energy source shall not become a class 3 energy source.*

*For a class 3 energy source, during and after a **single fault condition**, at least one **safeguard** shall continue to comply with the requirements for that **safeguard**.*

B.4.9 Battery charging under single fault conditions

Under **single fault conditions**, the **maximum charging current**, **upper limit charging voltage**, **lowest charging temperature** and the **highest charging temperature** shall comply with the requirements of Annex M as applicable.

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Annex C (normative)

UV radiation

C.1 Protection of materials in equipment from UV radiation

C.1.1 General

This annex defines the test requirements and test procedures for materials that have safety properties and that are subject to UV radiation exposure.

C.1.2 Requirements

The following requirements apply only to equipment containing lamps that produce significant UV radiation in the spectrum 180 nm to 400 nm, as specified by the lamp manufacturer.

NOTE 1 General-purpose incandescent and fluorescent lamps, with ordinary glass envelopes, are not considered to emit significant UV radiation.

NOTE 2 Filters and/or lenses may provide a **safeguard** and may serve as part of the **enclosure**.

Table C.1 – Minimum property retention limits after UV exposure

Parts to be tested	Property	Standard for the test method	Minimum retention after test
Parts providing mechanical support	Tensile strength ^a	ISO 527 series	70 %
	or flexural strength ^{a b}	ISO 178	70 %
Parts providing impact resistance	Charpy impact ^c or	ISO 179-1	70 %
	Izod impact ^c or	ISO 180	70 %
	Tensile impact ^c	ISO 8256	70 %
All parts	Material flammability class	See Clause S.4 of this standard	^d

^a Tensile strength and flexural strength tests are to be conducted on specimens no thicker than the actual thicknesses.
^b The side of the sample exposed to UV radiation is to be in contact with the two loading points when using the three point loading method.
^c Tests conducted on 3,0 mm thick specimens for Izod impact and tensile impact tests and 4,0 mm thick specimens for Charpy impact tests are considered representative of other thicknesses, down to 0,75 mm.
^d The **material flammability class** may change as long as it does not fall below that specified in Clause 6 of this standard.

C.1.3 Test method

Compliance is checked by examination of the construction and of available data regarding the UV resistance characteristics of the parts exposed to UV radiation in the equipment. If such data is not available, the tests in Table C.1 are carried out on the parts.

Samples taken from the parts, or consisting of identical material, are prepared according to the standard for the test to be carried out. They are then exposed to UV radiation (conditioned) according to Clause C.2. After conditioning, the samples shall show no signs of significant deterioration, such as crazing or cracking. They are then kept at room ambient conditions for not less than 16 h and not more than 96 h, after which they are tested according to the standard for the relevant test.

In order to evaluate the percentage retention of properties after test, samples that have not been conditioned according to Clause C.2 are tested at the same time as the conditioned samples.

The retention shall be as specified in Table C.1.

C.2 UV light conditioning test

C.2.1 Test apparatus

Samples are exposed to UV light by using one of the following apparatus:

- *a twin enclosed carbon-arc (see C.2.3) with continuous exposure. The test apparatus shall operate with a black-panel temperature of $63\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$; or*
- *a xenon-arc (see C.2.4) with continuous exposure. The test apparatus shall operate with a 6 500 W, water-cooled xenon-arc lamp, a spectral irradiance of $0,35\text{ W/m}^2$ at 340 nm, a black-panel temperature of $63\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$.*

C.2.2 Mounting of test samples

The samples are mounted vertically on the inside of the cylinder of the light exposure apparatus, with the widest portion of the samples facing the arcs. They are mounted so that they do not touch each other.

C.2.3 Carbon-arc light-exposure test

The apparatus described in ISO 4892-4, or equivalent, is used in accordance with the procedures given in ISO 4892-1 and ISO 4892-4 using a type 1 filter, without water spray.

NOTE The wording "without water spray" indicates that the samples are not sprayed with water during the test. This should not be confused with water cooling that is necessary for operation of the apparatus.

Materials are exposed to the light continuously for a minimum of 720 h.

Materials tested with water spray are also considered acceptable.

C.2.4 Xenon-arc light-exposure test

The apparatus described in ISO 4892-2, or equivalent, is used in accordance with the procedures given in ISO 4892-1 and ISO 4892-2:2006 using cycle 2 of method A of Table 3, without water spray.

NOTE The wording "without water spray" indicates that the samples are not sprayed with water during the test. This should not be confused with water cooling that is necessary for operation of the apparatus.

Materials are exposed to the light continuously for a minimum of 1 000 h.

Materials tested with water spray are also considered acceptable.

Annex D (normative)

Test generators

D.1 Impulse test generators

These circuits produce test pulses as referenced in Table D.1. In this table:

- the circuit 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 circuit 2 surge is typical of earth potential rises due to either lightning strikes to power lines or power line faults;
- the circuit 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 .

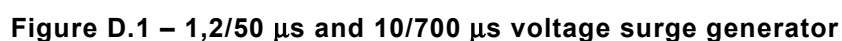
The circuit in Figure D.1, using the component values in circuits 1 and 2 of Table D.1, is used to generate impulses, the C_1 capacitor being charged initially to a voltage U_C .

Circuit 1 of Table D.1 generates 10/700 μs impulses (10 μs virtual front time, 700 μs virtual time to half value) to simulate transients in **external circuits** as indicated in Table 16, ID numbers 11, 12, 13, 14, 15, 16 and 17.

Circuit 2 of Table D.1 generates 1,2/50 μs impulses (1,2 μs virtual front time, 50 μs virtual time to half value) to simulate transients in power distribution systems.

The impulse wave shapes are under open-circuit conditions and can be different under load conditions.

*During the test, the peak voltage of the applied impulse shall not be less than the peak impulse test voltage (for example, see Table 20) and the pulse shape (for example, 1,2 μs virtual front time, 50 μs virtual time to half value for the 1,2/50 μs impulse) shall remain substantially the same as under open-circuit conditions. Components in parallel with the **clearance** may be disconnected during this test.*



The circuit in Figure D.1 using the component values of circuit 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 Table D.1 is a critical part of the circuit.

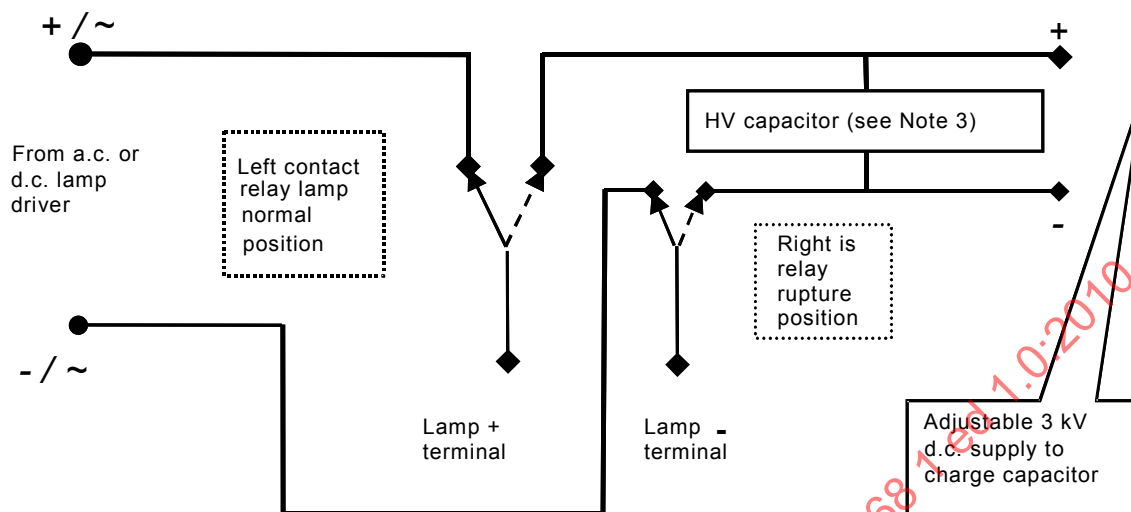


Table D.1 – Component values for Figure D.1 and Figure D.2

	Test impulse	Figure	R_s	C_1	C_2	R_1	R_2	R_3
Circuit 1	10/700 μ s	D.1	-	20 μ F	0,2 μ F	50 Ω	15 Ω	25 Ω
Circuit 2	1,2/50 μ s	D.1	-	1 μ F	30 nF	76 Ω	13 Ω	25 Ω
Circuit 3	-	D.2	15 M Ω	1 nF	-	1 k Ω	-	-

NOTE Circuits 1 and 2 are based on ITU-T Recommendation K.44.

D.3 Electronic pulse generator



NOTE 1 The operating pressure of the lamp can be converted to energy (Joules). The operating energy level is the recommended starting point for the test charge.

NOTE 2 The relay is a 5 kV double pole defibrillator type, nitrogen filled. A defibrillator qualified relay is sufficient. See IEC 60601-2-4.

NOTE 3 The HV capacitor is rated 0,42 μ F 5 kV.

Figure D.3 – Example of an electronic pulse generator

Annex E (normative)

Test conditions for equipment containing audio amplifiers

E.1 Audio amplifier normal operating conditions

Audio amplifiers shall operate at a frequency of 1 000 Hz. In cases where an amplifier is not intended for operation at 1 000 Hz, the **peak response frequency** shall be used.

All of the following shall be considered under **normal operating conditions**:

- a) The equipment shall be operated in such a way as to deliver 1/8 **non-clipped output power** to the **rated load impedance**. Alternatively, a band-limited pink noise signal may be used for operation after **non-clipped output power** is established using a sine wave. The noise bandwidth of the test signal shall be limited by a filter of a characteristic as shown in Figure E.1.

If clipping cannot be attained, the maximum attainable power shall be considered as the **non-clipped output power**.

Tone controls are to be set at mid-range.

- b) The most unfavourable **rated load impedance** or open circuit of any output whichever is most onerous.
- 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 and the equipment shall be adjusted to deliver 1/8 of the maximum attainable output power.
- d) 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.
- e) Where the intended amplifier function depends on phase difference between two channels, there shall be a phase difference of 90° between signals applied to the two channels. For multi-channel amplifiers, where some channels cannot be operated independently, those channels shall be loaded to 1/16 of the **non-clipped output power**.
- f) When determining whether a part or terminal contact is above ES1 or ES2 (see Table E.1), the equipment shall be operated to deliver maximum **non-clipped output power** into its **rated load impedance**. The load is removed and the electrical energy source class is determined from the resulting open-circuit output voltage.
- g) The temperature measurements shall be carried out with the equipment positioned in accordance with the instruction manual provided by the manufacturer, or, in the absence of instructions, the equipment shall be positioned 5 cm behind the front edge of an open-fronted wooden test box with 1 cm free space along the sides and top and 5 cm depth behind the equipment.

Table E.1 – Audio signal electrical energy source classes and safeguards

Audio signal voltage V r.m.s.	Class	Examples of safeguards between energy source and ordinary person	Example of safeguards between energy source and instructed person
0 up to 71	ES1	No safeguard necessary	No safeguard necessary
Above 71 and up to 120	ES2	Insulated terminals ^a marked with ISO 7000:2004, symbol  0434a or symbol  0434b	No safeguard necessary
		Instructional safeguard for uninsulated parts of terminals and bare wiring ^b	
Above 120	ES3	Connectors conforming to the requirements of IEC 61984 and marked with  , IEC 60417-5036 (2002)	

NOTE When using a single-pole plug or a bare wire to make connection with a contact of a terminal for earth or antenna or for audio, video or associated signals, accessibility is determined by the use of test probe in Figure V.5. The test is not applied to terminals marked with the symbol IEC 60417-5036 (2002).

^a Terminals that have no conductive parts **accessible** after wiring are installed according to instructions.

^b An **instructional safeguard** indicating that touching uninsulated terminals or wiring may result in an unpleasant sensation.

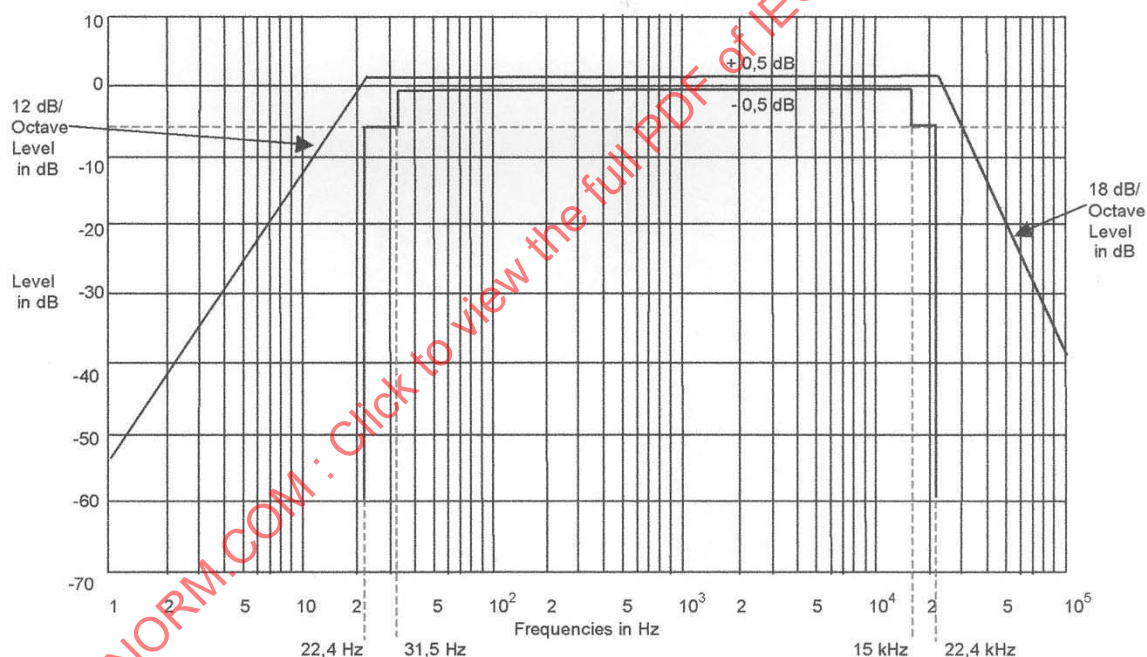


Figure E.1 – Band-pass filter for wide-band noise measurement

For equipment containing an audio amplifier, if continuous operation is not possible, the amplifier shall be operated at the maximum signal level that allows continuous operation.

E.2 Audio amplifier abnormal operating conditions

Abnormal operating conditions shall be simulated by adjusting the controls to the most unfavourable output power from zero up to the maximum attainable output power into the most unfavourable **rated load impedance** connected to the output terminals. Short circuit of the output terminals is also considered to be an **abnormal operating condition**.

Annex F (normative)

Equipment markings, instructions, and instructional safeguards

F.1 General

This annex specifies equipment markings, equipment instructions, and **instructional safeguards** necessary for equipment installation, operation, maintenance, and servicing in accordance with the requirements of this standard.

Unless symbols are used, safety related equipment marking, instructions and **instructional safeguards** must be in a language accepted in the respective countries.

This annex does not apply to markings on components. Markings on components are specified in the relevant component standard.

This annex may apply to sub-assemblies such as power supplies.

NOTE 1 Where the term marking is used in the standard, it also applies to instructions and required elements of an **instructional safeguard**.

NOTE 2 See Table F.1 for examples of markings. Equipment markings and instructions are not limited to those specified in this annex. Equipment may bear additional markings and may be provided with additional instructions not required by this annex. Other applicable standards and regulations may require additional markings or instructions. However, care shall be taken so that additional markings and instructions do not contradict the markings and instructions required by this annex.

F.2 Letter symbols and graphical symbols

F.2.1 Letter symbols

Letter symbols for quantities and units shall be in accordance with IEC 60027-1.

F.2.2 Graphical symbols

Graphical symbols shall be in accordance with IEC 60417 or ISO 3864-2 or ISO 7000. In the absence of suitable symbols in IEC 60417 or ISO 3864-2 or ISO 7000, the manufacturer may design specific graphical symbols.

NOTE A new symbol should be developed according to human factor principles and according to ISO 3864-2.

F.2.3 Compliance

Compliance is checked by inspection.

F.3 Equipment markings

F.3.1 Equipment marking locations

In general, equipment markings shall be located near or adjacent to the part or region that is the subject of the marking.

Equipment markings specified in F.3.2, F.3.3, F.3.6.2 and F.3.7 shall be on the exterior of the equipment, excluding the bottom. However, these markings may be in an area that is easily **accessible** by hand, for instance

- under a lid, or
- on the exterior of the bottom of
 - **direct plug-in equipment, hand-held equipment, transportable equipment, or**
 - **movable equipment** with a mass not exceeding 18 kg, provided that the location of the marking is given in the instructions.

Markings shall not be put on parts that can be removed without the use of a **tool**, unless they apply to this part

For **permanently connected equipment**, installation instructions shall be provided either as markings on the equipment, or in the instructions, or in a separate installation instruction document.

For rack or panel mounted equipment exceeding 18 kg, markings may be on any surface that becomes visible after removal of the equipment from the rack or panel.

Unless the meaning of the marking is obvious, the marking shall be explained in the instructions.

Compliance is checked by inspection.

F.3.2 Equipment identification markings

F.3.2.1 Manufacturer identification

The manufacturer or responsible vendor shall be identified by means of a marking on the equipment. Identification may be the manufacturer's name, the responsible vendor's name, trademark, or other equivalent identification.

F.3.2.2 Model identification

The model number, model name, or equivalent shall be identified by means of a marking on the equipment.

F.3.2.3 Compliance

Compliance is checked by inspection.

F.3.3 Equipment rating markings

F.3.3.1 Equipment without direct connection to mains

If a unit is not provided with a means for direct connection to the **mains**, it need not be marked with any electrical rating, such as its **rated voltage, rated current, rated power** or **rated frequency**.

F.3.3.2 Nature of the supply voltage

The nature of the supply voltage, d.c., a.c., or three-phase a.c., shall be marked on the equipment and shall immediately follow the equipment voltage rating. If a symbol is used to identify a.c. or d.c., the symbol $\sim$ IEC 60417-5032 (2002), shall be used for a.c. and the symbol $\equiv$ IEC 60417-5031 (2002), shall be used for d.c.

Three-phase equipment may be identified with “3-phase” or “3Ø” or any other arrangement that clearly indicates the phase of the supply voltage of the equipment.

F.3.3.3 Rated voltage

The **rated voltage** of the equipment shall be marked on the equipment. The voltage rating marking shall be immediately followed by the nature of the supply marking.

The **rated voltage** may be:

- a single, nominal value, or
- a single nominal value and a tolerance percentage of the nominal value, or
- two or more nominal values separated by a solidus (/), or
- a range indicated by minimum and maximum values separated by a hyphen, or

any other arrangement that clearly indicates the voltage of the equipment.

If the equipment has more than one nominal voltage, all such voltages may be marked on the equipment. However, the voltage for which the equipment is set shall be clearly indicated (see F.3.4).

Three-phase equipment shall be marked with the phase-to-phase voltage, a symbol indicating power supply system in accordance with IEC 61293, a solidus (/), the phase-to-neutral voltage, the symbol for voltage (V) and the number of phases, in that order. Any other arrangement that clearly indicates the three-phase **rated voltage** of the equipment is also acceptable.

NOTE The solidus (/) represents the word “or” and the hyphen (-) represents the word “to”.

F.3.3.4 Rated frequency

The **rated frequency** of the equipment shall be marked on the equipment.

The **rated frequency** may be:

- a single, nominal value, or
- a single nominal value and a tolerance percentage of the nominal value, or
- two or more nominal values separated by a solidus (/), or
- a range indicated by minimum and maximum values separated by a hyphen, or
- any other arrangement that clearly indicates the **rated frequency** of the equipment.

F.3.3.5 Rated current or rated power

The **rated current** or **rated power** of the equipment, as determined according to B.2.5, shall be marked on the equipment.

For three-phase equipment, the **rated current** or **rated power** is the current or power of one phase.

NOTE 1 The **rated current** or **rated power** need not be stated to more than one significant digit.

NOTE 2 In some countries, for markings on equipment, a comma is required as the decimal designator.

If the equipment has a socket-outlet for providing **mains** power to other equipment, the **rated current** or **rated power** of the equipment shall include the assigned current or power of the socket-outlet.

See F.3.5.1 for marking requirements for a **mains** socket-outlet.

If the equipment has more than one **rated voltage**, the **rated current** or **rated power** for each **rated voltage** shall be marked on the equipment. The arrangement of the markings shall clearly indicate the **rated current** or **rated power** associated with each **rated voltage** of the equipment.

F.3.3.6 Equipment with multiple supply connections

If the equipment has multiple supply connections, each connection shall be marked with its **rated current** or **rated power**.

If the equipment has multiple supply connections, and if each connection has a different **rated voltage** than the other supply connections, each connection shall be marked with its **rated voltage**.

The overall system electrical rating need not be marked.

F.3.3.7 Compliance

Compliance is checked by inspection.

F.3.4 Voltage setting device

If the equipment employs a voltage setting device that is operable by an **ordinary person** or an **instructed person**, the act of changing the voltage setting shall also change the indication of the voltage for which the equipment is set. The setting shall be readily discernable when the equipment is ready for use.

If the equipment employs a voltage-setting device that is operable only by a **skilled person**, and if the act of changing the voltage setting does not also change the indication of the voltage rating, an **instructional safeguard** shall state that, when changing the voltage setting, the indication of the voltage setting must also be changed.

Compliance is checked by inspection.

F.3.5 Terminals and operating devices

F.3.5.1 Mains appliance outlet and socket-outlet markings

If a **mains** appliance outlet in accordance with IEC 60320-2-2 is provided on the equipment, the **rated voltage** and assigned current or power shall be marked adjacent to the appliance outlet.

If the **mains** socket-outlet is configured in accordance with IEC/TR 60083 or a relevant national standard, the assigned current or power shall be marked. If the voltage of the socket-outlet is the same as the **mains** voltage, the voltage need not be marked.

F.3.5.2 Switch position identification marking

The position of a disconnect switch or circuit-breaker shall be identified. Such identification may be comprised of words, symbols, or an illuminated indicator.

If a symbol is used, the symbol shall be in accordance with IEC 60417.

F.3.5.3 Replacement fuse identification and rating markings

If a fuse is replaceable by an **ordinary person** or an **instructed person**, identification of a suitable replacement fuse shall be marked adjacent to the fuseholder. Identification shall include:

- fuse current rating;
- if the fuse needs a special breaking capacity which is necessary for the **safeguard** function, the appropriate symbol that indicates the breaking capacity;
- if the fuse can be replaced with a fuse of a different voltage rating, the fuse voltage rating;
- if the fuse is a time-delay fuse, and the time-delay is necessary for the **safeguard** function, the appropriate symbol that indicates the time-delay.

If a fuse is replaceable by an **ordinary person**, the codings of the relevant fuses shall be explained in the user instructions.

If a fuse is not replaceable by an **ordinary person** or an **instructed person**:

- identification of a suitable replacement fuse shall be marked adjacent to the fuse or shall be provided in the service instructions;
- if the fuse is or could be in the neutral of the **mains** supply, an **instructional safeguard** shall state that the fuse is in the neutral, and that the **mains** must be disconnected to de-energize the phase conductors.

If a fuse is not intended to be replaceable, fuse ratings need not be marked.

F.3.5.4 Replacement battery identification marking

If a battery can be replaced by an incorrect type of replaceable battery, an **instructional safeguard** shall be provided in accordance with Clause F.5

F.3.5.5 Compliance

Compliance is checked by inspection.

F.3.6 Equipment markings related to equipment classification

F.3.6.1 Class I equipment

F.3.6.1.1 Protective earthing conductor terminal

The terminal intended for connection of **class I equipment** to the installation **protective earthing conductor** shall be identified with the symbol , IEC 60417-5019 (2006).

A terminal intended for connection of a class I sub-assembly (for example, a power supply), or a component (for example, a terminal block) to the equipment **protective earthing conductor** may be identified with either symbol , IEC 60417-5019 (2006), or with symbol , IEC 60417-5017 (2006).

F.3.6.1.2 Neutral conductor terminal

For **permanently connected equipment**, the terminal, if any, intended exclusively for connection of the **mains** neutral conductor shall be identified by the capital letter “N”.

F.3.6.1.3 Protective bonding conductor terminals

Terminals for **protective bonding conductors** need not be identified. However, if such terminals are identified, they shall be marked with the earth symbol , IEC 60417-5017 (2006). A component terminal marked with the symbol , IEC 60417-5019 (2006), is acceptable as identification of a **protective bonding conductor** terminal.

F.3.6.1.4 Terminal marking location

The terminal markings specified in F.3.6.1 shall not be placed on screws, removable washers, or other parts that can be removed when conductors are being connected.

F.3.6.2 Class II equipment

Class II equipment shall bear the symbol , IEC 60417-5172 (2003).

The symbol shall not be used on:

- equipment that is provided with a **protective earthing conductor** or terminal, including equipment having (a) conductor(s) connected to such a terminal but the conductor(s) is not earthed for safety purposes (for example, a conductor used for functional purposes only); or
- equipment containing a **protective bonding conductor** used only to maintain continuity of protective earthing circuits to other equipment in a system of interconnected equipment.

F.3.6.3 Compliance

Compliance is checked by inspection.

F.3.7 Equipment IP rating marking

If the equipment is intended for other than IPX0, the equipment shall bear the IP number according to the degree of protection against ingress of water in accordance with IEC 60529.

If the equipment is intended for IP3X or better, the equipment shall bear the IP number according to the degree of protection against ingress of foreign objects.

Compliance is checked by inspection.

F.3.8 Durability, legibility and permanence of markings

In general, all markings required to be on the equipment shall be durable and legible, and shall be easily discernable under normal lighting conditions.

Unless otherwise specified, **instructional safeguards** do not have to be in colour. If an **instructional safeguard** is in colour, the colour should be in accordance with the ISO 3864 series. Markings that are engraved or moulded need not be in contrasting colours provided that they are legible and readily discernable under normal lighting conditions.

Compliance is checked by inspection.

Printed or screened markings shall also be permanent. Permanency is determined by the tests of F.3.9.

F.3.9 Test for the permanence of markings

F.3.9.1 General

Each printed or screened marking shall be tested according to this subclause.

If the data sheet for a label confirms compliance with the test requirements, the test need not be performed.

F.3.9.2 Testing procedure

The test is conducted by rubbing the marking by hand without appreciable force for 15 s with a piece of cloth soaked with water and at a different place or on a different sample for 15 s with a piece of cloth soaked with the petroleum spirit specified in F.3.9.3.

F.3.9.3 Petroleum spirit

Petroleum spirit is a reagent grade hexane with a minimum of 85 % n-hexane.

NOTE The designation "n-hexane" is chemical nomenclature for a "normal" or straight chain hydrocarbon. This petroleum spirit may further be identified as a certified ACS (American Chemical Society) reagent grade hexane (CAS# 110-54-3).

F.3.9.4 Compliance

After each test, the marking shall remain legible. If the marking is on a separable label, the label shall show no curling and shall not be removable by hand.

F.4 Instructions

When information with regard to safety is required according to this standard, this information shall be given in an instruction for installation or instruction for initial use. This information shall be available prior to installation and initial use of the equipment.

Equipment for use in locations where children are not likely to be present and that is evaluated using the jointed test probe of Figure V.2 shall have the following or equivalent statement in the user instructions.

NOTE 1 This equipment design typically applies to commercial or industrial equipment expected to be installed in locations where only adults are normally present.

This equipment is not suitable for use in locations where children are likely to be present.
--

NOTE 2 See also ISO/IEC Guide 37, instructions for use of products of consumer interest.

The instructions shall include the following as far as applicable.

- For equipment intended only for use in a **restricted access area**, the instructions shall state so.
- For audio equipment with terminals classified as ES3 in accordance with Table E.1, and for other equipment with terminals marked in accordance with F.3.6.1, the instructions shall require that the external wiring connected to these terminals shall be installed by a **skilled person**, or shall be connected by means of ready-made leads or cords that are constructed in a way that would prevent contact with any ES3 circuit.
- If protective earthing is employed as a **safeguard**, the instructions shall require connection of the equipment **protective earthing conductor** to the installation **protective**

earthing conductor (for example, by means of a power cord connected to a socket-outlet with earthing connection).

- d) For equipment with **protective earthing conductor** current exceeding the ES2 limits of 5.2.2.2, the equipment shall bear an **instructional safeguard** in accordance with 5.7.6.
- e) If a symbol is marked on the equipment, the instructions shall explain the meaning of the symbol.
- f) If a **permanently connected equipment** is not provided with an all-pole **mains** switch, the instructions for installation shall state that an all-pole **mains** switch in accordance with Annex L shall be incorporated in the electrical installation of the building.
- g) If a replaceable component or module provides a **safeguard** function, identification of a suitable replacement component or module shall be provided in the **ordinary person** instructions or **instructed person** instructions, or **skilled person** instructions, as applicable.

Compliance is checked by inspection.

F.5 Instructional safeguards

Unless otherwise specified in this standard:

- an **instructional safeguard** is comprised of element 1a or 2 or both, together with elements 3 and 4. Elements 1a, 1b, 2, 3, and 4 are specified in Table F.1. Any **instructional safeguard** element placed on the equipment must be visible to the person prior to potential exposure to the class 2 energy source or class 3 energy source parts.

Unless otherwise specified in this standard:

- the complete **instructional safeguard** shall be marked on the equipment, or
- element 1a or element 2 or both shall be marked on the equipment and the complete **instructional safeguard** shall be in the text of an accompanying document. If a suitable symbol for element 1a is not available, then element 1b may be marked on the equipment and the complete **instructional safeguard** shall be in the text of an accompanying document.

Table F.1 – Instructional safeguard element description and examples

Element	Description	Example
1a	A symbol that identifies the nature of the class 2 or class 3 energy source or the consequences that can be caused by the class 2 or class 3 energy source.	
1b	A symbol or set of symbols such as ISO 7000-0434 and ISO 7000-1641 to refer to text in an accompanying document. These symbols may be combined.	
2	Text that identifies the nature of the class 2 or class 3 energy source or the consequences that can be caused by the energy source, and the location of the energy source.	Hot parts!
3	Text that describes the possible consequences of energy transfer from the energy source to a body part.	Burned fingers when handling the parts
4	Text that describes the safeguard action necessary to avoid energy transfer to a body part.	Wait one-half hour after switching off before handling parts

The symbol for elements 1a and 1b shall be from IEC 60417, or ISO 3864-2, or ISO 7000, or equivalent.

Figure F.1 illustrates one example of the arrangement of the four elements that comprise a complete **instructional safeguard**. Other arrangements in the positioning of the elements are also acceptable.

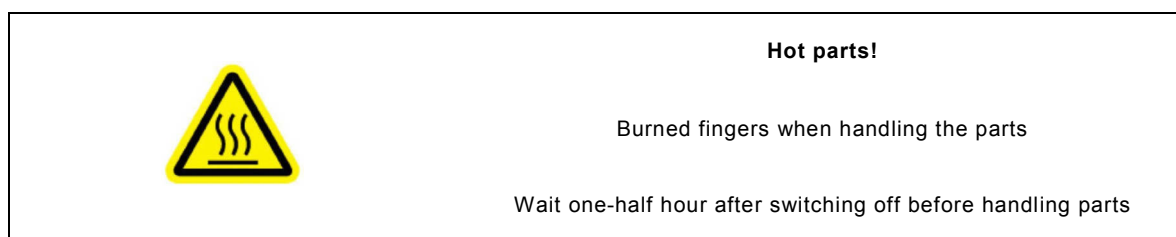


Figure F.1 – Example of an instructional safeguard

See Table F.2 for examples of markings, instructions, and **instructional safeguards**.

Table F.2 – Examples of markings, instructions, and instructional safeguards

Rating	Example
Rated d.c. voltage	48 V d.c. 48 V — — —
Rated a.c. voltage	230 V ~ 230 V ~ ±10 % 100/120/220/240 V a.c. 100–250 V a.c.
Rated 3-phase voltage	400 Y/230 V 3Ø 208 Y/120 V 3-phase 208 Y/120 V 3 ~
Rated frequency	50-60 Hz 50/60 Hz
Rated current	1 A
Instruction	Example
Positioning of cell, IEC 60417-5002 (2002)	
AC, IEC 60417-5032 (2002)	~
DC, IEC 60417-5031 (2002)	— — —
Class II equipment, IEC 60417-5172 (2003)	
Caution, ISO 7000, 0434a or 0434b (2004)	
Dangerous voltage, IEC 60417-5036 (2002)	
Earth; ground, IEC 60417-5017 (2006)	
Protective earth; protective ground, IEC 60417-5019 (2006)	

Annex G (normative)

Components

G.1 Switches

G.1.1 General

This subclause specifies requirements for switches that are located in PS2 or PS3 or in an **arcing PIS** or a **resistive PIS**.

G.1.2 Requirements for switches

A switch shall not be fitted in a **mains** supply cord.

A switch may be tested separately or in the equipment.

A switch shall comply with all of the following:

- comply with the requirements of IEC 61058-1, whereby the following applies:
 - 10 000 operating cycles (see 7.1.4.4 of IEC 61058-1:2000);
 - the switch shall be suitable for use in a normal pollution situation (see 7.1.6.2 of IEC 61058-1:2000);
 - the switch shall be of level 3 regarding the resistance to heat and fire (see 7.1.9.3 of IEC 61058-1:2000);
 - 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 operating conditions** as given below:
 - the ratings of the switch (see Clause 6 of IEC 61058-1:2000);
 - the classification of the switch according to:
 - nature of supply (see 7.1.1 of IEC 61058-1:2000);
 - type of load to be controlled by the switch (see 7.1.2 of IEC 61058-1:2000);
 - ambient air temperature (see 7.1.3 of IEC 61058-1:2000);

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 16.2.2 d), l) and m) of IEC 61058-1:2000, taking into account the total current rating 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 Figure 9 and Figure 10 of IEC 61058-1:2000. 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.

Switches used as **disconnect devices** shall comply with the requirements in Annex L.

Table G.1 – Peak surge current

Total current rating of the switch controlled socket-outlets A up to and including	Peak surge current A
0,5	20
1,0	50
2,5	100
over 2,5	150

G.1.3 Test method

For **mains** switches the tests of IEC 61058-1 shall be applied with the modifications shown in G.1.2.

G.1.4 Compliance

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-offs**G.2.1 Requirements for thermal cut-offs**

A **thermal cut-off safeguard** shall comply with requirements a) and b), or c).

a) The **thermal cut-off**, when tested as a separate component, shall comply with the requirements and tests of the IEC 60730 series as far as applicable:

- the **thermal cut-off** shall be of type 2 action (see 6.4.2 of IEC 60730-1:1999);
- the **thermal cut-off** shall have at least micro-disconnection, type 2B (see 6.4.3.2 and 6.9.2 of IEC 60730-1:1999);
- the **thermal cut-off** shall have a trip-free mechanism in which contacts cannot be prevented from opening against a continuation of a fault, type 2E (see 6.4.3.5 of IEC 60730-1:1999);
- the number of cycles of automatic action shall be at least:
 - 3 000 cycles for a **thermal cut-off** with automatic reset used in circuits that are not switched off when the equipment is switched off (see 6.11.8 of IEC 60730-1:1999),
 - 300 cycles for a **thermal cut-off** with automatic reset used in circuits that are switched off together with apparatus and for **thermal cut-off** with no automatic reset that can be reset by hand from the outside of the equipment (see 6.11.10 of IEC 60730-1:1999),
 - 30 cycles for a **thermal cut-off** with no automatic reset and that cannot be reset by hand from the outside of the equipment (see 6.11.11 of IEC 60730-1:1999);
- the **thermal cut-off** shall be tested as designed for a long period of electrical stress across insulating parts (see 6.14.2 of IEC 60730-1:1999);
- the **thermal cut-off** shall meet the conditioning requirements for an intended use of at least 10 000 h (see 6.16.3 of IEC 60730-1:1999);
- the contact gap, and the distance between the terminations and connecting leads of the contacts, shall comply with 13.1.4 and 13.2 of IEC 60730-1:1999.

b) The characteristics of the **thermal cut-off** with regard to

- the ratings of the **thermal cut-off** (see Clause 5 of IEC 60730-1:1999);

- the classification of the **thermal cut-off** according to the:
 - nature of supply (see 6.1 of IEC 60730-1:1999);
 - type of load to be controlled (see 6.2 of IEC 60730-1:1999);
 - degree of protection provided by **enclosures** against ingress of solid objects and dust (see 6.5.1 of IEC 60730-1:1999);
 - degree of protection provided by **enclosures** against harmful ingress of water (see 6.5.2 of IEC 60730-1:1999);
 - pollution situation for which the **thermal cut-off** is suitable (see 6.5.3 of IEC 60730-1:1999);
 - maximum ambient temperature limit (see 6.7 of IEC 60730-1:1999);

shall be appropriate for the application in the equipment.

c) The **thermal cut-off** when tested as a part of the equipment shall:

- have at least micro-disconnection according to IEC 60730-1 withstanding a test voltage according to 13.2 of IEC 60730-1:1999, and
- have a trip-free mechanism in which contacts cannot be prevented from opening against a continuation of a fault, and
- be conditioned for 300 h when the equipment is operated under **normal operating conditions** 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-off** tested as a separate component, by estimating the relevant fault conditions.

G.2.2 Test method

*The **thermal cut-off** is checked according to the test specifications of IEC 60730 series by inspection and by measurement. The test is made on three specimens.*

G.2.3 Compliance

The requirements of G.2.1 shall be fulfilled.

*No sustained arcing shall occur during the test. After the test, the **thermal cut-off** shall show no damage in the sense of this standard. In particular, it shall show no loosening of electrical connections or mechanical fixings.*

G.3 Thermal links

G.3.1 Requirements for thermal links

A thermal link shall meet either requirement 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 Clause 5 of IEC 60691:2002);
- the electrical conditions (see 6.1 of IEC 60691:2002);
- the thermal conditions (see 6.2 of IEC 60691:2002);
- the rating of the thermal link (see Clause 8 b) of IEC 60691:2002);
- the suitability for sealing in, or use with impregnating fluids or cleaning solvents (see Clause 8 c) of IEC 60691:2002),

shall be appropriate for the application in the equipment under **normal operating conditions** and under **single fault conditions**.

The electric strength of the thermal link shall meet the requirements of 5.4.11.1 of this standard except across the disconnection (contact parts) and except between terminations and connecting leads of the contacts, for which 10.3 of IEC 60691:2002 applies.

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 operating conditions** at an ambient temperature of 30 °C or higher if specified by the manufacturer, and
- subjected to such **single fault conditions** of the equipment that cause the thermal link to operate. During the test, no sustained arcing and no damage in the 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.3.2 Compliance and test method

If a thermal link is tested as a separate component according to G.3.1 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 according to G.3.1 b) above, compliance is checked by inspection and by the specified tests in the given order. The test is carried out three times. The thermal link is replaced partially or completely after each test.

NOTE When the thermal link cannot be replaced partially or completely, the complete component part including the thermal link (for example, a transformer) should be replaced.

No failure is allowed.

G.4 PTC thermistors

PTC thermistors used as **safeguards** shall comply with Clauses 15, 17, J.15 and J.17 of IEC 60730-1:1999 or shall provide IEC 60730-1 Type 2.A.L. action.

For PTC thermistors whose power dissipation exceeds 15 W for the rated zero-power resistance at an ambient temperature of 25 °C determined as given in IEC 60738-1, the encapsulation or tubing shall be made of **V-1 class material**.

Compliance is checked by inspection and where applicable by the tests of IEC 60730-1.

G.5 Overcurrent protective devices

Overcurrent protective devices shall comply with their applicable IEC standards.

Compliance is checked by inspection.

G.6 Protective devices not mentioned in Clauses G.2 to G.5

G.6.1 Other protective devices requirements

Such protective devices (for example, fusing resistors, fuse-links not standardized in IEC 60127 series 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.6.2 Compliance and test method

*Compliance is checked by inspection and by performing **single fault condition testing** as specified in Clause B.4.*

The test is carried out three times.

No failure is allowed.

G.7 Transformers

G.7.1 General

Transformers shall comply with one of the following:

- meet the requirements given in G.7.2 to G.7.3;
- in case of switch mode devices, meet the requirements of IEC 61204-7;
- meet the requirements of IEC 61558-1 and the relevant parts of IEC 61558-2 with the following additions and limitations:
 - the limit values for ES1 of this standard apply (see 5.2.2.2),
 - for **working voltages** above 1 000 V r.m.s., see 18.3 of IEC 61558-1:2005, the highest of the test voltages according to Table 31, Table 32 and Table 33 have to be applied,
 - the overload test according to G.7.3.

NOTE 1 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.

NOTE 2 Switch mode power supplies are addressed in IEC 61204-7.

G.7.2 Insulation

G.7.2.1 Requirements

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 5 and pass the relevant electric 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.

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 that 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.

If a transformer is fitted with an earthed screen for protective purposes, the transformer shall pass the test of 5.6.6.4 between the earthed screen and the earthing terminal of the transformer.

No electric 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 that have terminations continue to apply.

G.7.2.2 Compliance criteria

Compliance is checked by inspection, measurement and where applicable by test.

G.7.3 Transformer overload tests

G.7.3.1 Test conditions

If the tests are carried out under simulated conditions on the bench, these conditions shall include any protection device that 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 winding isolated from the **mains** loaded in turn, with any other winding isolated from the **mains** loaded between zero and its specified maximum load 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 condition** cannot occur or is unlikely to cause a **safeguard** to fail, the tests are not made.*

Maximum temperatures of windings shall not exceed the values in Table G.2 when measured as specified in B.1.7, and determined as specified below:

- with external overcurrent protection: at the moment of operation, for determination of the time until the overcurrent protection operates, reference may be made to a data sheet of the overcurrent protection device showing the trip time versus the current characteristics;
- with an automatic reset **thermal cut-off**: as shown in Table G.2 and after 400 h;
- with a manual reset **thermal cut-off**: at the moment of operation;
- for current limiting transformers: after the temperature has stabilized.

If the temperature of the windings of a transformer with a ferrite core, measured as specified in B.1.7, exceeds 180 °C, it shall be retested at maximum rated ambient temperature ($T_{amb} = T_{ma}$), and not as calculated according to B.2.6.3.

Windings isolated from the **main**s, that exceed the temperature limits but that become open circuit or otherwise require replacement of the transformer, do not constitute a failure of this test provided that the transformer continues to comply with B.4.8.

During the test the transformer shall not emit flames or molten metal.

**Table G.2 – Temperature limits for transformer windings and for motor windings
(except for the motor running overload test)**

Method of protection	Maximum temperature °C							
	Class 105 (A)	Class 120 (E)	Class 130 (B)	Class 155 (F)	Class 180 (H)	Class 200 (N)	Class 220 (R)	Class 250 -
Protection by inherent or external impedance	150	165	175	200	225	245	265	295
Protection by protective device that operates during the first hour	200	215	225	250	275	295	315	345
Protection by any protective device:								
– maximum after first hour	175	190	200	225	250	270	290	320
– arithmetic average during the 2nd hour and during the 72nd hour ^a	150	165	175	200	225	245	265	295

The classes are related to the classification of electrical insulating materials and electrical insulating systems in accordance with IEC 60085. The assigned letter designations are given in parentheses.

^a 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.

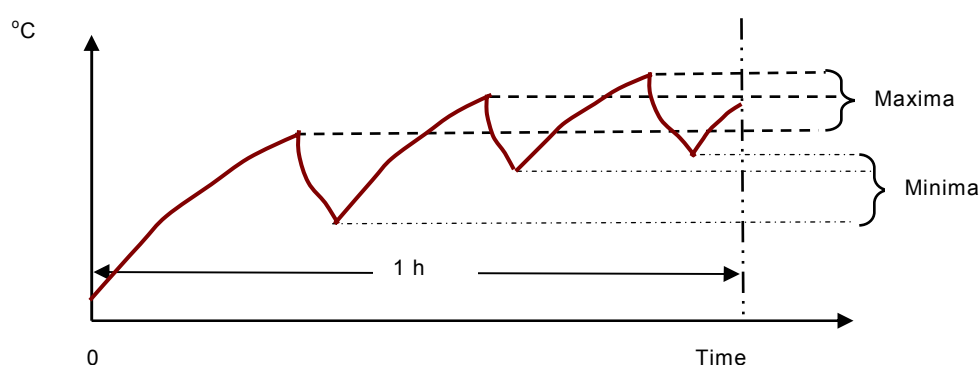


Figure G.1 – Determination of arithmetic average temperature

G.7.3.3 Alternative test method

The transformer is placed on a wooden board that is covered with a single layer of **wrapping tissue** and the transformer in turn is covered with a single layer of **cheesecloth** until either:

- the overload protection device operates,
- the winding becomes an open circuit,
- the load cannot be increased any further without reaching a short circuit or foldback condition,
- 7 h is reached.

During the test the transformer shall not emit flames or molten metal.

If the transformer voltage exceeds ES_1 , the **basic safeguard** or **reinforced safeguard** provided in the transformer shall withstand the electric strength test in 5.4.11.1 as applicable after it has cooled to room temperature.

G.8 Motors

G.8.1 General requirements

Motors other than d.c. motors, supplied from circuits isolated from the a.c. **mains** shall comply with the overload tests of G.8.3 and G.8.4 and, where applicable, G.8.8, G.8.9 and G.8.10.

However, the following motors are exempt from the test of G.8.3:

- motors that 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 supplied from circuits isolated from the a.c. **mains** shall comply with the tests of G.8.5, G.8.6 and G.8.10. DC motors that by their intrinsic operation normally operate under locked-rotor conditions, such as stepper motors, are not tested and d.c. motors that are used for air-handling only and where the air propelling component is directly coupled to the motor shaft are not required to pass the test of G.8.5.

G.8.2 Motor overload 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. Separate samples may be used for bench tests. Simulated conditions include:

- any protection device that would protect the motor in the complete equipment, and
- use of any mounting means that may serve as a heat sink to the motor frame.

Temperatures of windings are measured as specified in B.1.7. Where thermocouples are used they are applied to the surface of the motor windings. Temperatures are measured at the end of the test period where specified, otherwise when the temperature has stabilized, or at the instant of operation of fuses, **thermal cut-offs**, 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.

G.8.3 Running overload test

A running overload test is carried out by operating the motor under **normal operating conditions**. 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 G.8.4), until the overload protection device operates.

The motor winding temperatures are measured during each steady period.

G.8.4 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 10 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 may occur, 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 acceptable.

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.

G.8.5 Running overload test for d.c. motors

G.8.5.1 Requirement

The test of G.8.5.2 is carried out only if a possibility of an overload occurring is determined by inspection or by review of the design. For example, the test need not be carried out where electronic drive circuits maintain a substantially constant drive current.

Motors shall be tested in accordance with G.8.5.2.

If difficulty is experienced in obtaining accurate temperature measurements, due to the small size or unconventional design of the motor, the method of G.8.5.3 can be used instead.

G.8.5.2 Test method

*The motor is operated under **normal operating conditions**. 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, the winding becomes an open circuit or the load cannot be increased any further without reaching a locked rotor condition.*

The motor winding temperatures are measured during each steady period.

G.8.5.3 Alternative test method

*The motor is placed on a wooden board that is covered with a single layer of **wrapping tissue** and the motor in turn is covered with a single layer of **cheesecloth** until either:*

- *the overload protection device operates,*
- *the winding becomes an open circuit,*
- *the load cannot be increased any further without reaching a locked rotor condition,*
- *7 h is reached.*

*During or at the conclusion of the test, there shall be no ignition of the **wrapping tissue** or **cheesecloth**.*

G.8.5.4 Electric strength test

*Following the test of G.8.5.2 or G.8.5.3, as applicable, if the motor voltage exceeds ES1, the **basic safeguard** or **reinforced safeguard** provided in the motor shall withstand the electric strength test in 5.4.11.1 after it has cooled to room temperature, but with test voltages reduced to 0,6 times the specified values.*

G.8.6 Locked-rotor overload test for d.c. motors

G.8.6.1 Requirement

Motors shall pass the test in G.8.6.2.

Where difficulty is experienced in obtaining accurate temperature measurements because of the small size or unconventional design of the motor, the method G.8.6.3 can be used instead followed by the electric strength test of G.8.7.1.

G.8.6.2 Test method

The motor is operated at the voltage used in its application and with its rotor locked for 7 h or until steady conditions are established, whichever is longer.

G.8.6.3 Alternative test method

*The motor is placed on a wooden board that is covered with a single layer of **wrapping tissue**, and the motor in turn covered with a single layer of **cheesecloth**.*

The motor is then operated at the voltage used in its application and with its rotor locked for 7 h or until steady conditions are established, whichever is the longer.

*There shall be no ignition of the **wrapping tissue** or **cheesecloth**.*

G.8.7 Compliance

G.8.7.1 Electric strength test

Following the test of G.8.6.2 or G.8.6.3, as applicable, if the motor voltage exceeds ES1, and after it has cooled to room temperature, the motor shall withstand the electric strength test in 5.4.11.1 but with test voltages reduced to 0,6 times the specified values.

G.8.7.2 Maximum temperatures

For the tests according to G.8.4 and G.8.6.2 the temperature limits as specified in Table G.2 shall not be exceeded.

For the tests according to G.8.3 and G.8.5.2, the temperature limits as specified in Table G.3 shall not be exceeded for each class of insulating material.

Table G.3 – Temperature limits for running overload tests

Maximum temperature °C							
Class 105 (A)	Class 120 (E)	Class 130 (B)	Class 155 (F)	Class 180 (H)	Class 200 (N)	Class 220 (R)	Class 250 -
140	155	165	190	215	235	255	275
The classes are related to the classification of electrical insulating materials and electrical insulating systems in accordance with IEC 60085. The assigned letter designations are given in parentheses.							

G.8.8 Compliance and test method 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.

Temperatures during and after the test shall not exceed the values specified in Table G.2.

NOTE Locked-rotor is specified because some motors may not start and variable results could be obtained.

G.8.9 Compliance and test method for three-phase motors

*Three-phase motors are tested under **normal operating conditions**, 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.

Temperatures during and after the test shall not exceed the values specified in Table G.2.

G.8.10 Compliance and test method 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.

*After the test, windings and connections shall not have worked loose and all applicable **safeguards** shall remain effective.*

G.9 Mains supply cords

G.9.1 General

Except as specified in 5.6.7.2, a **mains** supply cord 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 60245-1 (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 60227-1 (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 according to IEC 60227-1 (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 60227-1 (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;
- other types of cords can be used if they have similar electro-mechanical properties as above.

Mains supply cords shall have conductors with cross-sectional areas not less than those specified in Table G.4 (see also 5.6.7).

Table G.4 – Sizes of conductors in mains supply cords

Rated current of the equipment ^a A up to and including	Nominal cross-sectional area mm ²	AWG [cross-sectional area in mm ²] see NOTE 2
3	0,50 ^b	20 [0,5]
6	0,75	18 [0,8]
10	1,00 (0,75) ^c	16 [1,3]
16	1,5 (1,0) ^d	14 [2]
25	2,50	12 [3]
32	4,00	10 [5]
40	6,00	8 [8]
63	10,00	6 [13]
80	16,00	4 [21]
100	25,00	2 [33]
125	35,00	1 [42]
160	50,00	0 [53]

NOTE 1 IEC 60320-1 specifies acceptable combinations of appliance couplers and flexible cords, including those covered by conditions ^b, ^c and ^d. However, a number of countries have indicated that they do not accept all of the values listed in this table, particularly those covered by conditions ^b, ^c and ^d.

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.

^a The **rated current** includes currents that can be drawn from a socket-outlet providing **mains** power for other equipment.

^b 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.

^c The value in parentheses applies to detachable power supply cords fitted with the connectors rated 10 A in accordance with IEC 60320-1 (types C13, C15, C15A and C17), provided that the length of the cord does not exceed 2 m.

^d The value in parentheses applies to detachable power supply cords fitted with the connectors rated 16 A in accordance with IEC 60320-1 (types C19, C21 and C23), provided that the length of the cord does not exceed 2 m.

Equipment intended to be used by musicians on the stage (for example, musical instruments and amplifiers) shall have:

- an appliance inlet according to IEC 60320-1 for connection to the **mains** by detachable cord sets; or
- a means of stowage to protect the **mains** cord when not in use (for example, a compartment, hooks or pegs).

G.9.2 Compliance and test method

Compliance is checked by inspection.

In addition, screened cords shall comply with IEC 60227-7.

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 electric strength test between the screen and all other conductors.*

G.9.3 Cord anchorages and strain relief for non-detachable power supply cords

G.9.3.1 General

This subclause specifies **safeguards** against strain being transmitted to the equipment terminations of the conductors of cords or interconnecting cables connected to ES2, ES3, PS3, or **mains** circuits.

G.9.3.2 Cord strain relief

G.9.3.2.1 Requirements

A knot shall not be used as a strain relief mechanism.

A screw that bears directly on the cord or cable shall not be used as a strain relief mechanism.

When a linear force and a torque is applied to a **non-detachable power supply cord** or cable, a **basic safeguard** shall prevent strain from being transmitted to the cord or cable terminations. Furthermore, the strain relief shall prevent the cord or cable from being longitudinally displaced by more than 2 mm. **Clearances** and **creepage distances** shall not be reduced below the values specified in 5.4.2 (**clearances**), and 5.4.3 (**creepage distances**).

The linear force applied to the cord or cable is specified in Table G.5. The force is applied in the most unfavourable direction for 1 s and repeated 25 times.

Table G.5– Strain relief test force

Mass of the equipment kg	Force N
Up to and including 1	30
Over 1 up to and including 4	60
Over 4	100

A torque of 0,25 Nm is applied for 1 min to the cord or cable immediately after the linear force application. The torque is applied as close as practicable to the strain relief mechanism and is repeated in the opposite direction.

Compliance is determined by applying the linear force and torque and inspecting the conductor slack during the test.

G.9.3.2.2 Strain relief mechanism failure

If the **basic safeguard** (strain relief mechanism) should fail and strain is transmitted to the **non-detachable power supply cord** or cable terminations, a **supplementary safeguard** shall ensure that the earth termination is the last to take the strain.

*Compliance is determined by inspection and, if necessary, by defeating the **basic safeguard** and inspecting the conductor slack while applying the force in Table G.5.*

G.9.3.2.3 Cord sheath or jacket position

The cord or cable sheath or jacket shall extend from the **basic safeguard** (strain relief mechanism) into the equipment at least one-half the diameter of the cord or cable.

Compliance is checked by inspection.

G.9.3.2.4 Strain relief comprised of polymeric material

If the **basic safeguard** (strain relief mechanism) is comprised of polymeric material, the **basic safeguard** shall retain its structural properties following the mould stress relief according to Clause T.8.

*Compliance is determined according to the force and torque tests of G.9.3.2 after the **basic safeguard** has come to room temperature.*

G.9.4 Cord entry

This subclause specifies **safeguards** against electric shock and electrically-caused fire from cords or cables connected to ES3, PS3, or **mains** circuits.

The entry of a cord or cable into the equipment shall be provided with the **safeguards** against electric shock as specified in Clause 5. If the cord jacket passes the electric strength test of 5.4.11.1 for **supplementary insulation**, the cord jacket may be considered a **supplementary safeguard**.

The cord or cable entry shall be provided with a **supplementary safeguard** so as:

- to prevent abrasion of the cord or cable surface which might lead to electrically-caused fire; and
- to prevent the cord or cable from being pushed into the equipment and touching parts or surfaces which might electrically or physically damage the cord or cable jacket or insulation that, in turn, might lead to electric shock or electrically-caused fire.

*Compliance is determined following the tests of G.9.3 by an electric strength test between the cord or cable conductors and **accessible** conductive parts. The test voltage shall be as required for the applied **safeguards** in accordance with 5.4.11.1.*

G.9.5 Non-detachable cord bend protection

G.9.5.1 Requirements

The **non-detachable power supply cord** of **hand-held equipment** or equipment intended to be moved while in operation shall be provided with a **safeguard** against jacket, insulation, or conductor damage due to bending at the equipment entrance.

Alternatively, the inlet or bushing shall be provided with a smoothly rounded bell-mouthed opening having a radius of curvature equal to at least 1,5 times the overall diameter of the cord with the largest cross-sectional area to be connected.

The cord bending **safeguard** shall:

- be so designed as to protect the cord against excessive bending where it enters the equipment;
- be of insulating material;
- be fixed in a reliable manner; and
- project outside the equipment beyond the inlet opening for a distance of at least five times the overall diameter or, for flat cords, at least five times the major overall cross-sectional dimension of the cord.

G.9.5.2 Compliance and test method

*The equipment is so placed that the axis of the cord bending **safeguard**, where the cord emerges, projects at an angle of 45° when the cord is free from stress. A mass equal to*

$10 \times D^2$ g is then attached to the free end of the cord, where D is the overall diameter or, for flat cords, the minor overall dimension of the cord, in millimetres.

If the cord guard is of temperature-sensitive material, the test is made at $23\text{ °C} \pm 2\text{ °C}$.

Flat cords are bent in the plane of least resistance.

Immediately after the mass has been attached, the radius of curvature of the cord shall nowhere be less than $1,5 D$.

Compliance is checked by inspection, by measurement and, where necessary, by the test of G.9.5.2 with the cord as delivered with the equipment.

G.9.6 Cord replacement

If the equipment **enclosure** is not sealed, **non-detachable power supply cords** are considered replaceable by an **instructed person** or by a **skilled person**.

To facilitate replacement, the design of cord terminations shall permit easy disconnection and reconnection without damaging the replacement cord or the equipment terminals. Specifically, cord terminations shall not be soldered to a printed wiring board.

Furthermore, for ordinary replacement cords, the strain relief mechanism shall be readily removable and re-installable.

Compliance is checked by inspection.

G.9.7 Supply wiring space

G.9.7.1 General requirements

The supply wiring space provided inside, or as part of, the equipment for permanent connection or for connection of an ordinary **non-detachable power supply cord** shall be designed:

- to allow the conductors to be introduced and connected easily; and
- so that the uninsulated end of a conductor is unlikely to become free from its terminal, or, should it do so, cannot come into contact with:
 - an **accessible** conductive part that is not protectively earthed; or
 - an **accessible** conductive part of **hand-held equipment**; and
- to permit checking before fitting the cover, if any, that the conductors are correctly connected and positioned; and
- so that covers, if any, can be fitted without risk of damage to the supply conductors or their insulation; and
- so that covers, if any, giving access to the terminals can be removed with a commonly available **tool**.

Compliance is checked by inspection and by an installation test with cords of the largest cross-sectional area of the appropriate range specified in Table G.4.

G.9.7.2 Stranded wire

G.9.7.2.1 Requirements

The end of a stranded conductor shall not be consolidated by soft soldering at places where the conductor is subject to contact pressure unless the method of clamping is designed so as to reduce the likelihood of a bad contact due to cold flow of the solder.

Spring terminals that compensate for the cold flow are considered to satisfy this requirement.

Preventing the clamping screws from rotating is not considered to be adequate.

Terminals shall be located, guarded or insulated so that, should a strand of a flexible conductor escape when the conductor is fitted, there is no likelihood of accidental contact between such a strand and:

- **accessible** conductive parts; or
- unearthed conductive parts separated from **accessible** conductive parts by **supplementary insulation** only.

G.9.7.2.2 Compliance and test method

Compliance is checked by inspection and, unless a special cord is prepared in such a way as to prevent the escape of strands, by the following test.

A piece of insulation approximately 8 mm long is removed from the end of a flexible conductor having the appropriate nominal cross-sectional area. One wire of the stranded conductor is left free and the other wires are fully inserted into, and clamped in the terminal. Without tearing the insulation back, the free wire is bent in every possible direction, but without making sharp bends around the guard.

*If the conductor is an ES3 source, the free wire shall not touch any conductive part which is **accessible** or is connected to an **accessible** conductive part or, in the case of double insulated equipment, any conductive part which is separated from **accessible** conductive parts by **supplementary insulation** only.*

If the conductor is connected to an earthing terminal, the free wire shall not touch any ES3 source.

G.10 Metal Oxide Varistors

G.10.1 General

This subclause specifies how to provide **safeguards** against electric shock and against fire, caused by failure of the MOV.

An MOV connected between **mains** and earth shall comply with the **basic safeguard** of G.10.2. In addition, for fire and shock hazard, the MOV shall comply with the **supplementary safeguards** of G.10.3 and with the reliable earthing requirements of 5.6.8.2.

An MOV connected across the **mains** shall comply with the **basic safeguard** of G.10.2 and **supplementary safeguards** of G.10.3.

NOTE 1 An MOV is sometimes referred to as a VDR.

NOTE 2 Such connections described above make the MOV a **PIS**.

G.10.2 Basic safeguard

This subclause specifies requirements for a MOV that serves as a **basic safeguard** against fire or electric shock.

Component properties:

An MOV shall comply with IEC 61051-2, taking into account all of the following:

a) Preferred climatic categories (2.1.1 of IEC 61051-2:1991):

- lower category temperature: – 10 °C
- upper category temperature: + 85 °C
- duration of damp heat, steady state test: 21 days.

b) Maximum continuous voltage (2.1.2 of IEC 61051-2:1991):

- 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 (Table I group 1 of IEC 61051-2:1991).

For the test, a combination pulse 6 kV/3 kA is used, having a shape of 1,2/50 µs for voltage and 8/20 µs for current.

In addition to the performance requirements of Table I group 1 of IEC 61051-2:1991, the MOV voltage after the test shall not have changed by more than 10 % when measured with the manufacturer's specified current.

The body of surge suppression MOVs shall be made of **V-0 class material**.

G.10.3 Supplementary safeguards

G.10.3.1 General

This subclause specifies **supplementary safeguards** to be provided against fire resulting from both sudden and gradual failure of an MOV connected directly across the **mains** or between **mains** and protective earth (see 5.6.8.2).

G.10.3.2 Sudden failure

One of the following **safeguards** shall be provided:

a) The use of a restricted area for an **arcing PIS** circuit as specified in 6.4.7.

b) The use of a protective device:

- 10 A maximum rated fuse of adequate breaking capacity, or equivalent, is connected in series with the MOV; or
- another protective device may be used, provided that the combination complies with a limited short-circuit test, with the MOV shorted out. The product shall be tested in accordance with 9.3.1 of IEC 60127-1:2006, Method A, for breaking capacity of 1 500 A. The test shall not result in the failure of **safeguards** against fire or shock.

c) The use of a **fire enclosure** meeting the requirements of 6.4.8. If the MOV is separated from the **fire enclosure** by a distance of less than 13 mm, the requirements for smaller separation distances in 6.4.8.3 shall apply.

G.10.3.3 Gradual failure

*The **safeguard** is that requirements for a PS3 circuit shall be complied with, including one of the following:*

a) 6.4.3, prevent ignition; or

b) 6.4.6, control of fire spread.

For fault tests as required in a) above, failure is simulated by the following test method.

If the voltage rating of the MOV is such that it will conduct at twice the maximum **rated voltage** of the equipment, ($2 \times V_r$) or lower, the equipment and a test resistor R_x connected in series with the **mains** supply to the equipment is energized from an a.c. source of $2 \times V_r$. Components in parallel with the MOV that may be affected by this test shall be disconnected.

The test shall be performed with $R1 = 2 \times V_r / 0,125$.

If the circuit does not open, the test shall be continued for 4 h, then repeated with lower values of R_x in turn, until the circuit opens:

$$R2 = 2 \times V_r / 0,5,$$

$$R3 = 2 \times V_r / 2,5,$$

$$R4 = 2 \times V_r / 5,$$

$$R5 = 2 \times V_r / 10,$$

$R6 = \text{half the previous value, etc.}$

The test shall not result in fire or shock within the sense of this standard.

NOTE 1 For temporary overvoltages from the **mains**, see IEC 60664-1.

NOTE 2 A gas discharge tube may be used in series with the MOV.

G.11 Wound components

G.11.1 Wire insulation in wound components

G.11.1.1 General

The following requirements apply to winding wire including lead-out wires whose insulation provides **basic insulation**, **supplementary insulation** or **reinforced insulation**.

NOTE 1 For insulation provided in addition to insulation on winding wire, see G.11.2.

Solvent-based enamel is not considered to provide **supplementary insulation** or **reinforced insulation**, under any circumstances.

Solvent-based enamel is only accepted as **basic insulation** if used for winding insulation as described in G.11.1.2.

If the **peak working voltage** does not exceed ES2, there is no dimensional or constructional requirement.

If the **peak working voltage** exceeds ES2, one of the following, a), b), or c) applies:

- a) There is no dimensional or constructional requirement for **basic insulation** that is not under mechanical stress (for example, from winding tension). For **basic insulation** that is under such mechanical stress, b) or c) applies.

NOTE 2 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 thickness of at least 0,4 mm provided by a single layer; or

- comply with 5.4.4.6 and with Annex J.
- c) The winding wire shall comply with Annex J. 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 5.4.4.5 a), b) or c).

NOTE 3 For wires insulated by an extrusion process, sealing is inherent to the process.

The winding wire shall pass a **routine test** for electric strength test, using the test as specified in Clause J.3.

G.11.1.2 Solvent-based enamel winding insulation

Solvent-based enamel is considered **basic insulation** where all the following conditions are met:

- the **basic insulation** provided in a wound component between an **external circuit** or internal circuit operating at ES2 and ES1;
- the insulation over all conductors comprises enamel complying with the requirements of a grade 2 winding wire of IEC 60317 series of standards with the **routine test** conducted at the highest voltage of Table 31 and Table 32;
- the finished component is subjected to a **type test** for electric strength (between windings and between windings and the core, see G.7.2.1), in accordance with 5.4.11.1;
- the finished component is subjected to **routine tests** for electric strength (between windings and between windings and the core, see G.7.2.1), in accordance with 5.4.11.1.

Except as given in 4.3.2.3, the core of the above wound component shall not be **accessible** to an **ordinary person**.

G.11.1.3 Protection against mechanical stress in wound components

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. For example, this protection can be achieved by providing physical separation in the form of insulating sleeving or sheet material, or by using double the required number of insulation layers on the winding wire; or
- the wound component passes the endurance tests of G.11.3.

Additionally, **basic insulation**, **supplementary insulation** or **reinforced insulation** in finished wound components shall pass **routine test** for electric strength in accordance with 5.4.11.1.

G.11.1.4 Compliance and test method

Compliance is checked by 5.4.4.1 and, where required, by G.11.3. If the tests of Annex J are required, they are not repeated if the material data sheets confirm compliance.

G.11.2 Additional insulation in wound components

G.11.2.1 General requirements

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

- 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 ES2, there is no dimensional or constructional requirement.

If the **peak working voltage** exceeds ES2,

- for **basic insulation** there is no dimensional or constructional requirement;
- **supplementary insulation** or **reinforced insulation** shall either:
 - have a thickness of at least 0,4 mm, provided by a single layer; or
 - comply with 5.4.4.6.

G.11.2.2 Compliance and test method

Compliance is checked by inspection and measurement.

G.11.3 Endurance test on wound components

G.11.3.1 General test requirements

Where required by G.11.1.3, three samples of the wound component are subjected to 10 test cycles with each test cycle consisting of a heat run (see G.11.3.3), a vibration test (see G.11.3.4) and a humidity conditioning (see 5.4.10).

After the heat run (see G.11.3.3), the samples are allowed to cool down to ambient temperature.

The samples are then subjected to a vibration test of G.11.3.4.

The samples are then subjected for two days to the humidity conditioning of 5.4.10.

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

The electric strength test of 5.4.11.1 is carried out.

*After the electric strength test, the test of G.11.3.5 is made on wound components that are supplied from the **mains**, except for switching mode power supply.*

G.11.3.2 Compliance

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

For wound components supplied from the **mains**, there shall be no breakdown of the insulation between the turns of a winding, between input and output windings, between adjacent input windings and between adjacent output windings, or between the windings and any conductive core.

G.11.3.3 Heat run test

Depending on the type thermal classification of the insulation, the specimens are kept in a heating cabinet for a combination of time and temperature as specified in Table G.6. The 10 cycles are carried out with the same combination.

The temperature in the heating cabinet shall be maintained within a tolerance of $\pm 5^{\circ}\text{C}$.

Table G.6 – Test temperature and testing time (days) per cycle

Thermal classification	Class 105 (A)	Class 120 (E)	Class 130 (B)	Class 155 (F)	Class 180 (H)	Class 200 (N)	Class 220 (R)	Class 250 -
Test temperature °C	Testing time duration for the test of G.11.3.2							
290								4 days
280								7 days
270								14 days
260							4 days	
250							7 days	
240						4 days	14 days	
230						7 days		
220					4 days	14 days		
210					7 days			
200					14 days			
190				4 days				
180				7 days				
170				14 days				
160			4 days					
150		4 days	7 days					
140		7 days						
130	4 days							
120	7 days							
The classes are related to the classification of electrical insulating materials and electrical insulating systems in accordance with IEC 60085. The assigned letter designations are given in parentheses. The manufacturer shall specify the test duration or the test temperature.								

G.11.3.4 Vibration test

Specimens are tested according to G.21.3.4.

G.11.3.5 Wound components supplied from the mains

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, multiple wire 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.*

*The test voltage is initially set at **rated voltage** and gradually increased up to 1,2 times the initial value, and then maintained for the time specified. If during the test there is a non-linear change of current in an uncontrollable manner, it is regarded as breakdown between winding turns.*

G.12 Circuits generating starting pulses

G.12.1 Insulation in circuits generating starting pulses

For a circuit generating starting pulses to ignite a discharge lamp, and if the circuit is an ES1, the requirements for **functional insulation** apply between the circuit and other conductive parts.

If the circuit is not ES1, the requirements for **basic insulation**, **supplementary insulation** and **reinforced insulation** apply to **creepage distances** and distances through insulation. For **clearances**, see G.12.2.

NOTE For **working voltages** in the above cases, see 5.4.1.9.1, i).

G.12.2 Clearances in circuits generating starting pulses

For a circuit generating starting pulses to ignite a discharge lamp, and if the circuit is not ES1, the **clearances** are determined by one of the following methods:

- a) Determine the minimum **clearance** in accordance with 5.4.2.7; or
- b) Conduct electric strength tests, using one of the following procedures. During the tests, the lamp terminals are shorted together:
 - test in accordance with 5.4.11.1, or
 - apply 30 pulses having amplitude equal to the highest of the required test voltages in Table 31, Table 32 and Table 33 from an external pulse generator. The pulse width shall be equal to or greater than that of the internally generated starting pulse.

NOTE For **working voltages** see 5.4.1.9.1, i).

G.13 IC current limiters

IC current limiters used for current limiting in power sources to become PS1 or PS2 are not shorted from input to output if all of the following conditions are met:

- **clearances** and **creepage distances** for **reinforced insulation** are provided between the input and output pins for the applicable **working voltage**, except for IC current limiters in ES1 circuits;
- the IC current limiters limit the current to manufacturer's defined value (not to be more than 5 A) under **normal operating conditions** with any specified drift taken into account;
- the IC current limiters are entirely electronic and have no means of manual operation or reset; are supplied by a source whose output does not exceed 250 VA and the output current is limited to 5 A or less;
- the IC current limiters limit the current or voltage to manufacturer's defined drift after each of the following conditioning tests:

NOTE The power source for the tests should be capable of delivering 250 VA minimum unless the IC current limiter is tested in the end product.

- Clause H.17.1.4.2 of IEC 60730-1:1999;

- 10 000 cycles of turning enable on and off with a 100 Ω resistor and 425 μ F capacitor in parallel with the output;
- 10 000 cycles of turning enable on and off with an iron-core inductor having 352 mH inductance at 1 kHz and 11 Ω d.c. resistance connected in the output circuit;
- 10 000 cycles of turning enable on and off while input connected to a capacitor rated 425 μ F and shorting the output;
- 10 000 cycles of turning input pin on and off while a capacitor rated 425 μ F to the input supply keeping enable active and shorting the output;
- 10 000 cycles of turning input pin on and off with an iron-core inductor having 352 mH inductance at 1 kHz and 11 Ω d.c. resistance connected to the input supply keeping enable active and shorting the output;
- 50 cycles with enable pin held active and applying short to output with power on and off;
- 50 cycles with enable pin held active and output loaded to maximum power with power on and off;
- 50 cycles with enable pin held active and applying power, apply short to output; remove power, apply power, remove short, remove power;
- 3 cycles of exposing the device (not energised) to 70 °C for 24 h; followed by at least 1 h at room ambient; followed by at least 3 h at –30 °C; followed by 3 h at room ambient;
- 10 cycles of exposing the device (while energised) to 49 °C for 10 min; followed by 10 min at 0 °C with a 5 min period of transition from one state to the other.

After each of the tests above, the device shall limit the current in accordance with its specification as applicable (an open circuit is considered an acceptable result).

G.14 Test for resistors serving as safeguard

G.14.1 General

This subclause specifies test requirements for resistors bridging insulation to ensure that they do not significantly change in value over a long period of time.

When required by 5.5.2.7 or 5.5.3.6, ten samples are tested for the resistor test of G.14.2. A sample is a single resistor if used alone, or a group of resistors in series.

G.14.2 Resistor test

Before the test, the resistance of each sample is measured.

The samples are subjected to the damp heat test according to IEC 60068-2-78, with the following details:

- temperature: 40 °C $\pm$ 2 °C;*
- humidity: 93 % $\pm$ 3 % relative humidity;*
- test duration: 21 days;*
- each sample is then subjected to 10 impulses of alternating polarity, using the impulse test generator circuit 2 of Table D.1. The interval between successive impulses is 60 s, and U_c is equal to the applicable **required withstand voltage**.*

After the test, the resistance of each sample shall not have changed by more than 10 %. No failure is allowed.

The lowest resistance value of the ten samples tested is used to measure the current when determining compliance with Table 4.

NOTE If a resistor or a group of resistors is connected between a circuit supplied by the **mains** and coaxial cable, G.14.3 applies.

G.14.3 Test for resistors serving as safeguards between the mains and an external circuit consisting of a coaxial cable

G.14.3.1 General

This subclause specifies test requirements for resistors bridging insulation between the **mains** and an **external circuit** consisting of a coaxial cable and ensures that they do not significantly change in value over a long period of time.

When required by 5.5.4, ten samples of resistors (a sample is a single resistor if used alone or a group of resistors in series) are subjected to the conditioning of G.14.2 and the test in detail d) of G.14.2 is replaced by the following test of G.14.3.2 or G.14.3.3 as applicable.

G.14.3.2 Voltage surge test

Each sample is then subjected to 50 discharges from the impulse test generator circuit 3 of Table D.1, at not more than 12 discharges per minute, with U_c equal to 10 kV if the sample resistor is connected to coaxial cable connected to antenna (see Table 16).

G.14.3.3 Impulse test

Each sample is subjected to 10 pulses from the impulse test generator circuit 1 of Table D.1, with U_c equal to 4 kV or 5 kV of alternating polarity with a minimum of 60 s interval between pulses as applicable (see Table 16).

G.14.3.4 Compliance

After the tests of G.14.3.2 or G.14.3.3, the resistance of each sample shall not have changed by more than 20 %. No failure is allowed.

G.15 Capacitors and RC units serving as safeguards bridging insulation

G.15.1 General

This subclause specifies conditioning requirements when testing capacitors and RC units or discrete components serving as **safeguards** and provides selection criteria for capacitors and RC units that comply with IEC 60384-14.

G.15.2 Conditioning of capacitors and RC units

When required by 5.5.2.2 or 5.5.3.2, the following conditioning is applied when evaluating a capacitor or an RC unit to the requirements of IEC 60384-14.

The duration of the damp heat, steady-state test as specified in 4.12 of IEC 60384-14:2005, shall be 21 days at a temperature of $40\text{ }^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and a relative humidity of $93\text{ \%} \pm 3\text{ \%}$.

Capacitors subjected to a duration that is longer than 21 days during the above test are considered acceptable.

G.15.3 Rules for selecting capacitors

The appropriate capacitor subclass shall be selected from those listed in Table G.7, according to the rules of application in the table.

Table G.7 – Capacitor ratings according to IEC 60384-14

Capacitor subclass according to IEC 60384-14	Rated voltage of the capacitor V r.m.s.	Type test impulse voltage of the capacitor kV peak	Type test r.m.s. test voltage of the capacitor kV r.m.s.
Y1	Up to and including 500	8	4
Y2	Over 150 up to and including 300	5	1,5
Y4	Up to and including 150	2,5	0,9
X1	Up to and including 760	4 ^a	-
X2	Up to and including 760	2,5 ^a	-

Rules for the application of this table.

- The voltage rating of the capacitor shall be at least equal to the **r.m.s. working voltage** across the insulation being bridged, determined according to 5.4.1.9.2.
- For a single capacitor (X type) serving as **functional insulation**, failure of the capacitor shall not result in the failure of a **safeguard** and the **type test** impulse voltage shall be at least equal to the **required withstand voltage**.
- For a single capacitor serving as a **basic safeguard** or **supplementary safeguard**, the rated peak impulse test voltage of the capacitor shall be at least equal to the **required withstand voltage**.
- For a single capacitor serving as a **double safeguard** or **reinforced safeguard**, the rated peak impulse test voltage of the capacitor shall be at least equal to twice the **required withstand voltage**.
- For a single capacitor serving as a **basic safeguard**, **supplementary safeguard** or **reinforced safeguard** the peak a.c. value of the r.m.s. test voltage shall not be smaller than the highest of the test voltages in Table 31, Table 32 and Table 33.
- A higher grade capacitor than the one specified may be used, as follows:
 - subclass Y1 if subclass Y2 is specified;
 - subclass Y1 or Y2 if subclass Y4 is specified;
 - subclass Y1 or Y2 if subclass X1 is specified;
 - subclass X1, Y1 or Y2 if subclass X2 is specified.
- Two or more capacitors may be used in series in place of the single capacitor specified, as follows:
 - subclass Y1 or Y2 if subclass Y1 is specified;
 - subclass Y2 or Y4 if subclass Y2 is specified;
 - subclass X1 or X2 if subclass X1 is specified.
- If two or more capacitors are used in series they shall comply with 5.5.2.2 and 5.5.3.2 as applicable and comply with the other rules above.

^a For capacitance values of more than 1 µF, this test voltage is reduced by a factor equal to $\sqrt{C}$, where C is the capacitance value in µF.

G.15.4 Informative examples of the application of capacitors

Table G.8 gives informative examples for the number of Y capacitors required bridging **basic insulation**, **supplementary insulation** or **reinforced insulation** based on the **required withstand voltage**. Table G.9 gives the maximum voltage that can appear across a Y capacitor based on the **peak working voltage**.

Table G.10 gives examples for the number of Y capacitors required bridging **basic insulation** and **reinforced insulation** based on the temporary overvoltages. Table G.11 gives a number of informative examples of the application of X capacitors selected in accordance with Table G.7. Other examples are possible.

**Table G.8 – Informative examples of the application of Y capacitors
based on required withstand voltage**

AC mains supply voltage up to and including V r.m.s.	Overvoltage category	Mains transient voltage kV	Bridged insulation	Capacitor type	Required number of capacitors
150	II	1,5	B or S	Y2	1
	II	1,5	D or R	Y2	2
	II	1,5	D or R	Y1	1
	III	2,5	B or S	Y2	2
	III	2,5	D or R	Y1	1
	IV	4,0	B or S	Y1	1
	IV	4,0	D or R	Y1	2
300	II	2,5	B or S	Y2	2
	II	2,5	D or R	Y1	1
	II	2,5	D or R	Y2	2
	III	4,0	B or S	Y1	1
	III	4,0	B or S	Y2	2
	III	4,0	D or R	Y1	2
	III	4,0	D or R	Y2	3
	IV	6,0	B or S	Y1	2
	IV	6,0	D or R	Y1	2
500	II	4,0	B or S	Y1	1
	II	4,0	D or R	Y1	2
	III	6,0	B or S	Y1	2
	III	6,0	D or R	Y1	2
	IV	8,0	B or S	Y1	2
	IV	8,0	D or R	Y1	3
B basic insulation S supplementary insulation			D double insulation R reinforced insulation		

Table G.9 – Informative examples of the application of Y capacitors based on peak working voltage

Capacitor type	Bridged insulation	Peak working voltage across the capacitor not to exceed kV
Any type ^a	B	Capacitors located in circuits isolated from the mains ^b , shall comply with the electric strength test of 5.4.11.1
Y4	B or S	0,978
Y4	D or R	0,795
Y2	B or S	1,631
Y2	D or R	1,325
Y1	B or S	4,350
Y1	D or R	3,535
^a For capacitors that bridge basic insulation and are located in circuits isolated from the mains , see 5.5.3.2. ^b For application of Y capacitor located in circuits connected to the mains , see Table G.8 and Table G.10.		
B basic insulation S supplementary insulation		D double insulation R reinforced insulation

Table G.10 – Informative examples of the application of Y capacitors based on temporary overvoltages

Nominal mains voltage V r.m.s.	Bridged insulation	Capacitor type	No. of capacitors
120	B	Y4	2
	R	Y4	3
	B	Y2	1
	R	Y2	2
	B	Y1	1
	R	Y1	1
230	B	Y2	1
	R	Y2	2
	B	Y1	1
	R	Y1	1
600	B	Y2	2
	R	Y2	3
	B	Y1	1
	R	Y1	1
B basic insulation R reinforced insulation			

Table G.11 – Informative examples of the application of X capacitors, line to line or line to neutral

AC mains supply voltage up to and including V r.m.s.	Overvoltage category	Mains transient voltage kV	Capacitor type	Required number of capacitors based on required withstand voltage
150	II	1,5	X2	1
	III	2,5	X2	1
	IV	4,0	X1	1
250	II	2,5	X2	1
	III	4,0	X1	1
	IV	6,0	X1	2
500	II	4,0	X1	1
	III	6,0	X1	2
	IV	8,0	X1	2

G.16 Optocouplers as safeguards

This subclause specifies compliance requirements for optocouplers serving as a **basic safeguard**, **supplementary safeguard** or a **reinforced safeguard**.

Optocouplers shall comply with the requirements of IEC 60747-5-5. In the application of IEC 60747-5-5,

- the voltage $V_{ini,a}$ for **type testing** as specified in 7.4.3 of IEC 60747-5-5:2007, and
- the voltage $V_{ini,b}$ for **routine testing** as specified in 7.4.1 of IEC 60747-5-5:2007

shall be the appropriate value of the test voltage in 5.4.11.1 of this standard.

NOTE 1 The above constructions may contain cemented joints, in which case 5.4.4.5 of this standard also applies.

NOTE 2 The previous version 60747-5-1, IEC 60747-5-2 and IEC 60747-3 must include their amendments to be considered adequate for compliance with the requirements and provisions of this subclause.

G.17 Relays

G.17.1 General

This subclause specifies requirements for relays that are located in PS2 or PS3 or in an **arcing PIS** or a **resistive PIS**.

G.17.2 Requirements for relays

The relay may be tested separately or in the equipment.

For resistance to heat and fire, see Clause 13 in IEC 61810-1:2008.

A relay shall comply with the requirements of IEC 61810-1, taking into account the following:

- 10 000 operating cycles for endurance (see 5.5 of IEC 61810-1:2008) and during the electric endurance test (see Clause 11 of IEC 61810-1:2008), no temporary malfunction shall occur;

NOTE A temporary malfunction is an event that has to be eliminated during the test at latest after one additional energization cycle without any external influence (see Clause 11 of IEC 61810-1:2008).

- the relay shall be suitable for use in the applicable pollution situation (see Clause 13 of IEC 61810-1:2008);
- for **mains** relays the speed of contact making and breaking shall be independent of the rate of rise of the coil voltage;
- characteristics of the relay with regard to the ratings and classification (see IEC 61810-1), shall be appropriate for the function of the relay under **normal operating condition** as given below:
 - rated coil voltage and rated coil voltage range (see 5.1 of IEC 61810-1:2008);
 - rated contact load and the type of load (see 5.7 of IEC 61810-1:2008);
 - a.c. or d.c. relay (see 5.3 of IEC 61810-1:2008);
 - the ambient air temperature and upper and lower limit of the temperature (see 5.8 of IEC 61810-1:2008);
 - only relay technology category RT IV and RT V shall be considered to meet **pollution degree** 1 environment; for example, the relay meets 5.4.8 of this standard (see 5.9 of IEC 61810-1:2008);
- electric strength (see 10.3 of IEC 61810-1:2008), except the test voltages shall be the highest of the voltages of Table 31, Table 32 and Table 33 of this standard;
- **clearances** in accordance with Table 17 of this standard, if the **required withstand voltage** (referred to as impulse withstand voltage in IEC 61810-1) exceeds 12 kV;
- **creepage distances** in accordance with Table 23 of this standard, if the **r.m.s. working voltage** (referred to as voltage r.m.s. in IEC 61810-1) exceeds 500 V;
- **solid insulation** in accordance with 13.3 of IEC 61810-1:2008 or with 5.4.4 of this standard.

Compliance is checked according to IEC 61810-1 and the requirements of this standard.

G.17.3 Overload test

Except as specified in G.17.1, a relay shall withstand the following test.

The contact of the relay is subjected to an overload test consisting of 50 cycles of operation at the rate of 6 to 10 cycles per minute, making and breaking 150 % of the current imposed in the application, except that where a contact switches a motor load, the test is conducted with the rotor of the motor in a locked condition. After the test, the relay shall still be functional.

G.17.4 Electric strength test

*Except as specified in Table G.1, a relay shall withstand an electric strength test as specified in 5.4.11.1. The test may be conducted at room temperature. If the contact switches a voltage exceeding that of ES2, the test voltage is as specified for **reinforced insulation**. If the contact switches a voltage less than that of ES3, the test voltage is as specified for **basic insulation**.*

G.17.5 Relay controlling mains socket-outlets

A **mains** relay controlling **mains** socket-outlets shall withstand the endurance test with an additional load that is equal to the total marked load of the socket-outlets. The peak surge current of the additional load shall have a value as shown in Table G.1.

G.17.6 Test method

For **mains** relays, the tests of IEC 61810-1 and this standard shall be applied with the modifications shown in Clause G.17 of this standard.

G.17.7 Compliance

After the tests, the relay 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.18 Printed boards

G.18.1 General

This subclause specifies the requirements for insulation on printed boards.

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

G.18.2 Uncoated printed boards

This subclause specifies the requirements for insulation on uncoated boards.

The insulation between conductors on the outer surfaces of an uncoated printed board shall comply with the minimum **clearance** requirements of 5.4.2 and the minimum **creepage distance** requirements of 5.4.3.

Compliance is checked by inspection and by measurement.

G.18.3 Coated printed boards

This subclause specifies the requirements for separation distances before the boards are coated.

An alternative method to qualify coated printed boards is given in IEC 60664-3:2003.

For printed boards whose outer surfaces are to be coated with a suitable coating material, the minimum separation distances of Table G.12 apply to conductive parts before they are coated.

Double insulation and **reinforced insulation** shall pass **routine tests** for electric strength of 5.4.11.1.

Either one or both conductive parts and the entire distances over the surface between the conductive parts shall be coated.

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 5.4.2 and the minimum **creepage distances** of 5.4.3 shall apply:

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

Compliance is checked by inspection and measurement, taking Figure O.11 and Figure O.12 into account, and by the tests of G.18.6.

Table G.12 – Minimum separation distances for coated printed boards

Peak working voltage up to and including V peak	Basic insulation or supplementary insulation mm	Reinforced insulation mm
71 ^a	0,025	0,05
89 ^a	0,04	0,08
113 ^a	0,063	0,125
141 ^a	0,1	0,2
177 ^a	0,16	0,32
227 ^a	0,25	0,5
283 ^a	0,4	0,8
354 ^a	0,56	1,12
455 ^a	0,75	1,5
570	1,0	2,0
710	1,3	2,6
895	1,8	3,6
1 135	2,4	3,8
1 450	2,8	4,0
1 770	3,4	4,2
2 260	4,1	4,6
2 830	5,0	5,0
3 540	6,3	6,3
4 520	8,2	8,2
5 660	10	10
7 070	13	13
8 910	16	16
11 310	20	20
14 140	26	26
17 700	33	33
22 600	43	43
28 300	55	55
35 400	70	70
45 200	86	86
Linear interpolation may be used between the nearest two points, the calculated spacing being rounded up to the next higher 0,1 mm increment.		
^a The test of G.18.6 is not required.		

G.18.4 Insulation between conductors on the same inner surface

This subclause specifies the requirements for insulation on the same inner layer of a multilayer board.

On an inner surface of a multi-layer printed board (see Figure O.17), the path between any two conductors shall comply with the requirements for a cemented joint in 5.4.4.5.

G.18.5 Insulation between conductors on different surfaces

This subclause specifies the requirements for insulation on the different layers of a multilayer board.

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 provided by a single layer or conform with one of the specifications and pass the relevant tests in Table G.13.

Table G.13 – Insulation in printed boards

Specification of insulation	Type tests ^a	Routine tests for electric strength ^c
Two layers of sheet insulating material including pre-preg ^b	No	Yes
Three or more layers of sheet insulating material including pre-preg ^b	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
NOTE 1 Pre-preg is the term used for a layer of glass cloth impregnated with a partially cured resin.		
NOTE 2 For definition of ceramic, see IEC 60050-212.		
^a Thermal conditioning of G.18.6.2 followed by the electric strength test of 5.4.11.1.		
^b Layers are counted before curing.		
^c Electric strength testing is carried out on the finished printed board.		

G.18.6 Tests on coated printed boards

G.18.6.1 Sample preparation and preliminary inspection

Three sample printed boards (or, for coated components in Clause G.19, two components and one board) identified as samples 1, 2 and 3 are required. Either actual boards or specially produced samples with representative coating and minimum separations may be used. 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.

G.18.6.2 Thermal conditioning

Sample 1 is subjected to the thermal cycling sequence of 5.4.7.

Sample 2 is aged in a full draught oven at a temperature and for a time duration chosen from the graph shown in Figure G.2 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 G.2, interpolation may be used between the nearest two temperature index lines.

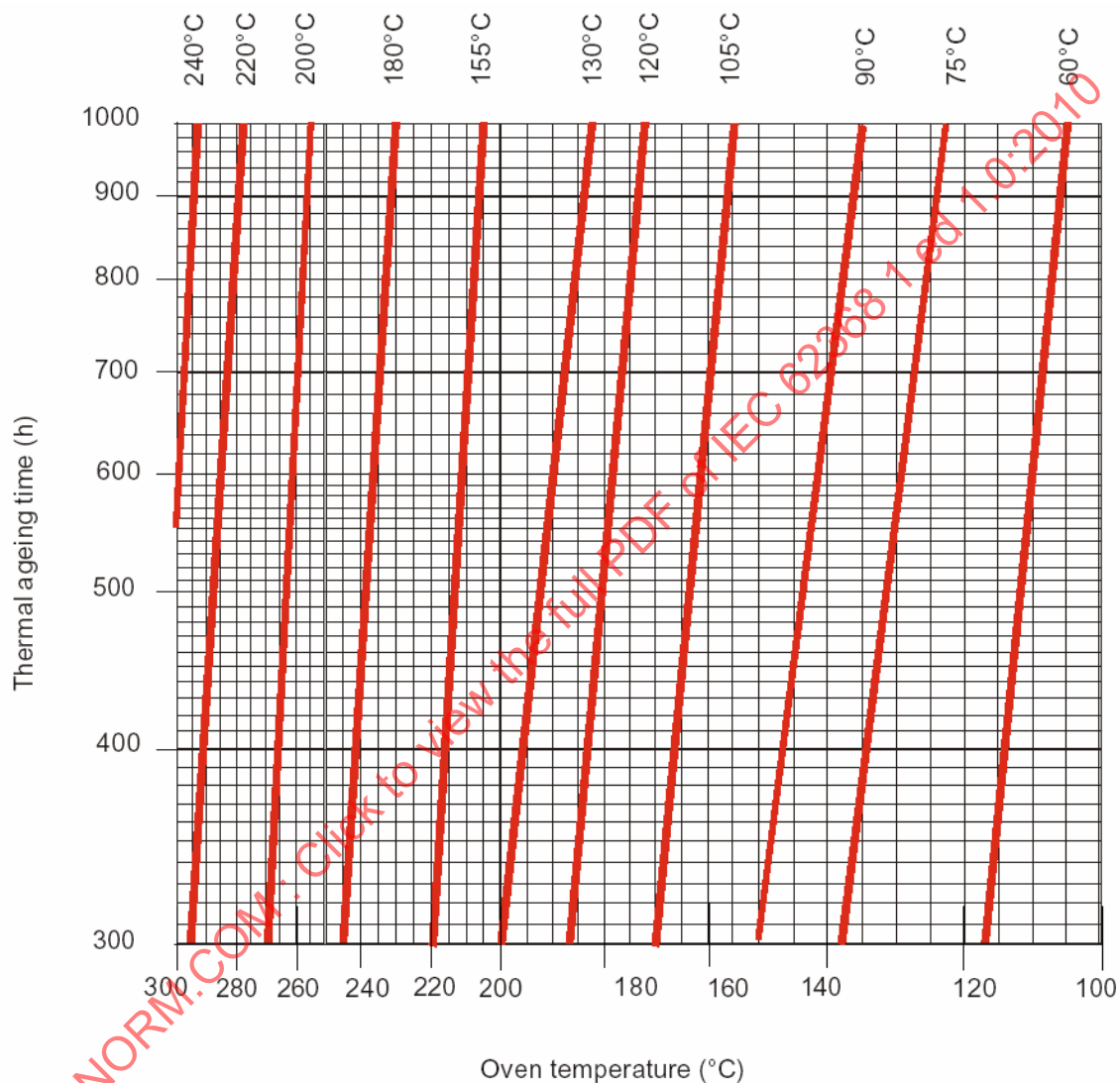


Figure G.2 – Thermal ageing time

G.18.6.3 Electric strength test

Samples 1 and 2 are then subjected to the humidity conditioning of 5.4.10 and shall withstand the electric strength test of 5.4.11.1 between conductors.

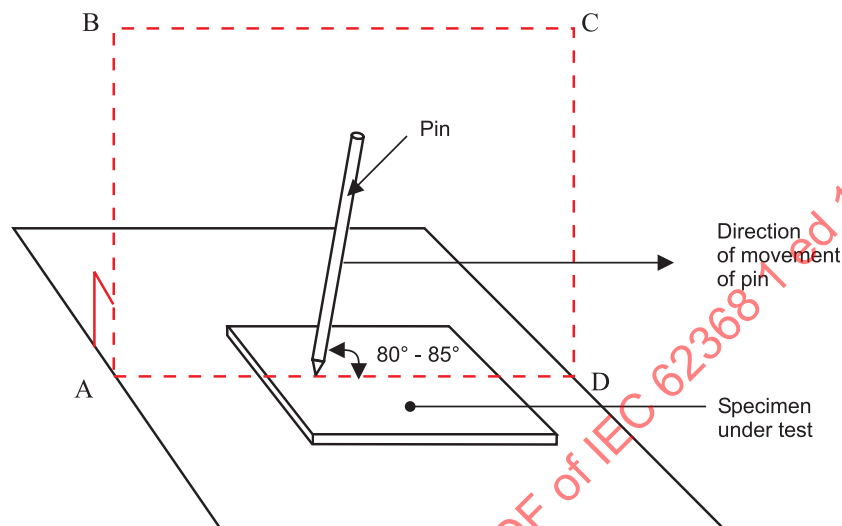
G.18.6.4 Abrasion resistance test

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 $0,25 \text{ mm} \pm 0,02 \text{ mm}$.

Scratches are made by drawing the pin along the surface in a plane perpendicular to the conductor edges at a speed of $20 \text{ mm/s} \pm 5 \text{ mm/s}$ as shown in Figure G.3. The pin is so loaded that the force exerted along its axis is $10 \text{ N} \pm 0,5 \text{ N}$. 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 that is perpendicular to the specimen under test.

Figure G.3 – Abrasion resistance test for coating layers

After the test, the coating layer shall neither have loosened nor have been pierced. The coating shall withstand an electric strength test as specified in 5.4.11.1 between conductors. In the case of metal core printed boards, the substrate is one of the conductors.

NOTE If mechanical stress or bending is applied to the board, additional tests to identify cracking may be needed (see IEC 60664-3).

G.19 Coatings on component terminals

G.19.1 Requirements

This subclause specifies the requirements for coatings on component terminals and the like.

Coatings may be used over external terminations of components to increase effective **clearances** and **creepage distances** (see Figure O.11). The minimum separation distances of Table G.12 apply to the component before coating, and the coating shall meet all the requirements of G.18.3. 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 that would crack the coating or reduce the separation distances between conductive parts below the values in Table G.12 (see G.18.3).

G.19.2 Compliance and test method

Compliance is checked by inspection taking into account Figure O.11 and by applying the sequence of tests covered by G.18.6.1, G.18.6.2 and G.18.6.3. These tests are carried out on a completed assembly including the component(s).

The abrasion resistance test of G.18.6.4 is carried out on a specially prepared sample printed board as described for sample 3 in G.18.6.1, except that the separation between the conductive parts shall be representative of the minimum separations and maximum potential gradients used in the assembly.

G.20 Mains connectors

Mains connectors that are listed in IEC/TR 60083 or that comply with one of the following standards IEC 60309-1, IEC 60320-1, IEC 60906-1 or IEC 60906-2, are considered acceptable without further evaluation.

G.21 Liquid filled components

G.21.1 General

This subclause provides construction and test requirements for LFCs used inside the equipment to avoid injury due to leaks of the liquid in the LFC within the meaning of this standard.

This subclause does not apply to components containing small amounts of liquids not likely to cause any chemical hazard (for example, liquid crystal displays, electrolytic capacitors, liquid cooling heat pipes, etc.).

For wet cell batteries, see Annex M.

G.21.2 Requirements

An LFC located internal to the equipment shall comply with all of the following requirements:

NOTE 1 Additional requirements need to be applied if located outside the equipment **enclosure**.

- flammable or conductive liquid shall be stored in a container, and the LFC shall comply with the tests of G.21.3.3, G.21.3.4, G.21.3.5 and G.21.3.6;
- the liquid shall be provided with protection in accordance with Clause 7 (chemical hazards);
- non-metallic parts of the container system shall withstand the tests of G.21.3.1 and G.21.3.2;

NOTE 2 Additional requirements of this standard may apply to the end product using an LFC if the LFC is evaluated as a component or subassembly.

- the LFC shall be mounted within the equipment in such a way that the tubing shall not come into contact with sharp edges or any other surface that could damage the tubing and if the LFC bursts or relieves its pressure, the fluid cannot come in contact with ES3 parts.

The order of tests is not specified. The tests may be performed on separate samples, except after the test of G.21.3.2, the test of G.21.3.1 is conducted.

G.21.3 Compliance and test methods

G.21.3.1 Hydrostatic pressure test

Compliance is checked by evaluation of the available data or by the following test. An LFC that is open to the atmosphere is not subjected to this test.

One sample of the LFC is subjected to a hydrostatic pressure test for 2 min at room temperature and at a pressure that is the highest of the following:

- five times the maximum working pressure measured at the maximum temperature reached during **normal operating conditions**; and
- three times the maximum measured working pressure at the maximum temperature reached during application of the **abnormal operating conditions** of Clause B.3 and **single fault conditions** of Clause B.4.

G.21.3.2 Creep resistance test

Two samples of the LFC, of which one or more parts are made of non-metallic materials, shall be conditioned for 14 days at a temperature of 87 °C and placed in a full draft air-circulating oven. Following the conditioning, the system shall comply with the test of G.21.3.1 and non-metallic parts shall show no sign of deterioration such as cracking and embrittlement.

G.21.3.3 Tubing and fittings compatibility test

Three samples of tubing and associated fittings of the LFC, of which one or more parts are made of non-metallic materials, shall be tested for tensile strength in accordance with the ISO 527 series before and after a conditioning test for 40 days at 38 °C in a full draft air-circulating oven or a water bath maintained at 38 °C. The internal pressure of the assemblies is maintained at atmospheric pressure. The tensile strength after conditioning shall not be less than 60 % of the tensile strength before the test.

G.21.3.4 Vibration test

One sample of the LFC, or the equipment containing the LFC, is fastened to the vibration generator in its 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.

G.21.3.5 Thermal cycling test

One sample of the LFC is subjected to three cycles of conditioning for 7 h at a temperature that is 10 °C above the maximum temperature obtained during **normal operating conditions**, **abnormal operating conditions** of Clause B.3 and **single fault conditions** of Clause B.4, followed by room temperature for 1 h.

NOTE The LFC is not energized during the above test.

G.21.3.6 Force test

One sample of the LFC is subjected to the tests of Clause T.2 (10 N test applied to fittings **accessible** to a **skilled person**) and Clause T.3 (30 N test applied to fittings **accessible** to an **instructed person** or to an **ordinary person**).

G.21.4 Compliance

Compliance is checked by inspection and evaluation of the available data or by the tests of G.21.3. During and after these tests, there shall be no rupture, no leaks and no loosening of any connection or part.

G.22 Connectors other than mains connectors

Connectors other than for connecting **mains** power shall be so designed that the plug has such a shape that insertion into a **mains** socket-outlet or appliance coupler is unlikely to occur.

NOTE Examples of connectors meeting this requirement are those constructed according to IEC 60130-2, IEC 60130-9, IEC 60169-2 or IEC 60169-3, when used as prescribed. An example of a connector not meeting the requirements of this subclause is the so-called "banana" plug.

Compliance is checked by inspection.

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Annex H (normative)

Criteria for telephone ringing signals

H.1 General

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 that 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 protective earth do not exceed the limits specified, as follows.

- a) For **normal operating conditions**, 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:

- for cadenced ringing ($t_1 < \infty$), the current given by the curve of Figure H.2 at t_1 ;
- for continuous ringing ($t_1 = \infty$), 16 mA.

I_{TS1} , in mA, is as given by

$$I_{TS1} = \frac{I_p}{\sqrt{2}} \quad \text{for } (t_1 \leq 600 \text{ ms})$$

$$I_{TS1} = \frac{t_1 - 600}{600} \times \frac{I_{pp}}{2\sqrt{2}} + \frac{1200 - t_1}{600} \times \frac{I_p}{\sqrt{2}} \quad \text{for } (600 \text{ ms} < t_1 < 1200 \text{ ms})$$

$$I_{TS1} = \frac{I_{pp}}{2\sqrt{2}} \quad \text{for } (t_1 \geq 1200 \text{ ms})$$

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 operating conditions**, 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);

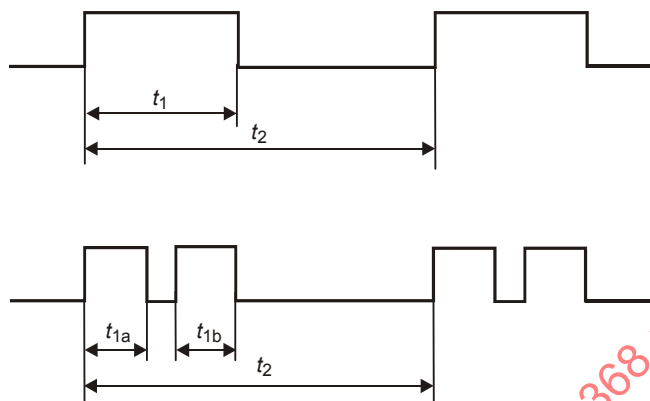
I_{dc} is the d.c. current in mA flowing through the 5 000 Ω resistor during the non-active period of the cadence cycle;

t_1 and t_2 are expressed in ms.

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:

- I_{TS1} shall not exceed the current given by the curve of Figure H.2, or 20 mA, whichever is greater; and
- I_{TS2} shall not exceed a limit of 20 mA.



where

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 the duration of one complete cadence cycle.

Figure H.1 – Definition of ringing period and cadence cycle

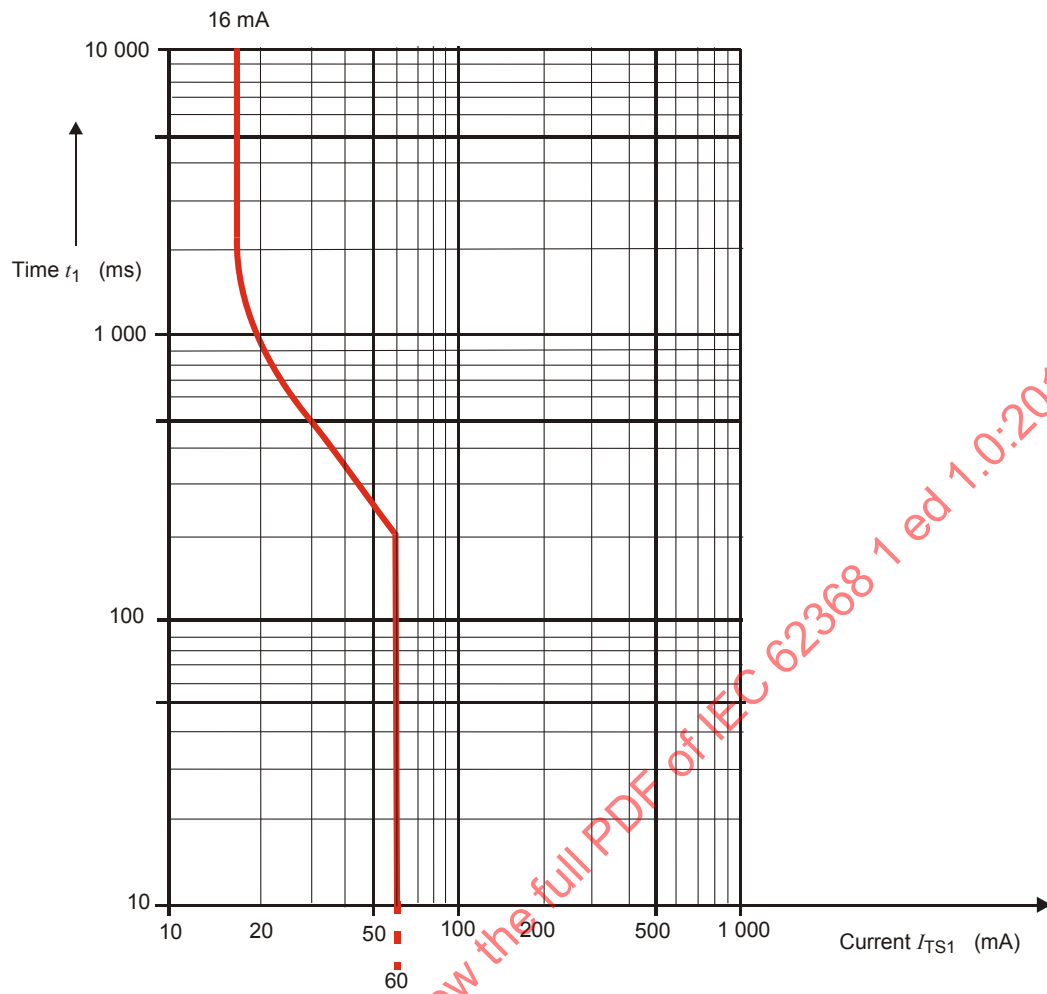


Figure H.2 – I_{TS1} limit curve for cadenced ringing signal

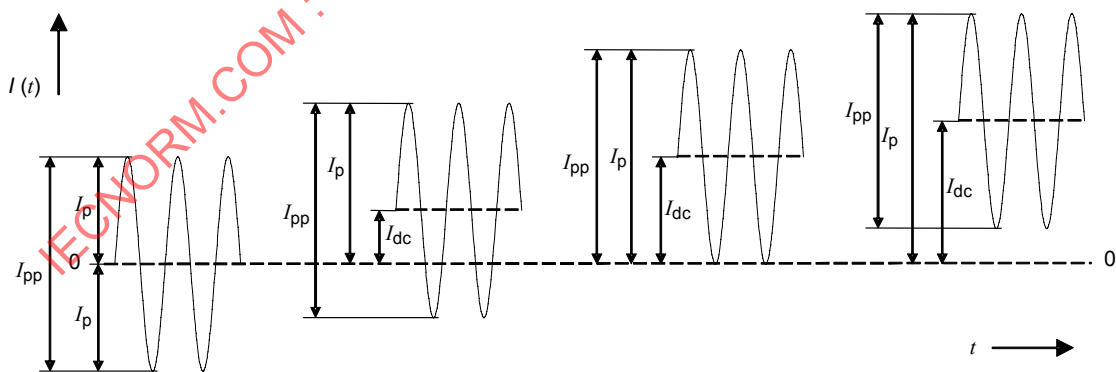


Figure H.3 – Peak and peak-to-peak currents

H.3 Method B

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 M Ω .

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 60 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

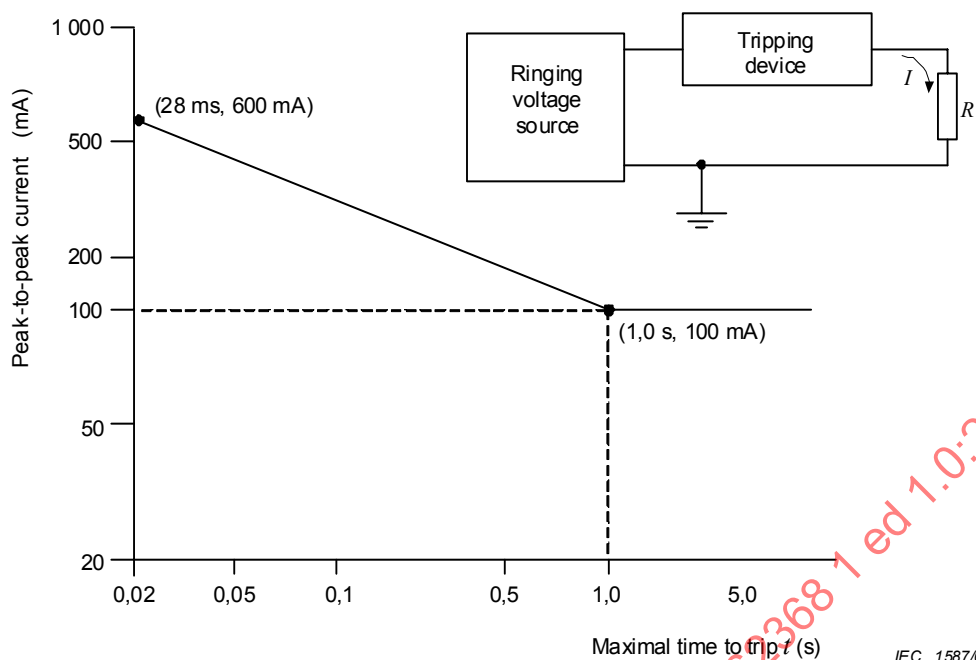
H.3.2.1 Conditions for use of a tripping device or a monitoring voltage

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 or greater 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 or greater resistor exceeds 100 mA peak-to-peak, a tripping device shall be included. If the tripping device meets the trip criteria specified in Figure H.4 with $R \geq 500 \Omega$, no monitoring voltage is required. If, however, the tripping device only meets the trip criteria with $R \geq 1 500 \Omega$, a monitoring voltage shall also be provided;
- if the current through a 500 Ω or greater resistor exceeds 100 mA peak-to-peak, but the current through a 1 500 Ω or greater resistor does not exceed this value, either:
 - a tripping device shall be provided, meeting the trip criteria specified in Figure H.4 with $R \geq 500 \Omega$, or
 - a monitoring voltage shall be provided.

NOTE 1 Tripping devices are, in general, current-sensitive and do not have a linear response, due to the resistance/current characteristics and time delay/response factor in their design.

NOTE 2 In order to minimize testing time, a variable resistor box should be used.



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 that will trip ringing as specified in Figure H.

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 60 V d.c., whenever the ringing voltage is not present (idle state).

Annex I (informative)

Overvoltage categories (see IEC 60364-4-44)

The largest transient voltage 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** is allocated to the **mains** voltage and the overvoltage category, I to IV (see Table 15 of this standard).

The overvoltage category therefore has to be identified for each equipment intended to be connected to the **mains** (see Table I.1).

The concept of overvoltage categories is used for equipment energized directly from the a.c. **mains**.

The overvoltage categories have a probabilistic implication rather than the meaning of physical attenuation of the transient voltage downstream in the installation.

NOTE 1 This concept of overvoltage categories is used in IEC 60364-4-44:2007, section 443.

NOTE 2 The term overvoltage category in this standard is synonymous with impulse withstand category used in IEC 60364-4-44:2007, section 443.

The term overvoltage category is not used in connection with d.c. power distribution systems in this standard.

Table I.1 – Overvoltage categories

Overvoltage category	Equipment and its point of connection to the a.c. mains	Examples of equipment
IV	Equipment that will be connected to the point where the mains supply enters the building	- Electricity meters - Communications ITE for remote electricity metering
III	Equipment that 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 that will be supplied from the building wiring	- Household appliances, portable tools, home electronics - Most ITE used in the building
I	Equipment that 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 J (normative)

Insulated winding wires for use without interleaved insulation

J.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 solid winding wires having diameters between 0,05 mm and 5,0 mm and stranded winding wires with equivalent cross-sectional areas.

J.2 Sampling tests

J.2.1 General

*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.*

J.2.2 Electric strength

The test sample is prepared according to 4.4.1 of IEC 60851-5:2008 (for a twisted pair). The sample is then subjected to the electric strength test of 5.4.11.1 with a test voltage not less than twice the highest of the appropriate voltages of Table 31, Table 32 and Table 33, 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**.

J.2.3 Flexibility and adherence

Test 8 in 5.1.1 of IEC 60851-3:2009 shall be used, using the mandrel diameters of Table J.1.

The test sample is then examined in accordance with 5.1.1.4 of IEC 60851-3:2009, followed by the electric strength test of 5.4.11.1 in this standard. The test voltage shall be not less than the highest of the appropriate voltages in Table 31, Table 32 and Table 33, 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 J.1 – Mandrel diameter

Nominal conductor diameter mm	Mandrel diameter mm
0,05 up to and including 0,35	4,0 ± 0,2
over 0,35 up to and including 0,50	6,0 ± 0,2
over 0,50 up to and including 0,75	8,0 ± 0,2
over 0,75 up to and including 2,50	10,0 ± 0,2
over 2,50 up to and including 5,00	Four times the conductor diameter ^a
^a 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 $118 \text{ MPa} \pm 10 \%$ ($118 \text{ N/mm}^2 \pm 10 \%$).

J.2.4 Heat shock

Test 9 of IEC 60851-6:1996, followed by the electric strength test 5.4.11.1 except that the test voltage is applied between the wire and the mandrel. The test voltage shall be not less than the highest of the appropriate voltages in Table 31, Table 32 and Table 33, 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 J.2. The mandrel diameter and tension applied to the wire during winding on the mandrel are as in Table J.1. The electric strength test is conducted at room temperature after removal from the oven.

Table J.2 – Oven temperature

Thermal class	Class 105 (A)	Class 120 (E)	Class 130 (B)	Class 155 (F)	Class 180 (H)	Class 200 (N)	Class 220 (R)	Class 250 -
Oven temperature °C	200	215	225	250	275	295	315	345
Oven temperatures shall be maintained within $\pm 5^\circ$ of the specified temperature.								
The classes are related to the classification of electrical insulating materials and EISs in accordance with IEC 60085. The assigned letter designations are given in parentheses.								

J.2.5 Retention of electric strength after bending

Five samples are prepared as in J.2.3 and tested as follows. Each sample is removed from the mandrel, placed in a container and positioned so that it can be surrounded by at least 5 mm of metal shot. The ends of the conductor in the sample shall be sufficiently long to avoid flash over. The shot shall be not more than 2 mm in diameter and shall consist of balls of stainless steel, nickel or nickel plated iron. The shot is gently poured into the container until the sample under test is covered by at least 5 mm of shot. The shot shall be cleaned periodically with a suitable solvent (for example, 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 fourth edition (2008) of that standard.

The test voltage shall be not less than the highest of the appropriate voltages in Table 31, Table 32 and Table 33, 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 Clause J.2.

J.3 Testing during manufacturing

J.3.1 General

The wire shall be subjected by the wire manufacturer to electric strength tests during manufacture as specified in J.3.2 and J.3.3.

J.3.2 Routine test

The test voltage for **routine test** shall be the highest of the appropriate voltages in Table 31, Table 32 and Table 33 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**.

J.3.3 Sampling test

Twisted pair samples shall be tested in accordance with 4.4.1 of IEC 60851-5:2008. The test voltage for the **sampling test** shall be the highest of the appropriate voltages in Table 31, Table 32 and Table 33 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**.

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Annex K (normative)

Safety interlocks

K.1 General

K.1.1 General requirements

Safety interlocks shall be so designed that, for an **ordinary person**, the class 2 energy sources and class 3 energy sources will be removed before the cover, door, etc. is in a position that those parts become **accessible** as a class 1 energy source.

Safety interlocks shall be so designed that, for an **instructed person**, the class 3 energy sources will be removed before the cover, door, etc. is in a position that this part becomes **accessible** as a class 2 energy source or less.

The interlock shall either:

- necessitate previous de-energisation of such parts, or
- automatically initiate disconnection of the supply to such parts, and to reduce to a:
 - class 1 energy source within 2 s for an **ordinary person**; and
 - class 2 energy source within 2 s for an **instructed person**.

For hot parts and for moving parts, reduction of the energy source may be longer than 2 s if an **instructional safeguard** is provided in accordance with Clause F.5 indicating the time when the energy source will be reduced to the required class. The **instructional safeguard** shall be placed on the door, cover or other part that initiates the interlock action and is opened or removed to gain access. An additional **instructional safeguard** in accordance with Clause F.5 shall be placed on or beside the part that was a class 2 or 3 energy source before the interlock action was initiated.

K.1.2 Compliance and test method

The energy level of class 2 or class 3 energy source parts are monitored.

Compliance is checked by inspection, measurement and use of the rigid test finger according to Annex V.

K.2 Components of the safety interlock safeguard mechanism

The components comprising the **safety interlock** mechanism shall be considered **safeguards**, and shall comply with applicable **safeguard** requirements and shall be subject to applicable requirements of Annex G.

Compliance is checked in accordance with Annex G and by inspection.

K.3 Inadvertent change of operating mode

A **safety interlock** shall not be operable by means of probes specified in Annex V so as to change the energy class within the area, space or access point being controlled to a class 3 energy source for an **instructed person**, or to a class 2 energy source or a class 3 energy source for an **ordinary person**.

Compliance is checked in accordance with Annex V and by inspection.

K.4 Interlock safeguard override

A **safety interlock** may be overridden by a **skilled person**. The **safety interlock** override system:

- shall require an intentional effort to operate; and
- shall reset automatically to normal operation when servicing is complete, or prevent normal operation unless the **skilled person** has carried out restoration; and
- if located in an area **accessible** to an **ordinary person** or, if applicable, an **instructed person**, shall not be operable by means of probes specified in Annex V, and shall require a **tool** for operation.

Compliance is checked in accordance with Annex V and by inspection.

K.5 Fail-safe

K.5.1 Requirement

In the event of any **single fault condition** in the **safety interlock** system, the space controlled by the **safety interlock** shall

- revert to a class 1 energy source for an **ordinary person** or a class 2 energy source for an **instructed person**, or
- be locked in the **normal operating condition** and comply with applicable requirements for a class 3 energy source.

K.5.2 Compliance and test method

*Compliance is checked by introduction of electrical, electro-mechanical, and mechanical component faults, one at a time. **Single fault conditions** are described in Clause B.4. For each fault, the space controlled by the **safety interlock** shall comply with the applicable requirements for **single fault conditions** for the respective energy source. Fixed separation distances in **safety interlock** circuits (for example, those associated with printed boards) are not subjected to simulated **single fault conditions** if the separation distances comply with K.7.1.*

K.6 Mechanically operated safety interlocks

K.6.1 Endurance requirement

Moving mechanical parts in mechanical and electromechanical **safety interlock** systems shall have adequate endurance.

K.6.2 Compliance and test method

*Compliance is checked by inspection of the **safety interlock** system, available data and, if necessary, by cycling the **safety interlock** system through 10 000 operating cycles. In the event of any fault during or after the 10 000 operating cycles in the **safety interlock** system, the space controlled by the **safety interlock** shall:*

- *revert to a class 1 energy source for an **ordinary person** or a class 2 energy source for an **instructed person**, or*
- *be locked in the **normal operating condition** and comply with applicable requirements for a class 3 energy source.*

NOTE The above test is conducted to check the endurance of moving parts other than those in **safety interlock** systems, switches and relays. **Safety interlock** systems, switches and relays, if any, are subject to Annex G.

K.7 Interlock circuit isolation

K.7.1 Separation distances for contact gaps and interlock circuit elements

If the switch or relay disconnects a circuit conductor in a circuit connected to the **mains**, the separation distances for contact gaps and their related circuits shall be not less than that for a **disconnect device** (see Annex L).

If the switch or relay is in a circuit isolated from the **mains**, the separation distances for contact gaps shall be not less than the relevant minimum **clearance** value for **basic insulation** for isolation of class 2 energy sources. Interlock circuit elements, the failure of which can defeat the interlock system, shall have **basic insulation**.

If the switch or relay is in a circuit isolated from the **mains**, the separation distances for contact gaps shall be not less than the relevant minimum **clearance** value for **reinforced insulation** for isolation of class 3 energy sources. Interlock circuit elements, the failure of which can defeat the interlock system, shall have **reinforced insulation**.

Two independent interlock systems employing **basic insulation** may be used as an alternative to the provision of **reinforced insulation**.

Alternatively, the separation gap between contacts in the off position shall withstand the electric strength test of 5.4.2.8 at a test voltage required for **basic insulation**. The contact gap shall comply with the above requirements before and after the 10 000 cycle endurance test of K.6.2. The endurance test condition shall represent the maximum **normal operating condition** within the equipment with respect to voltage and current that the contacts interrupt.

The contact gap **clearance** may be the required distance for a homogeneous field according to Table 17 provided the switch or relay complies with K.7.2, K.7.3 and K.7.4.

The above requirements do not apply to switches complying with Clause G.1 and relays complying with Clause G.17.

K.7.2 Overload test

*The contact of a switch or relay in the **safety interlock** system is subjected to an overload test consisting of 50 cycles of operation at the rate of 6 to 10 cycles per minute, making and breaking 150 % of the current imposed in the application, except that where a switch or relay contact switches a motor load, the test is conducted with the rotor of the motor in a locked condition.*

*After the test, the **safety interlock** system, including the switch or relay, shall still be functional.*

K.7.3 Endurance test

*The contact of a switch or relay in the **safety interlock** system is subjected to an endurance test, making and breaking 100 % of the current imposed in the application at a rate of 6 to 10 cycles of operation per minute. A higher rate of cycling may be used if requested by the manufacturer.*

*For reed switches used in a **safety interlock** system in ES1 or ES2, the test is 100 000 operating cycles. For other switches and relays in a **safety interlock** system, the test is 10 000 operating cycles.*

After the test, the **safety interlock** system, including the switch or relay, shall still be functional.

K.7.4 Electric strength test

Except for reed switches in ES1 or ES2, an electric strength test as specified in 5.4.11.1 is applied between the contacts after the tests of K.7.3. If the contact is in a circuit connected to the **mains**, the test voltage is as specified for **reinforced insulation**. If the contact is in a circuit isolated from the **mains**, the test voltage is as specified for **basic insulation** in a circuit connected to the **mains**.

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Annex L (normative)

Disconnect devices

L.1 General requirements

L.1.1 General

A **disconnect device** shall be provided to disconnect the equipment from the supply. If a **disconnect device** interrupts the neutral conductor, it shall simultaneously interrupt all phase conductors.

A **disconnect device** may be:

- the plug on the power supply cord;
- an appliance coupler;
- an isolating switch;
- a circuit breaker; or
- any equivalent means for disconnection.

NOTE The following requirements do not apply to functional switches where a **disconnect device** is also provided.

For equipment intended to be powered from an a.c. **mains** that is Overvoltage Category I, Overvoltage Category II or Overvoltage Category III, or from a d.c. **mains** that is ES3, a **disconnect device** shall have a contact separation of at least 3 mm. For an a.c. **mains** that is Overvoltage Category IV, see IEC 60947-1. When incorporated in the equipment, the **disconnect device** shall be connected as closely as practicable to the incoming supply.

For equipment intended to be powered from a d.c. **mains** that is not at ES3,

- a **disconnect device** shall have a contact separation at least equal to the minimum **clearance** for **basic insulation**;
- a removable fuse may be used as a **disconnect device**, provided that it is **accessible** only to an **instructed person** or to a **skilled person**.

L.1.2 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.

L.1.3 Parts that remain energised

Parts on the supply side of a **disconnect device** in the equipment, that 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.

L.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**. If only a single pole disconnect device is provided in the equipment, 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 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.

L.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.

L.1.6 Switches as disconnect devices

Where the **disconnect device** is a switch incorporated in the equipment, the on and off positions shall be marked in accordance with F.3.5.2.

L.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 easily **accessible**. For pluggable equipment intended for installation by an **ordinary person**, the installation instructions shall be made available to the **ordinary person**.

L.1.8 Multiple power sources

Where a unit receives power from more than one source (for example, 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 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**.

L.2 Compliance

Compliance is checked by inspection.